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Acknowledgements

The authors wish to thank Don McCaffery, NSW DPI and Rebecca Byrne, formerly NSW DPI, for their assistance with this publication.

Cover design by Belinda Keen, production by Barry Jensen, both NSW DPI, Orange.

Front cover photograph (large): A seed crop of Moonbi soybeans, Paul Fleming. (small photos): Moonbi grain, Sorghum on the Liverpool Plains, Sunflower, Natalie Moore, NSW DPI, Grafton.
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Crop rotation plays an important role in spreading risks associated with seasons and markets. As our knowledge of the agronomic value of crop rotation increases – reducing disease severity, lowering the risks of herbicide resistance, controlling hard to kill weeds, maintaining arbuscular mycorrhizae levels, legumes for an alternate source of nitrogen – fixed cropping systems are being replaced by opportunity-based systems that include a broader selection of crops. As summer cropping is playing an increasing role in today’s farming systems. The mix of summer and winter cropping is recognised for improving cash flow and reducing the overhead costs for small–mid size enterprises. By spreading the workload through more of the year greater productivity is achieved from machinery and labour resources.

Excluding cotton and rice, sorghum accounts for 64% of the summer crop area sown in NSW. However sunflower, maize, mungbean, soybean and safflower can add flexibility to the summer cropping program. Sunflower can be sown 4–6 weeks earlier than sorghum. As spring rainfall can be variable, an early sowing opportunity could mean the difference between sowing and not sowing a summer crop. Legumes fix their own nitrogen and mungbean has a relatively short cropping period. Good seasons can be taken advantage of when a double-crop option such as mungbean or soybean can be included. Maize can be grown as an excellent source of silage as well as for grain and there are hybrids with adaptation to locations across the state. Maize and soybean have human consumption markets providing an opportunity to diversify farm income.

This publication contains information to assist with the key agronomic decisions made in the production of grain sorghum, maize, mungbean, soybean and sunflower. Recommendations for both dryland and irrigated production systems are included where possible. For each crop the topics of; paddock selection, sowing time, plant population, row spacing, hybrid or variety characteristics, nutrition, subsoil constraints, irrigation, weed management, diseases, insect pests, harvest and marketing are addressed. In addition to crop production recommendations, at the back of this guide is a summary on the requirements for safe storage of summer grains and receiveal standards. The authors have considered the needs of readers new to summer cropping by including descriptions of the growth stages that underpin many of the agronomic recommendations. Sources of further information are also listed at the end of each section.

The NSW DPI Summer crop production guide aims to provide the latest commercial information relevant to variety selection, together with agronomic recommendations, in a format that is easy to use, and readily available, both in hard copy and electronic format. This publication can be downloaded from www.dpi.nsw.gov.au/pubs/summer-crop-production-guide. The authors hope you find this publication to be a valuable resource and welcome feedback on opportunities for its improvement in the future.
Grain sorghum
Nicole Carrigan, Loretta Serafin and Guy McMullen

Brief crop description
Grain sorghum is the dominant summer crop grown in NSW, with the bulk of the crop grown in northern NSW. Smaller areas are grown in central west NSW and the Murrumbidgee Irrigation Area (MIA). Sorghum being a sub-tropical plant 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 friable vertosols on the plains and the duplex red soils (often chromosols) on the slopes. (See Table 1).

The current range of hybrids assures robust tolerance to disease and insect pests making it an excellent break crop in rotations.

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 continued interest in sorghum as a source for ethanol production.

Paddock selection
The majority of sorghum is sown using no-till or minimum-till into a long fallow following a winter cereal. Alternatively, sorghum may be sown into a field sown to sorghum the previous summer such that the fallow period is 6 months in length. Only in years of above average rainfall should sorghum be double cropped in northern NSW and sown directly following harvest of a winter cereal or pulse crop. Successful sorghum crops have been grown immediately after winter pulse crops, provided the soil water profile is full to a depth of 1 metre.

Growing sorghum immediately following canola or mustard has previously been discouraged for the antagonistic effect these crop residues were thought to impose on germination, establishment, growth and yield of sorghum. However, research conducted within the northern cropping region of NSW in 2009 (Robertson, Holland & Bambach) failed to validate this claim. Further research on this matter would prove beneficial.

Table 1. NSW Grain Sorghum Production 2009–2013 (Source: NSW DPI Grains Report).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (ha)</td>
<td>Average Yield (t/ha)</td>
<td>% of NSW production</td>
<td>Area (ha)</td>
</tr>
<tr>
<td>North West</td>
<td>84,900</td>
<td>4.3</td>
<td>95.10</td>
<td>150,000</td>
</tr>
<tr>
<td>Central West</td>
<td>3,850</td>
<td>5.6</td>
<td>4.30</td>
<td>11,100</td>
</tr>
<tr>
<td>South West</td>
<td>350</td>
<td>7.2</td>
<td>0.40</td>
<td>400</td>
</tr>
<tr>
<td>Tablelands</td>
<td>80</td>
<td>3.0</td>
<td>0.09</td>
<td>50</td>
</tr>
<tr>
<td>Coastal</td>
<td>125</td>
<td>3.0</td>
<td>0.14</td>
<td>–</td>
</tr>
<tr>
<td>State Total</td>
<td>89,305</td>
<td>4.6</td>
<td>3.9</td>
<td>161,550</td>
</tr>
</tbody>
</table>
No-till and minimum-till are well established farming practices in the northern grains region. Grain sorghum grown under no-till has been shown to consistently yield approximately 0.5–1.0 t/ha more than conventional crops because no-till fallows store approximately an extra 30 mm of plant available water provided adequate weed control is maintained. Cereal stubbles also provide high levels of ground cover and maximise protection against soil erosion in predominantly summer rainfall environments. Using no-till and minimum-till fallows enables crops to be sown for up to 7 weeks after rain as moisture retention in the seeding zone is greater. This widens the planting window, increasing the likelihood of sowing at an optimum time. It can also mean the difference between planting a crop or not.

Targeted occasional cultivation in a no-till farming system has proven effective for control of herbicide resistant weeds, breakdown of cereal stubble and amelioration of soils compacted following wet harvests, without negatively impacting on soil biological activity, organic matter levels or crop yield (Dang, Rincon-Florez, Ng, Argent, Bell, Dalal, Moody & Schenk, 2013). Provided the cultivation occurs immediately following harvest of the preceding crop so as to maximise the opportunity for soil water storage during the fallow period, a strategically-timed cultivation has actually been found to slightly improve grain yield.

Fallow weed control within minimum and no-tillage systems is via the use of knockdown and residual herbicides. It is crucial to ensure that prior to sowing sorghum into fallowed fields, guidelines for time elapsed between spraying and sowing (plantback period) are met otherwise poor establishment and crop injury will result. It is common for herbicide manufacturers to specify both a specific number of days and a rainfall requirement prior to commencement of the plantback period. For example, 2,4-D products have a plantback period of 3–10 days (dependent on application rate) and a rainfall requirement of 15 mm if applied to dry soil. Sorghum growers also need to be aware that there may be a limit to the quantity of a particular herbicide product allowed to be applied within a year (ie. atrazine) without causing harm to the sorghum crop and that rules for use of some products differ according to the presence or absence of irrigation and the method of application, 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 such that in-crop chemical weed control options for grasses are limited. In contrast, broadleaf weed control options are more varied. Sorghum is resistant to the Pratylenchus thornei species of root-lesion nematodes. Resistance denotes that in the presence of P. thornei sorghum inhibits their reproduction and levels decrease in number within the soil. No negative symptoms are exhibited by sorghum sown into paddocks containing high P. thornei numbers making sorghum an effective management strategy to reduce nematode numbers to reduce the impact on intolerant crops in rotation, such as wheat and chickpeas (Owen, Clewett, Sheedy & Thompson, 2011). It should be noted that sorghum is susceptible to P. neglectus meaning the same benefit is not evident where this pathogen is at high levels.

Soil moisture

Knowledge of soil moisture status at critical stages can aid producers in making appropriate decisions regarding fallow length, crop choice and input investment so as to optimize production and improve profitability.

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

Crops sown on heavy clay soils with 1.5 m of wet soil and receiving 100 mm of effective in-crop rain should yield about 3.5 t/ha but crops starting with 1 m of wet soil plus 50 mm of effective rain will yield only 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.

Sowing time

Sorghum should be planted when the soil temperature at 8 am EST at the intended seed depth (about 3–5 cm) is at least 16°C (preferably 18°C) for three to four consecutive days and the risk of frosts has passed. Planting into cold soil slows emergence, reduces germination and establishment and increases susceptibility to seedling blight. Low soil and air temperatures slow plant growth and reduce nutrient uptake (especially phosphorus) inducing purpling in some hybrids. Very early planted paddocks have a higher likelihood of requiring replanting. Note that some hybrids do have better cold tolerance than others.

The preferred planting time for the Moree and Narrabri districts is late September through to early October and for Gunnedah, Inverell and Tamworth districts, mid October to late November. Refer to Table 2. Complete planting by early January so that the crops finish flowering by mid-late March which may reduce the risk of sorghum ergot infection. January planted midge resistant hybrids with good soil moisture and nutrition can still have good yield potential despite being slower to dry down.

Generally, the earlier that sorghum is planted in recommended windows, the better. Planting sorghum at the beginning of sowing opportunities minimizes the probability of moisture and heat stress during the critical flowering and grain-fill period. In addition, early sowing is a recommended strategy to avoid sorghum midge problems and enable producers the option to double-crop should sufficient rainfall be received.

It is therefore necessary that a compromise be made between getting sorghum in early and avoiding excessively cool soil and air temperatures. The reliability of early sowing may be improved by; using varieties that exhibit cold tolerance, ensuring the use of fungicidal and insecticidal seed dressings, and shallow sowing with a disc planter (Wylie, 2008).

If ergot avoidance is a major consideration for the season, the sowing date of sorghum should be adjusted so as to ensure that flowering does not occur whilst temperatures are less than 13°C, since these conditions are most conducive for infection. This may be achieved by having sorghum sown by early January
such that the crop will have ceased flowering by mid-March, prior to the onset of cooler temperatures.

Sorghum midge adults emerge from overwintering diapause in spring and produce larvae that feed on the developing ovary of sorghum grains. Early sowing is a recommended preventative measure for sorghum midge in combination with a midge resistant hybrid however, sowing of midge resistant varieties as late as January can still have good yield potential.

**Row spacing**

Solid plant rows (75 or 100 cm) out-yield skip row or wide rows (150 cm) under good growing conditions, therefore solid plant is more appropriate with high-yielding dryland environments or irrigated crops.

Research conducted by NSW DPI and GRDC in northwest NSW has indicated that once yield potentials are above 3.5–4.0 t/ha there are significant advantages of solid plant (100 cm) over single and double skip configurations. In this research it has been shown that solid plant (100 cm) row spacings can yield up to 50% more than double skip configurations in very favourable seasons when yield potentials are as high as 6 t/ha.

Skip rows are a useful method of conserving water during the vegetative stage of a crop, for use at flowering and grain fill. This term ‘skip row’ indicates that the row configuration is changed by ‘skipping’ or not planting rows. This ‘skip row’ management strategy has been used with peanuts, cotton and maize, as well as sorghum. When discussing row spacing for sorghum (and some other crops, such as cotton), it is useful to refer to Table 3.

Solid row advantages decrease rapidly as soil moisture reserves decline, especially in more marginal areas. Table 4 is a useful guide to determine which row spacing is more appropriate for a particular target yield in dryland systems. In more marginal western dryland areas wider rows or skip rows are preferred for risk management to decrease yield variability and greatly reducing 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 solid plant on an area basis (same plants/ha). Uniform plant establishment within rows will maximise the water use between the wide rows and 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 of the wider rows will be lost. Wide rows can also allow inter-row cultivation or shielded spraying for weed control.

Sorghum sown using wide or skip row spacings may have a lower risk of pest problems (midge), lower herbicide costs (less sprayed area) and more even flowering and dry-down time, improving harvestability.

The yields from skip row spacings in wet seasons are less than solid plant, however, research indicates that in some instances where chickpeas are double cropped following skip row sorghum, the gross margin was higher than where the chickpeas were double cropped out of solid plant sorghum. These results will obviously depend on both the summer and winter seasonal conditions and the relative crop commodity prices.

### Table 3. Row configurations used to plant sorghum.

<table>
<thead>
<tr>
<th>Row configuration</th>
<th>Rows planted</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.75 or 1.0 m solid plant</td>
<td>All rows planted on 0.75 or 1.0 m row spacing</td>
</tr>
<tr>
<td>1.5 m solid plant</td>
<td>All rows planted on 1.5 m row spacing</td>
</tr>
<tr>
<td>Single skip</td>
<td>Two rows planted, one row unplanted (1.0 m)</td>
</tr>
<tr>
<td>Double skip</td>
<td>Two rows planted, two rows unplanted (1.0 m)</td>
</tr>
</tbody>
</table>

### Table 4. Match row spacing to expected yield.

<table>
<thead>
<tr>
<th>Expected yield</th>
<th>Optimum row spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above 4 t/ha</td>
<td>≤ 0.75 m solid plant</td>
</tr>
<tr>
<td>3–4 t/ha</td>
<td>≤ 1.0 m</td>
</tr>
<tr>
<td>Below 3 t/ha</td>
<td>≥ 1.0 m or skip rows</td>
</tr>
</tbody>
</table>

### Plant population

Even though target plant populations vary with conditions, the uniformity of the established plant population is always extremely important. The plant population targeted depends on the depth of soil moisture at planting and the likely growing conditions (Table 5). Under dryland situations, lower tillering hybrids should be planted at slightly higher populations.

Consider re-planting when populations are less than 15,000 plants/ha, especially with quick maturity or low tillering hybrids as significant yield penalties will occur if there are insufficient plants to optimise grain production. High tillering hybrids may be able to compensate for lower plant stands.

### Table 2. Suggested sowing times for sorghum in NSW.

<table>
<thead>
<tr>
<th>Region</th>
<th>Early plant</th>
<th>Late plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aug</td>
<td>Sept</td>
</tr>
<tr>
<td>North west plains</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>North west slopes, Liverpool Plains</td>
<td>&lt;</td>
<td>*</td>
</tr>
<tr>
<td>Central west</td>
<td>&lt;</td>
<td>*</td>
</tr>
<tr>
<td>Southern irrigation areas</td>
<td>&lt;</td>
<td>*</td>
</tr>
</tbody>
</table>

< Earlier than ideal, but acceptable.  * Optimum sowing time.  > Later than ideal, but acceptable.
In skip row situations, aim for plant populations similar to those for good dryland moisture conditions.

When calculating planting rates allow for an extra 20–25% for establishment losses when planting into a very good seedbed on heavy black soil using press wheels and 40–50% losses when seedbed conditions are fair or when press wheels are not used. Obtain the number of seeds per kg and the germination percentage from the bag.

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

Required number of plants/m² × 10,000

Seeds/kg × germ % × establishment %

Example calculation:

\[
\frac{4 \text{ (target plant population/m²) } \times 10,000}{30,000 \text{ (seeds/kg)} \times 0.90 \text{ (germ %)} \times 0.75 \text{ (establishment %)}} = 1.98 \text{ kg seed/ha}
\]

Table 5. Recommended sorghum plant populations.

<table>
<thead>
<tr>
<th>Growing conditions</th>
<th>Target population /m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dryland</td>
<td></td>
</tr>
<tr>
<td>Good conditions</td>
<td>4–6</td>
</tr>
<tr>
<td>Average conditions</td>
<td>4–5.5</td>
</tr>
<tr>
<td>Marginal conditions</td>
<td>3–4.5</td>
</tr>
<tr>
<td>Irrigation</td>
<td></td>
</tr>
<tr>
<td>Supplementary</td>
<td>5–10</td>
</tr>
<tr>
<td>Full</td>
<td>10–15</td>
</tr>
</tbody>
</table>

Crop establishment

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

Uniform establishment and accurate depth placement of seed is essential. Precision planters achieve both of these. Planters should be in small enough sections to follow the paddock undulations with large diameter depth wheels located within the frame and 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 plates.

Narrow points or discs are better suited to no-till and minimum-till conditions and work very well in free flowing soils but excessive planting speeds will reduce establishment.

In moist seedbeds, the seed should be placed about 3–5 cm deep. In dry seedbeds using moisture seeking for deep furrow planting, the seed is also placed 5 cm deep. That may be 10–12 cm below the original soil surface.

Press wheels are essential not only to improve establishment but also to help control soil insect pests of germinating and emerging sorghum, including true and false wireworms. Use press wheel pressures of 4 to 6 kg/cm width of press wheel for conventional seedbeds and 6 to 10 kg/cm for no-till and minimum-till seedbeds. Use pressures at the higher end of the range when sowing moisture is marginal, seed is deeply planted or soil insects are present. Use pressures at the lower end of the range when soils are hard setting or surface crusting. Crop establishment is improved when the shape of the press wheel matches the shape of the seed trench.

Hybrid characteristics

Selecting the right hybrid will depend on the location and forecast seasonal conditions. Growing two or three hybrids with slightly different characteristics can help spread your production risk. Hybrid characteristics are listed in Table 6 and hybrid yield performance in dryland trials is presented in Table 7. This may assist in selecting hybrids suitable for your area.

Hybrid maturity

Select hybrids with a maturity length suitable for the local climatic conditions. With good to average dryland conditions on the North West slopes and Liverpool Plains, the medium to medium-slow maturity hybrids are recommended. On the North West plains, the 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, quick maturity hybrids take about 66 days from planting to the start of flowering, medium maturity hybrids take about 73 days and slow maturity hybrids take about 80 days. The time a hybrid takes to flower will vary, depending 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 to 65 days if sown during 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 on your farm over several seasons and grow those that perform best on average. Use the results of hybrid evaluation trials, such as those in Table 7 as a guide.

Lodging and disease resistance

Lodging can be a problem in all dryland growing areas. Select hybrids with good lodging resistance where moisture stress is likely during the latter stages of grain fill. Moisture stress is the most common cause of lodging. Fusarium and charcoal stem rots are also associated with lodging, leading to plant death and considerable yield loss. Crops that remain green with some available soil moisture during grain fill are generally less prone to lodging.

Agronomic practices such as no-till, stubble retention and controlled traffic farming, which all aim to store more fallow and in-crop rainfall, will help reduce lodging. The use of wide or skip rows, especially in the North West plains, will also help. These practices allow medium maturity hybrids with higher yield potential to be grown.

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

**Table 6. Sorghum hybrid characteristics 2014–15.**

The information presented in this table was kindly supplied by seed companies and is not based on NSW 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.

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>HYBRID</th>
<th>MATURITY</th>
<th>HEIGHT</th>
<th>STANDABILITY</th>
<th>SORGHUM MIDGE</th>
<th>ORGANOPHOSPHATE REACTION*</th>
<th>HEAD TYPE</th>
<th>IRRIGATION SUITABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUSEED</td>
<td>Tiger</td>
<td>MQ</td>
<td>MS</td>
<td>4</td>
<td>3</td>
<td>CC</td>
<td>SC</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>Dominator</td>
<td>M</td>
<td>M</td>
<td>5</td>
<td>5</td>
<td>MIN</td>
<td>O</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>Liberty White</td>
<td>M</td>
<td>MT</td>
<td>4</td>
<td>4</td>
<td>MIN</td>
<td>SO</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>Enforcer</td>
<td>MS</td>
<td>MT</td>
<td>3</td>
<td>6</td>
<td>MIN</td>
<td>O</td>
<td>YES</td>
</tr>
<tr>
<td>PACIFIC SEEDS</td>
<td>MR Bazley</td>
<td>MQ</td>
<td>S-M</td>
<td>5</td>
<td>4</td>
<td>CC</td>
<td>SO</td>
<td>YES—limited only</td>
</tr>
<tr>
<td></td>
<td>MR Taurus</td>
<td>MQ</td>
<td>M</td>
<td>5</td>
<td>6</td>
<td>CC</td>
<td>SO</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>MR Eclipse</td>
<td>M</td>
<td>M</td>
<td>4</td>
<td>6</td>
<td>MIN</td>
<td>SO</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>Pacific MR 43</td>
<td>M</td>
<td>M</td>
<td>4.5</td>
<td>5</td>
<td>MIN</td>
<td>O</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>MR Buster</td>
<td>M</td>
<td>S-M</td>
<td>5</td>
<td>4</td>
<td>SEV</td>
<td>SO</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>MR Scorpio</td>
<td>M</td>
<td>M</td>
<td>4.5</td>
<td>6</td>
<td>CC</td>
<td>SO</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>MR Apollo</td>
<td>MS</td>
<td>M</td>
<td>5</td>
<td>7</td>
<td>CC</td>
<td>SO</td>
<td>YES</td>
</tr>
<tr>
<td>DUPONT PIONEER</td>
<td>84G99</td>
<td>M</td>
<td>S-M</td>
<td>5</td>
<td>5</td>
<td>MIN</td>
<td>O</td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td>84G22</td>
<td>M</td>
<td>M</td>
<td>5</td>
<td>4</td>
<td>MIN</td>
<td>SO</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>85G33</td>
<td>M/Q</td>
<td>S-M</td>
<td>5</td>
<td>6</td>
<td>N/A</td>
<td>SO</td>
<td>YES</td>
</tr>
<tr>
<td>HERITAGE SEEDS</td>
<td>HGS 102</td>
<td>M</td>
<td>M</td>
<td>4</td>
<td>7</td>
<td>MIN</td>
<td>SO</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>HGS 114</td>
<td>M</td>
<td>M-S</td>
<td>5</td>
<td>6</td>
<td>MIN</td>
<td>SO</td>
<td>YES</td>
</tr>
</tbody>
</table>

*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.

* Joint seed company approved ratings based on visible leaf damage only. Ratings may not reflect possible yield losses due to the chemical.

**Sorghum midge resistance**

Most hybrids have some level of resistance to sorghum midge. Newly released hybrids are tested by the Industry Testing Group, comprising DAFF Qld and seed companies, for their midge resistance. Refer to Table 6 for midge resistance ratings and to Table 12 for control thresholds. 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 spotting to intense purpling of leaves and stems. When crops are likely to be sprayed with OP insecticides, it is suggested to grow tolerant hybrids with a rating of 4 or 5 to reduce possible yield losses. See Table 6 and consult seed companies for hybrid ratings.

**Growth stages**

Sorghum is a perennial tropical grass which has a growing season of between 115 and 140 days. The rate of growth is strongly dependent on temperature and moisture but can also be influenced by soil fertility, insect and disease damage.

**Germination and establishment**

Emergence usually occurs within 3 to 10 days of planting. Under warm temperatures, adequate soil moisture, good seed vigour and normal sowing depth, the time taken from planting to emergence is closer to 3 days. Sorghum has hypocotyl emergence, meaning a shoot emerges from the seed and pushes through the soil surface.

Sorghum sown into slightly cooler soil is expected to have emergence delayed 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.
Table 7. DPI 2005/6–2013/14 dryland grain sorghum hybrid evaluation trials. Across sites and seasons analysis.

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>Mean yield**</th>
<th>No. of trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>MR Eclipse (PAC 2423)</td>
<td>5.21</td>
<td>6</td>
</tr>
<tr>
<td>MR Scorpio</td>
<td>4.31</td>
<td>8</td>
</tr>
<tr>
<td>MR Bazley</td>
<td>4.27</td>
<td>9</td>
</tr>
<tr>
<td>MR 43</td>
<td>4.25</td>
<td>17</td>
</tr>
<tr>
<td>HGS114</td>
<td>4.24</td>
<td>4</td>
</tr>
<tr>
<td>Tiger</td>
<td>4.21</td>
<td>9</td>
</tr>
<tr>
<td>MR Buster</td>
<td>4.19</td>
<td>17</td>
</tr>
<tr>
<td>HGS102</td>
<td>4.15</td>
<td>4</td>
</tr>
<tr>
<td>MR Apollo</td>
<td>4.13</td>
<td>5</td>
</tr>
<tr>
<td>B4G22</td>
<td>4.12</td>
<td>7</td>
</tr>
<tr>
<td>Enforcer</td>
<td>4.06</td>
<td>19</td>
</tr>
<tr>
<td>BSG33</td>
<td>4.05</td>
<td>1</td>
</tr>
<tr>
<td>MR Eclipse</td>
<td>4.03</td>
<td>2</td>
</tr>
<tr>
<td>B4G99</td>
<td>4.02</td>
<td>6</td>
</tr>
<tr>
<td>Dominator</td>
<td>3.94</td>
<td>19</td>
</tr>
<tr>
<td>Liberty</td>
<td>3.88</td>
<td>13</td>
</tr>
<tr>
<td>LSD (t/ha)*</td>
<td>0.37</td>
<td></td>
</tr>
<tr>
<td>Mean (t/ha)***</td>
<td>4.12</td>
<td></td>
</tr>
</tbody>
</table>

* The least significant difference (LSD) indicates whether the yields of two varieties is statistically similar or different. In this analysis the yields of two varieties are statistically different if they differ by at least 0.37 t/ha.

** Mean Yield of twenty four dryland trials in north west NSW during 2005–2014 seasons.

*** Mean is the mean of all hybrids in the analysis.

DPI would like to extend its thanks to the grower co-operators for hosting and assisting with these trials and to Heritage Seeds, Nuseed, Pacific Seeds and Dupont Pioneer for their support of these trials.

Vegetative development

Following shoot emergence, leaves will progressively unfold. The first leaf can easily be identified as it has a rounded instead of a pointed tip. The growing point remains below ground until approximately 30 days following 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 per 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 point 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 becoming visible. Flowering commences, beginning at the top of the head and moving downwards over a period of 4–5 days.

Once pollination has occurred, seeds will begin to form, taking around 30 days to reach full development. Visually the seeds become rounded, up to around 4 mm in size and will then start 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

The grain is said to be physiologically mature when a black spot appears at the point where the seed attaches to the plant. At this point the seed is fully mature and will not gain any more nutrients or moisture from the plant. The moisture content is usually around 30% at this time.

If using desiccation this is the optimum time to apply a registered herbicide to kill the plant, preventing additional moisture use.

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 the application of nitrogen. Numerous trials across northern NSW have demonstrated the likely yield benefits. The maximum nitrogen response though will not result, even in soils known to be deficient, if concentrations of other nutrients such as P, K and S are limiting. Therefore, it may prove uneconomical to apply N without prior knowledge of the concentrations of other major nutrients within the soil.

N is best applied either pre-plant or at the time of sowing in the northern cropping region since the opportunity to apply N within the season is not guaranteed due to sporadic in-crop rainfall. Should the opportunity arise, N may be applied to sorghum post-emergence up to the 7 leaf stage and still contribute positively to yield as opposed to grain protein (McMullen, Mitchell, Butler & Southwell, 2008). If nitrogen application is delayed beyond this point a greater proportion ends up contributing to grain protein and not yield.

Rates of 100–150 kg/ha of nitrogen are commonly applied to high yield potential crops grown after winter cereals on the Liverpool Plains. Nitrogen represents a large proportion of input costs however its use is justified since an appreciable return on investment of $2–$5 for every $1 spent on N fertilizer results in circumstances where a yield response occurs (Gardner, McMullen, Formann & Serafin, 2013).

A balance must be sought between application of sufficient N to maximise yield and avoidance of excess application which leads to increases in grain protein content but not yield. Premiums are not paid for sorghum with high grain protein hence allocation of N resources towards grain protein is uneconomical and should be avoided. Table 8 provides a guide to rates of N fertilizer that incorporate the N impact of the previous crop for dryland and irrigated crops respectively, however soil testing and completing a nitrogen budget are the more accurate and preferred methods for determining application.

Table 8. Nitrogen rates (kg N/ha) for sorghum, as influenced by crop rotation, on the Liverpool Plains.

<table>
<thead>
<tr>
<th>Previous crop</th>
<th>Dryland sorghum target yield</th>
<th>Irrigated sorghum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4 t/ha</td>
<td>6 t/ha</td>
</tr>
<tr>
<td>Sorghum, sunflower, cotton</td>
<td>100</td>
<td>140</td>
</tr>
<tr>
<td>Cowpea, mungbean</td>
<td>60</td>
<td>120</td>
</tr>
<tr>
<td>Soybean</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Long fallow winter cereal</td>
<td>80</td>
<td>120</td>
</tr>
<tr>
<td>Long fallow faba bean</td>
<td>30</td>
<td>90</td>
</tr>
<tr>
<td>Long fallow chickpea</td>
<td>45</td>
<td>100</td>
</tr>
<tr>
<td>Lucerne (good stand)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
The contribution of a pulse crop or pasture to soil N largely depends on the quantity of dry matter produced and levels of nodulation. However, as a guide, compared with a previous sorghum crop, cowpea and mungbean crops may leave up to 40 kg/ha of soil N, while soybeans and pigeon peas may leave 25–50 kg N/ha. Sorghum sown following lucerne pastures can produce higher yields than cowpeas or long fallow, based on the nitrogen supplied as long as sufficient moisture to refill the profile has been provided.

Nitrogen budgeting is used to determine the nitrogen requirements of a crop 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.

\[ N \text{ removed in grain (kg/ha):} \]
\[ = \text{Target yield (t/ha)} \times \text{grain protein %} \times 1.6 \text{(conversion factor)} \]
\[ N \text{ required for crop (kg/ha):} \]
\[ = \frac{N \text{ removed in grain}}{2} \text{ (N use efficiency)} \]

**Example calculation:**
\[ (5 \text{ t/ha target yield}) \times 10\% \times 1.6 \text{(conversion)} \times 2 \text{(efficiency)} \]
\[ = 160 \text{ kg/ha} \]

N uptake by a crop comes from the available soil nitrate N and from fertiliser N. Soil nitrate N is estimated by soil testing to 90 cm depth (or deeper) and from the cropping history, especially the grain yield and protein content of the previous crop. Additional N will be mineralised from organic matter throughout the season and available for uptake by the crop. The rate of mineralisation is determined by various factors. The possible mineralised N is not included in these calculations. Once the nitrogen requirement for a crop is known, the amount of N that already exists within the soil may then be subtracted to generate an estimation of the quantity of N that must be applied via fertilizer to produce a crop with the target grain protein content and yield.

Using the above example, if only 80 kg/ha of nitrate N was available in the soil, then a further 80 kg N/ha would be needed. The protein content of grain is a good indicator of the adequacy of N supply to a crop, as shown in Table 9.

Maximum yield is thought to be achieved when grain protein content is between 9–10% (Gardner et. al, 2013). At lower protein readings, the crop is considered to have been protein content is between 9–10% (Gardner et. al, 2013). At maximum yield is thought to be achieved when grain protein content is between 9–10% (Gardner et. al, 2013). At minimum yield is thought to be achieved when grain protein content is between 9–10% (Gardner et. al, 2013). At minimum yield is thought to be achieved when grain content is between 9–10% (Gardner et. al, 2013). At

**Table 9. Crop N status as indicated by protein % of grain (at a given moisture content %).**

<table>
<thead>
<tr>
<th>Indicated N supply</th>
<th>Grain protein %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wheat (12% mc)</td>
</tr>
<tr>
<td>Acute N deficiency. Yield will increase with N addition.</td>
<td>&lt; 11.5%</td>
</tr>
<tr>
<td>Marginal N deficiency. Probable yield increase with N addition.</td>
<td>11.5–12.5%</td>
</tr>
<tr>
<td>N not limiting. Additional N will increase grain protein but not yield.</td>
<td>&gt; 12.5%</td>
</tr>
</tbody>
</table>

**Phosphorus (P)**

Sorghum is much more tolerant of low soil phosphorus levels than wheat or barley as it is more efficient at extracting P from the soil profile. As a guide, soils with less than 20–25 mg/kg P in the top 0–10 cm and less than 10 mg/kg in the subsoil (Colwell), are likely to respond to phosphorus application.

Results from a BSES test should also be referenced. Laboratory testing of soil for P will identify soils with insufficient reserves to meet crop demands. Trial work is currently underway within the northern grains region to better refine critical soil P values for vertosol soils. Results of this work to date are presented in Table 10 (Bell, Lester, Power, Zull, Cox, McMullen & Laycock, 2014).

It is recommended that both Colwell-P and BSES-P tests be used to gauge soil P concentration rather than reliance on the Colwell-P test, as was traditional practice. The Colwell-P test provides a measure of labile P within soil whilst the BSES-P test measures both labile P and Ca-bound P. Alkaline, vertosol soils, such as those predominant within the northern cropping region, are dominated by Ca–phosphate soils which are thought to contribute a significant quantity of available P to sorghum crops upon mineral dissolution. This reserve is not detected via the Colwell-P test whereas it is with the BSES-P test. This means that the Colwell-P test potentially underestimates P availability whilst the BSES-P test potentially overestimates it. Consideration of results from both tests will assist decision making with regards to P response from fertilization.

**Sulfur (S)**

Sulfur deficiency of soils within the northern cropping region has been brought to attention in recent years. Sulfur should be measured to depth in increments of 30 cm every 5 years to detect gypsum layers and potential subsoil reserves. More frequent monitoring of surface layers is recommended. Crops are generally not seen to respond to S fertilisers in the northern cropping region unless surface soil (0–30 cm) S concentration is less than 3 mg/kg (Guppy, 2013).

**Zinc (Zn)**

Sorghum frequently responds to zinc on the heavy alkaline clay soils. Zinc deficient soils typically have pH greater than 7.5, high P levels and low organic matter content.

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

**Subsoil constraints**

Subsoil salinity is reasonably common in the brown, grey and black clay soils in northern NSW. Salinity is the salt concentration in the soil solution. While past research from experimentally imposed salt levels had indicated that grain sorghum is tolerant of salinity, more recent research in northern NSW indicates that grain sorghum is much more sensitive to salinity.
In this research there was a rapid decline in plant growth and yield as soil salinity increased, that is, when Electrical Conductivity (saturated extract – EC) increased from 2 to 5 dS/m. These experimental results are supported by anecdotal evidence fromgrowers and agronomists that where there is subsoil salinity, root exploration by grain sorghum into these saline layers is greatly reduced.

In addition to subsoil salinity, subsoil sodicity is also reasonably common in northern NSW. A sodic soil has an excess of exchangeable sodium ions attached to clay particles. This excess of ions affects the physical characteristics of a soil, by causing dispersion. When a clay soil disperses with water, the clay particles swell as they are no longer bound together and minimise drainage through the soil pores (spaces). A dispersive soil sets hard when dry.

Subsoil sodicity restricts rooting depth. It therefore restricts crop access to water and nutrients. Surface sodicity results in surface sealing, reductions in water infiltration and may cause waterlogging on the surface or inhibit emergence.

**Irrigation**

Quantities of water required for full irrigation of a sorghum crop will vary depending on seasonal and soil conditions, however budget on 1.4 ML/ha (delivered to the field) for a pre-irrigation and 3 irrigations of 1.2 ML/ha during the growing season. The timing of the first irrigation in the absence of rainfall should be mid to late tillering, while the 2nd and 3rd irrigations should be at flowering and 10–14 days later during early grain fill. Irrigated yield potentials are in the vicinity of 10–12 t/ha.

**Weed management**

Significant yield losses occur if weeds are not controlled after planting. For effective control of most weeds, apply atrazine either before planting, at planting or immediately after planting. Apply Primextra® Gold, Dual® Gold or other metolachlor products as a pre-emergent spray for grass control, especially liverseed grass. Treat seed with Concep®II seed safener when using Primextra® Gold, Dual® Gold or other S-metolachlor products.

No-till and minimum-till fallowed crops where atrazine and glyphosate have been used, should have excellent 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 the planting of crops other than sorghum or maize for 18 months after application of 2.5–6.5 L/ha of atrazine 500 g/L, 1.4–3.3 kg/ha of atrazine 900 g/kg or more than 3.2 L/ha of Primextra® Gold. Check the herbicide label. Where chemical residues may occur on soils with a pHc greater than 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) may tolerate atrazine residues. Most other crops are highly sensitive.

Herbicide resistance is an emerging problem in most grain producing areas. Producers should target their weed control carefully so that the correct rate and timing of application is achieved and rotate herbicide groups. This is particularly important for harder to kill weeds such as barnyard grass, liverseed grass, fleabane and bindweed.

**Diseases**

**Sorghum ergot (Claviceps africana)**

Sorghum ergot has been found in late flowering commercial grain crops in northern NSW. It has also occurred in seed production crops in the Macquarie Valley and at Boggabri and in late flowering forage sorghum crops in the Moree and Gunnedah districts. It is difficult to estimate the impact of sorghum ergot on yields of commercial grain crops in NSW.

**Symptoms**

Sorghum ergot is a fungus whose spores compete with pollen at flowering. Ergots are creamy coloured sclerotes usually smaller than sorghum seed that replace the developing seed.

**Conditions favouring development**

The fungus (Claviceps africana) infects sorghum heads at flowering and is favoured by mild temperatures (15–30°C), high humidity and overcast conditions. Ergot spores compete with pollen in the 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 later 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 affected by cold temperatures during flowering.
Sorghum ergot can cause harvest delays with the sticky honeydew clogging machinery. At levels higher than 0.3% by weight, they are toxic to livestock. If precautions are in place to ensure the 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 in humid coastal areas. The incidence of leaf rust in northern NSW has been increasing in recent years.

Symptoms
Leaf rust appears as small reddish brown spots on the leaves. As they develop the pustules become raised and release a powdery spore.

Conditions favouring development
The spores germinate on wet leaves, penetrating the leaf and will then take around 10–14 days for the pustules to appear. The spores are primarily dispersed by wind. Little is known about the fungus but suggestions are that the rust tends to occur in cool wet conditions.

Table 11. Herbicides registered for use in sorghum.

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Example product</th>
<th>Group</th>
<th>Sorghum use pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pre-plant</td>
</tr>
<tr>
<td>2,4-D amine</td>
<td>2,4-D amine 625</td>
<td>I</td>
<td>✓</td>
</tr>
<tr>
<td>atrazine</td>
<td>Atrazine 500 SC</td>
<td>C</td>
<td>✓</td>
</tr>
<tr>
<td>dicamba</td>
<td>Banvel® 200</td>
<td>I</td>
<td>✓</td>
</tr>
<tr>
<td>dicamba + atrazine</td>
<td>Cadence® WG + Gesaprim® 600 SC</td>
<td>I &amp; C</td>
<td>✓</td>
</tr>
<tr>
<td>fluroxypyr</td>
<td>Starane™ 200</td>
<td>I</td>
<td>✓</td>
</tr>
<tr>
<td>fluroxypyr + atrazine</td>
<td>Starane™ 200 + Atrazine 500</td>
<td>I &amp; C</td>
<td>✓</td>
</tr>
<tr>
<td>S-metolachlor*</td>
<td>Dual® Gold</td>
<td>K</td>
<td>✓</td>
</tr>
<tr>
<td>S-metolachlor + atrazine</td>
<td>Primextra® Gold</td>
<td>K &amp; C</td>
<td>✓</td>
</tr>
<tr>
<td>triclopyr</td>
<td>Garlon® 600</td>
<td>I</td>
<td>✓</td>
</tr>
<tr>
<td>tribenuron-methyl</td>
<td>Express®</td>
<td>B</td>
<td>✓</td>
</tr>
<tr>
<td>glyphosate</td>
<td>Roundup® PowerMAX™</td>
<td>M</td>
<td>✓</td>
</tr>
<tr>
<td>amitrole + paraquat</td>
<td>Alliance®</td>
<td>L &amp; Q</td>
<td>✓</td>
</tr>
<tr>
<td>diquat</td>
<td>Reglone®</td>
<td>L</td>
<td>✓</td>
</tr>
<tr>
<td>paraquat</td>
<td>Gramoxone® 250</td>
<td>L</td>
<td>✓</td>
</tr>
<tr>
<td>paraquat + diquat</td>
<td>Spray.Seed® 250</td>
<td>L</td>
<td>✓</td>
</tr>
</tbody>
</table>

*Use only on Concep® II treated sorghum.
Insect pests

**Aphids (Corn – Rhopalosiphon maidis, Oat – R. padi and Rusty plum aphid – Hysteroneura setariae)**

The most common aphid to infest sorghum is the corn aphid, with less frequent occurrences of the oat and rusty plum aphid.

**Damage**
Aphids frequently infest sorghum heads towards the end of grain fill, however there is usually minimal economic damage, even when conditions are dry. Under extremely high populations they may affect yield and quality. Aphid honeydew can cause blockages and breakdowns and delay or extend harvest.

**Threshold**
There are no established thresholds.

**Management**
A pre-harvest spray with a knockdown herbicide will avoid the harvest problems caused by aphids. In severe cases chlorpyrifos is a registered option for corn aphids.

**Heliothis (Helicoverpa armigera)**

All heliothis caterpillars on sorghum are *Helicoverpa armigera*.

**Damage**
Heliothis can attack sorghum both in the vegetative and reproductive phases. It is only when they attack developing grain that control may be warranted.

**Threshold**
Economic thresholds (i.e. the no. of larvae per head where the cost of control is equal to the value of the grain saved) for sorghum can be calculated by using the following formula. It is based on one heliothis causing 2.4 g of yield loss.

**Economic Threshold:**
\[
\text{No of larvae/head} = \frac{(C \times R)}{(V \times N \times 2.4)}
\]

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

**Example calculation:**
Critical no. of larvae per head:
\[
0.83 = \frac{($36 \times 100)}{($180 \times 10 \times 2.4)}
\]

**Management**
Checking for heliothis should be done very early in the morning or very late in the evening twice a week. Aim to control larvae before they reach 7 mm in length as larger larvae cause more damage and are harder to control. Eggs are laid between head emergence and flowering. Spray application at 3 days after 50% of the crop has brown anthers to the base of heads is ideal.

*Helicoverpa armigera* are often resistant to pyrethroids, organophosphates and carbamates. The effectiveness of these products depends on the percentage of resistant heliothis.

**Rutherglen bugs (Nysius vinitor) and Grey Cluster bug (N. clevelandensis)**

Rutherglen bugs are an insect pest of grain sorghum, especially in hot, dry weather.

**Damage**
Rutherglen bugs can cause damage when present in very high numbers, by sucking sap from the plant leaves, stems and heads; therefore reducing yield and/or quality.

**Threshold**
Rutherglen populations within a head can increase rapidly. Preliminary indications suggest at flowering a threshold of 20–25 bugs/head; increasing to 30–35 bugs/head at the soft dough stage. By the hard dough stage through to harvest no damage occurs.

While this number of adults/head causes little economic damage, the subsequent generations of nymphs may cause severe pinching of the grain.

**Management**
Control of the adults is generally recommended because of the rapid population build up as well as the difficulty in controlling nymphs hidden within the sorghum head. Carbaryl and madison are registered for their control.

**Sorghum midge (Contarinia sorghicola)**

**Damage**
Sorghum midge can severely reduce yields, especially in late sown crops.

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

**Control midge when:**
\[
\frac{\text{NM}}{\text{R}} > \frac{C \times W \times CB}{1.4 \times V \times RD}
\]

where;
- \(\text{NM}\) = number of midge/m row
- \(\text{R}\) = 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)

**Example calculation:**
\[
\frac{\text{NM}}{\text{R}} = \frac{4}{3} = 1.33
\]
\[
\frac{C \times W \times CB}{1.4 \times V \times RD} = \frac{17 \times 100 \times 2}{1.4 \times 155 \times 4} = 3.92
\]
As 1.33 < 3.92, do not spray at this stage.
Management
During head emergence and flowering, crops should be checked daily about 3–4 hours after sunrise. Midge are very mobile and so re-infestation of crops is common. A range of synthetic pyrethroids are available to control midge. Crops should be sprayed when the economic thresholds in Table 12 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 12. Sorghum midge/head warranting control in hybrids with different levels of midge resistance.

<table>
<thead>
<tr>
<th>Hybrid midge resistance (Tested Rating)</th>
<th>Flowering heads/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20,000</td>
</tr>
<tr>
<td>Susceptible (1)</td>
<td>2.5</td>
</tr>
<tr>
<td>Low (2)</td>
<td>5.0</td>
</tr>
<tr>
<td>Moderate (4)</td>
<td>10.0</td>
</tr>
<tr>
<td>High (6)</td>
<td>15.0</td>
</tr>
</tbody>
</table>

Avoid sorghum midge by planting during the preferred sowing window. Plant the slowest 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.

Use of synthetic pyrethroids for midge control can lead to increased aphid populations which can create harvest problems.

Wireworms (Orondina spp.)

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

Threshold
Control if 3 or more larvae per metre of row are present.

Management
Use seed treated with an insecticide. The use of press wheels at pressures of 4–6 kg/cm width of wheel reduces the mobility of soil insects near the seed and can improve establishment. Chlorpyrifos and terbufos are registered options for control.

Desiccation
Desiccation of sorghum is used to reduce the time to harvest, control late season weeds and start the fallow to store more soil moisture. It effectively reduces late season transpiration losses such that soil moisture may be conserved for use by the subsequent crop or for earlier commencement of the fallow period. Research conducted within the northern grains region identified that up to 24 mm of moisture may be conserved within the deeper (below 30 cm) layers of the soil profile as a result of timely desiccation (McMullen & Bowring, 2012). A pre-harvest spray of either glyphosate or Reglone®, knockdown herbicides can be applied immediately after physiological maturity has been reached. This will hasten dry down of the grain and should kill or desiccate the crop. Desiccation allows crops to be harvested earlier and more efficiently than if crops were not sprayed.

The timing of the pre-harvest sprays is critical. Crops should be sprayed preferably before the end of March when the 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 to a badly drought stressed crop or following a frost is likely to prove inefficient. In general, the efficiency of desiccants may be improved by application in the morning when the stomata are at their most open, the use of good quality water and appropriate water volumes. Be sure to adhere to specified withholding periods associated with desiccant products. The aim is to maximise yield through the assimilation of carbohydrate in the seed, but balance this moisture use with storing water for the next crop. When 95–100% of the grains have formed a ‘black layer’ (i.e. are physiologically mature), the crop is ready to be desiccated. Sprayed crops should be harvested as soon as they have dried down and the withholding period for the herbicide has been met as they are more prone to lodging.

Research by NSW DPI and the Northern Grower Alliance has shown significant reductions in yield and quality occurs when crops are sprayed prior to physiological maturity. In contrast when spraying is delayed beyond physiological maturity the amount of water stored in the profile is reduced. Timeliness of desiccation is crucial to maximising both grain yield and quality and avoiding issues associated with lodging. If sorghum is desiccated too early, yield is significantly reduced. One particular trial established a 50%, 20% and 10% reduction in yield when desiccation occurred 3, 2 and 1 week earlier than ideal, respectively (McMullen & Bowring, 2012). Premature
desiccation also leads to small grain, low test weight and increased lodging. Delaying desiccation beyond the ideal timing also has significant consequences. It presents poor returns on the spray operation and causes excessive losses in soil moisture, potentially limiting future planting options.

It is crucial that the physiological maturity status of sorghum not be gauged by the colour of the grain but rather the development of the black abscission layer at the base of the seed. Inspection for the black layer should be conducted on sorghum heads of the latest maturity that you wish to harvest. The grain that exists two-thirds of the way down the southern side of the head should be observed since it is the southern side that will be the last to mature. If the black abscission layer is found to be present 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. Should you wait until the time at which all of the grains in the bottom third of the sorghum head are physiologically mature, the approach is considered too conservative.

Sorghum varieties with high amounts of stay-green are designed such that they have more green leaf area during grain fill and at physiological maturity than traditional senescent varieties. In order to fully exploit the advantages provided by the stay-green trait during grain-fill, it is considered most desirable to delay the desiccation of such varieties until 100% physiological maturity. This is in contrast to the advice given for traditional senescent varieties.

Harvest can be expected to occur within 10–14 days following application of a desiccant. Environmental conditions may vary this. It is crucial to ensure that sorghum crops are not standing for a prolonged period of time awaiting harvest after having been desiccated since lodging becomes a concern. When disease pathogens are present prior to desiccation, the likelihood of lodging is increased since desiccation commonly promotes the rapid development of pathogens. In such cases, the acceptable timeframe between desiccation and harvest is reduced so as to harvest the crop prior to the occurrence of lodging.

**Harvest**

Once grain has dried to a level that it can be safely stored (< 13.5%) or transported to an accumulation site, harvest should commence. The availability of good on-farm storage can speed up harvest and allow attention to the post-harvest marketing of grain. Both aeration and drying facilities may also assist in progressing harvest. It is most important that storage facilities are clean and free from grain insect pests. Issues of trafficability should also be addressed particularly on the heavier clay soils. Serious soil compaction can occur when soils are too wet. This can result in long term soil damage reducing the performance of following crops.

**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 the major grain accumulators such as GrainCorp. The marketing of grain takes particular skill but time spent on tracking markets and using the financial mechanisms available, such as forward selling and hedging, can make a substantial difference to farm profits.

Plans to construct ethanol refineries at Gunnedah (Northern NSW) and Dalby (Southern Qld) to produce alternatives to petroleum fuels remain. These plants are likely to consume a considerable tonnage of sorghum and other grains, therefore competing with other users of feed grains. This has the potential to expand the area planted to these crops.

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

**Further information**

Other relevant NSW DPI publications available through NSW DPI offices and at www.dpi.nsw.gov.au are;

- Insect and mite control in field crops 2013
- Weed control in summer crops 2012–13

**References**


**Contributing authors**

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Maize
Loretta Serafin and Nicole Carrigan

Key management issues

- Organise marketing contracts before planting. Growers should 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.
- Plant at the optimum time to avoid early frosts, extreme heat at flowering and cool, slow dry down.
- 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 when there is at least one metre depth of wet soil.
- 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 prior to tasselling to the start of the milk line stage.
- Always use press wheels at planting.
- Adjust plant population and row spacing according to the target yield.
- Apply nitrogen, phosphate and potassium 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), improve moisture storage and reduce fuel costs.

Table 1. NSW Maize Production.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (ha)</td>
<td>Average yield (t/ha)</td>
<td>% of NSW production</td>
<td>Area (ha)</td>
</tr>
<tr>
<td>Northern Inland</td>
<td>7,150</td>
<td>6.8</td>
<td>58</td>
<td>10,080</td>
</tr>
<tr>
<td>Central Inland</td>
<td>560</td>
<td>6.1</td>
<td>5</td>
<td>3,410</td>
</tr>
<tr>
<td>Southern Inland</td>
<td>2,415</td>
<td>11</td>
<td>20</td>
<td>8,650</td>
</tr>
<tr>
<td>Tablelands</td>
<td>200</td>
<td>3</td>
<td>1.5</td>
<td>200</td>
</tr>
<tr>
<td>North Coast</td>
<td>1,900</td>
<td>7.6</td>
<td>15.5</td>
<td>765</td>
</tr>
<tr>
<td>State Total</td>
<td>12,225</td>
<td>6.9</td>
<td>–</td>
<td>23,105</td>
</tr>
</tbody>
</table>


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 to 150 days from planting to harvest. Maize is primarily grown as an irrigated crop but is suited to favourable dryland areas as well. A high yielding crop uses up to 850 mm of water through evapotranspiration during the growing season. Crops can usually be grown successfully without irrigation along the coastal belt, in the tablelands, and in high yielding dryland environment.

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 similar under irrigation. Generally, the majority of maize production in NSW occurs in the inland irrigation areas (Table 1). Although in non-drought seasons the southern inland irrigation areas can account for 60–70% of NSW production.

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, pHca 5.5 to 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 irrigation. Farmers using minimum tillage together with permanent beds report improvement in soil structure as well as cost and time savings.
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. Recent research indicates that stubble retention does not automatically increase disease incidence. Before burning stubble also consider the impacts on nitrogen and potassium management. Mulching stubble, with good soil–stubble contact, soon after harvest will allow time for decomposition and reduce problems with nitrogen tie-up. Large quantities of potassium are leached from the retained residues back into the soil in a plant available form.

Many of the Group B herbicides have plant-back periods of 6–26 months that need to be observed before planting maize. Plant-back requirements are summarised in the DPI Management Guide; Weed Control in Summer Crops 2012–13.

**Sowing time**

Sowing time is governed by;
- soil temperature
- soil moisture
- targeted flowering date.

Commence sowing when the 9.00 am EST soil temperature at sowing depth reaches 12°C and is rising. For irrigated crops, the temperature of water used for pre-irrigation or watering-up can influence sowing time. If watering-up, allow for a 3°C to 4°C drop in soil temperature following watering. The rate of seedling emergence increases with increasing soil temperature. At 12°C emergence will occur in 14 days, whereas at 25°C emergence occurs in 4 to 5 days.

Sowing 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 ~8–10 weeks after planting for mid maturity hybrids. Temperatures above 35°C at this time 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 to occur between mid December and mid February. Sowing time should aim to avoid tasselling and silking during this period. Staggered sowing times mitigates the risk of large yield penalties due to pollen blast across the entire crop.

Early sowing balances the risks of frost soon after emergence and excessive heat at flowering. Cold conditions after emergence will slow seedling growth and foliage may turn purple as phosphorus 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.

Late sowing avoids excessive heat at flowering but increases the risks of insect attack by heliothis and mites, disease in late summer and slow dry down periods in cool, wet autumns. For these reasons, quick maturing hybrids are favoured for late sowings.

The north and central coast region has the longest growing season for maize. However early sowing opportunities tend to be limited to irrigated situations as spring is commonly a dry season. Main sowing is usually delayed until mid November through December. Coastal rain grown crops should be planted so that the critical period from two weeks before through to four weeks after silking occurs when there is a high probability of good rain.

On the south coast and in the tablelands, the safe sowing 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. See Table 2 for further detail.

**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 (Table 3).

Quick maturing hybrids produce smaller plants and so should be sown in higher populations. Conversely, slow maturing varieties generally produce larger plants so usually grow best when sown at lower densities. However, 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 synchronisation of silking with pollen shedding. Silage crops need higher populations than grain crops. See Table 3 below for general recommendations. Refer to seed companies for additional information.

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

**Table 2. Suggested sowing times for maize in NSW production areas.**

<table>
<thead>
<tr>
<th>Region</th>
<th>Early plant</th>
<th>Late plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aug</td>
<td>June</td>
</tr>
<tr>
<td>Northern Inland</td>
<td>&lt;</td>
<td>&lt;</td>
</tr>
<tr>
<td>Central Inland</td>
<td>&lt;</td>
<td>&lt;</td>
</tr>
<tr>
<td>Southern Inland</td>
<td>&lt;</td>
<td>&lt;</td>
</tr>
<tr>
<td>Tablelands</td>
<td>&lt;</td>
<td>&lt;</td>
</tr>
<tr>
<td>North and Central Coast</td>
<td>&lt;</td>
<td>&lt;</td>
</tr>
<tr>
<td>South Coast</td>
<td>&lt;</td>
<td>&lt;</td>
</tr>
</tbody>
</table>

< Earlier than ideal  ● Optimum sowing time  > Later than ideal
Maize is highly responsive to plant population and plant uniformity, meaning the sowing operation is critical for high yields, so care must be taken. Precision planting equipment such as vacuum seed metering systems are preferred. Sow at a uniform depth to ensure uniform emergence and achievement of the target plant stand. Opportunities to increase speed at sowing should only be used where the precision of the operation is not compromised.

**Calculating planting rate and seed spacing within the row**

When calculating the planting rate, allow an extra 5% to 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):

\[
\text{Planting rate (kg/ha)} = \frac{\text{Target plant population/m}^2 \times 10,000}{\text{germ.} \times \text{estab.} \times \text{seeds/kg}}
\]

Example calculation:

\[
7 \text{ (plant population/m}^2) \times 10,000
\]

\[
3,000 \text{ (seeds/kg)} \times 0.95 \text{ (germination)} \times 0.9 \text{ (establishment)}
\]

\[
= 27.3 \text{ kg/ha}
\]

**Row spacing**

Row spacing is commonly 75–110 cm. 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 rows will usually produce slightly higher yields as plants are more evenly spaced.

For dryland production in drier areas such as the north west plains, single or double skip on 100 cm rows are suggested so that soil moisture is conserved for grain fill. Trial work at Moree suggests that in moisture stressed conditions there may be no advantage of double skip over single skip configurations due to the inability of lateral roots to extract moisture from the centre of a double skip. With skip 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.

**Hybrid characteristics**

**Hybrid selection**

Select two or three hybrids to spread your risk. Growing hybrids of different corn relative maturity (CRM) and various planting times will reduce exposure to risks associated with adverse climatic conditions, especially during tasselling and grain fill. The characteristics of maize hybrids commercially available in 2014–15 are presented in Table 4.

**End use**

The desired end use of a maize crop should be considered, as if more than one market is intended, a different variety may be required for each in order to achieve best results.

**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 are recommended by the particular processor buying your maize. In many cases end users provide the seed at sowing time as their needs can be quite specific. Grit manufacturers, for example, require hard endosperm hybrids to make breakfast cereals and confectionary products. In Table 4, 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% amyllose. Starch from waxy maize has properties which make it particularly suited for food processing.

Waxy, high amyllose, white and popcorn hybrids should only be grown under contract as currently their markets in Australia are very small. Some special purpose hybrids may be less vigorous than yellow maize hybrids and yield less, especially high amyllose and popcorn hybrids. However, recently released waxy and white hybrids have improved performance and good lodging resistance.

**Grain for stockfeed**

If the crop is to be used as stockfeed, select varieties adapted to your area that produce a high grain yield.

**Silage**

Maize is a premium silage crop, producing a large bulk of high-energy forage without the need for wilting prior to ensiling or the addition of silage additives. It is best suited for chopped silage stored in a pit or bunker. The economic viability of maize silage is very dependent on yields and energy values. The major limiting factors are inadequate nutrition, low plant populations and delayed preparation leading to unsuitable hybrid selection. 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 amount of dry matter per ha);
- produce a high grain and biomass yield;
- retain a high proportion of green leaf through to harvest;
- tolerate relatively high density planting.

**Yielding ability**

Select hybrids that perform well over a range of seasonal conditions. Some quicker maturing hybrids may 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 farm and grow those best suited to the conditions. The slower maturing hybrids usually produce more silage than quicker maturity hybrids. Dryland yields from hybrid evaluation trials in Moree and Tamworth are presented in Table 5.
### Table 4. Maize Hybrid Characteristics 2014–15.

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 maize hybrids for particular markets and for particular localities.

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>CRM</th>
<th>NSW area of adaptation</th>
<th>End use</th>
<th>Husk cover</th>
<th>Disease reactions</th>
<th>Lodging</th>
<th>Company recommendations</th>
<th>Seed brand</th>
</tr>
</thead>
<tbody>
<tr>
<td>MFY136</td>
<td>82</td>
<td>All</td>
<td>Feed; Silage</td>
<td>M</td>
<td>8 7 9 9 9 9 75–100</td>
<td>40–75 35–45</td>
<td>HSR</td>
<td></td>
</tr>
<tr>
<td>MFY139</td>
<td>88</td>
<td>All</td>
<td>Feed; Silage</td>
<td>M</td>
<td>7 7 9 8 9 75–100</td>
<td>40–75 35–45</td>
<td>HSR</td>
<td></td>
</tr>
<tr>
<td>P9400</td>
<td>94</td>
<td>Southern Inland</td>
<td>Feed; Silage</td>
<td>M</td>
<td>7 6 6 8 8 80–100</td>
<td>– – Pioneer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P0021</td>
<td>100</td>
<td>Southern Inland</td>
<td>Feed; Silage</td>
<td>M</td>
<td>7 6 tbc 7 7 75–95</td>
<td>– – Pioneer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAC 301</td>
<td>102</td>
<td>Central/Southern NSW</td>
<td>Grain</td>
<td>VT</td>
<td>7 9 7 7 7 90–110</td>
<td>60–80 20–40</td>
<td>Pacific Seeds</td>
<td></td>
</tr>
<tr>
<td>Maximas</td>
<td>102</td>
<td>All</td>
<td>Feed; Silage</td>
<td>M</td>
<td>8 9 7 9 9 75–100</td>
<td>40–75 35–45</td>
<td>HSR</td>
<td></td>
</tr>
<tr>
<td>P1070</td>
<td>110</td>
<td>All</td>
<td>Feed, silage</td>
<td>M</td>
<td>6 5 7 8 9 70–90</td>
<td>45–65 20–15</td>
<td>Pioneer</td>
<td></td>
</tr>
<tr>
<td>Olympiad</td>
<td>112</td>
<td>All</td>
<td>Feed; Silage</td>
<td>M</td>
<td>8 8 8 9 9 75–100</td>
<td>40–75 35–45</td>
<td>HSR</td>
<td></td>
</tr>
<tr>
<td>NeroIT</td>
<td>112</td>
<td>All</td>
<td>Feed; Silage</td>
<td>M</td>
<td>7 8 7 9 9 75–100</td>
<td>40–75 35–45</td>
<td>HSR</td>
<td></td>
</tr>
<tr>
<td>P1467</td>
<td>114</td>
<td>All</td>
<td>Feed; Silage</td>
<td>M</td>
<td>5 5 7 8 8 70–90</td>
<td>45–65 20–15</td>
<td>Pioneer</td>
<td></td>
</tr>
<tr>
<td>32P55</td>
<td>114</td>
<td>All</td>
<td>Feed; Grits; Silage</td>
<td>MT</td>
<td>7 7 7 8 9 60–75</td>
<td>30–45 20–15</td>
<td>Pioneer</td>
<td></td>
</tr>
<tr>
<td>PAC 606</td>
<td>114</td>
<td>All</td>
<td>Feed; Silage</td>
<td>MT</td>
<td>9 7 7 7 8 80–100</td>
<td>40–60 20–40</td>
<td>Pacific Seeds</td>
<td></td>
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<tr>
<td>HM-114</td>
<td>114</td>
<td>All</td>
<td>Feed; Silage</td>
<td>T</td>
<td>5 7 – 8 9 60–75</td>
<td>30–45 20–30</td>
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<td></td>
</tr>
<tr>
<td>PAC 624</td>
<td>117</td>
<td>All</td>
<td>Feed; Silage</td>
<td>MT</td>
<td>7 7 7 8 7 65–75</td>
<td>35–45 20–35</td>
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<tr>
<td>P1756</td>
<td>117</td>
<td>All</td>
<td>Feed; Silage, Grit</td>
<td>M</td>
<td>6 7 7 8 9 60–75</td>
<td>30–45 20–35</td>
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<td>PAC 607IT</td>
<td>118</td>
<td>All</td>
<td>Feed; Silage</td>
<td>MT</td>
<td>7 7 7 8 7 65–75</td>
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<tr>
<td>PAC 735</td>
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<td>All</td>
<td>Grit; Silage</td>
<td>MT</td>
<td>7 8 7 9 9 55–75</td>
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<tr>
<td>Sirius</td>
<td>118</td>
<td>All</td>
<td>Feed; Silage</td>
<td>M</td>
<td>8 8 7 9 9 75–100</td>
<td>40–75 25–35</td>
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<td></td>
</tr>
<tr>
<td>P1813IT</td>
<td>118</td>
<td>All</td>
<td>Feed; Grit; Chips</td>
<td>T</td>
<td>7 6 7 8 8 60–75</td>
<td>30–45 20–35</td>
<td>Pioneer</td>
<td></td>
</tr>
<tr>
<td>Amadeus</td>
<td>118</td>
<td>All</td>
<td>Feed; Grit; Chips</td>
<td>M</td>
<td>9 9 8 8 8 75–100</td>
<td>40–75 35–45</td>
<td>HSR</td>
<td></td>
</tr>
<tr>
<td>Amadeus IT</td>
<td>118</td>
<td>All</td>
<td>Feed; Grit; Chips</td>
<td>M</td>
<td>9 9 8 8 8 75–100</td>
<td>40–75 35–45</td>
<td>HSR</td>
<td></td>
</tr>
<tr>
<td>HM-135</td>
<td>118</td>
<td>All</td>
<td>Feed; Silage</td>
<td>MT</td>
<td>5 7 – – – – 60–75</td>
<td>30–45 20–30</td>
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<tr>
<td>PAC 345IT</td>
<td>119</td>
<td>All</td>
<td>Feed; Grit; Chips</td>
<td>MT</td>
<td>5 7 8 8 6 60–70</td>
<td>35–45 25–35</td>
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<td></td>
</tr>
<tr>
<td>PAC 727</td>
<td>123</td>
<td>Northern Inland; North Coast</td>
<td>Feed; Grits; Silage</td>
<td>MT</td>
<td>6 7 7 8 7 55–70</td>
<td>35–50 20–30</td>
<td>Pacific Seeds</td>
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<tr>
<td>P2307</td>
<td>123</td>
<td>North Coast, South-Central Inland</td>
<td>Silage; Grit</td>
<td>VT</td>
<td>9 – 7 – 7 50–65</td>
<td>30–45 20–25</td>
<td>Pioneer</td>
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</tr>
<tr>
<td>HM-102</td>
<td>123</td>
<td>Northern Inland; North Coast</td>
<td>Feed; Silage</td>
<td>T</td>
<td>5 8 8 7 7 50–65</td>
<td>30–45 20–30</td>
<td>Heritage Seeds</td>
<td></td>
</tr>
</tbody>
</table>

**Specialty Hybrids**

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>End use</th>
<th>Disease reactions</th>
<th>Lodging</th>
<th>Company recommendations</th>
<th>Seed brand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thunderpop</td>
<td>Butterfly Popcorn</td>
<td>MT 7 7 8 7 7 75–100</td>
<td>40–90 30–50</td>
<td>Dolphin Seeds</td>
<td></td>
</tr>
<tr>
<td>Blaster</td>
<td>Mushroom Popcorn</td>
<td>MT 7 7 8 7 7 60–75</td>
<td>40–50 25–30</td>
<td>Dolphin Seeds</td>
<td></td>
</tr>
</tbody>
</table>

* IT = imidazolinone tolerant; *IR = imidazolinone resistant; * Husk Cover; M = moderate; MT = moderate/tight; T = Tight; VT = Very Tight; * Lodging Resistance; 1 = Poor; 5 = Average; 9 = Excellent; * Disease Reactions; 1 = Highly Susceptible; 5 = Intermediate; 9 = Highly Resistant; NR = Not Recommended; – = No Information; * CRM = Corn Relative Maturity
Table 5. DPI dryland maize hybrid evaluation trials. Sites at Moree and Tamworth in 2005–06 and 2007–08.

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>Company</th>
<th>No. of trials</th>
<th>CRM</th>
<th>Mean yield t/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>34N43</td>
<td>Pioneer</td>
<td>6</td>
<td>110</td>
<td>4.73</td>
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<tr>
<td>51136</td>
<td>HSR Seeds</td>
<td>2</td>
<td>85</td>
<td>4.65</td>
</tr>
<tr>
<td>Cobber-Flint</td>
<td>Nuseed</td>
<td>6</td>
<td>112</td>
<td>4.38</td>
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<tr>
<td>PAC 533</td>
<td>Pacific Seeds</td>
<td>10</td>
<td>109</td>
<td>4.36</td>
</tr>
<tr>
<td>32P55</td>
<td>Pioneer</td>
<td>6</td>
<td>117</td>
<td>4.31</td>
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<tr>
<td>Maximus</td>
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<td>10</td>
<td>102</td>
<td>4.31</td>
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<tr>
<td>PacM592</td>
<td>Pacific Seeds</td>
<td>6</td>
<td>99</td>
<td>4.28</td>
</tr>
<tr>
<td>36H36</td>
<td>Pioneer</td>
<td>10</td>
<td>100</td>
<td>4.27</td>
</tr>
<tr>
<td>PAC 502IT</td>
<td>Pacific Seeds</td>
<td>2</td>
<td>104</td>
<td>4.16</td>
</tr>
<tr>
<td>PAC 424</td>
<td>Pacific Seeds</td>
<td>10</td>
<td>115</td>
<td>4.13</td>
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<tr>
<td>3527</td>
<td>Pioneer</td>
<td>4</td>
<td>106</td>
<td>4.04</td>
</tr>
<tr>
<td>3237</td>
<td>Pioneer</td>
<td>4</td>
<td>118</td>
<td>3.96</td>
</tr>
<tr>
<td>Hannibal</td>
<td>HSR Seeds</td>
<td>10</td>
<td>112</td>
<td>3.91</td>
</tr>
<tr>
<td>PAC 675IT</td>
<td>Pacific Seeds</td>
<td>4</td>
<td>118</td>
<td>3.85</td>
</tr>
<tr>
<td>MYT140SM</td>
<td>HSR Seeds</td>
<td>6</td>
<td>103</td>
<td>3.83</td>
</tr>
<tr>
<td>PCM603IT</td>
<td>Pacific Seeds</td>
<td>2</td>
<td>104</td>
<td>3.78</td>
</tr>
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<td>31H50</td>
<td>Pioneer</td>
<td>4</td>
<td>123</td>
<td>3.63</td>
</tr>
<tr>
<td>Emperor TL</td>
<td>HSR Seeds</td>
<td>8</td>
<td>90</td>
<td>3.60</td>
</tr>
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<td>MY063NJ</td>
<td>HSR Seeds</td>
<td>4</td>
<td>90</td>
<td>3.46</td>
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<tr>
<td>Expt.8821.8501</td>
<td>Nuseed</td>
<td>6</td>
<td>90</td>
<td>3.28</td>
</tr>
</tbody>
</table>

Corn Relative Maturity (CRM)

Determination of 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 may increase the time between physiological maturity and harvest maturity where seasons are short.

Commercially available hybrids in NSW range in maturity from 90–126 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 may take 150+ days to reach 'maturity', which in the CRM system is more closely aligned with physiological maturity (black layer formation) rather than harvest maturity.

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

For grain production in NSW using irrigation or with 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 can 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 may have later maturity than those selected for grain.

Lodging resistance

The prevention of lodging is essential to avoid difficult harvesting and significant yield losses. Hybrid selection can play an important role in this. 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, imbalance of plant nutrients, stalk and root rots during grain-fill 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 sowing is not an effective technique for reducing lodging as it leads to slower seedling emergence and does not enhance plant standability or lead to the development of a deeper root system.

Disease resistance

Select hybrids that have 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 (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 prior to silking.

In coastal districts select hybrids with tight husk cover to help prevent weevil and heliothis damage and also to significantly reduce cob rots and weather damage. In inland regions lose 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 metres.
- Where there is less than an 800 metre isolation zone, maize crops should be separated by six weeks in sowing time 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 is dependent on temperature and moisture.
Vegetative development

At 3 weeks after emergence the plant is about 40 cm tall and has 5 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 4 weeks after emergence. By 5 weeks after emergence the crop is 80–90 cm tall, has 8 fully emerged leaves and the developing tassel is 15 cm above the soil. Over the next 2 weeks the stem continues to elongate, leaves expand to their maximum size and the cob begins rapid development. After ~9 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 dispersed from the tassel, fertilising the cobs. This occurs over a 3–8 day period. Moisture stress in the weeks prior to flowering can delay the emergence of the silks, causing the pollen to be shed and wasted in their absence, resulting in poor kernel set.

Grain fill and denting

The husks, cob and shank of the cob are fully developed ~12 days after the silks emerge. This point maybe referred to as ‘blister’ as the kernels are white and resemble a blister in shape. By this stage potassium uptake is almost complete.

The crop continues to rapidly take up nitrogen and phosphorus 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 commencement of denting. Denting refers to the changing shaped 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 the transfer of nutrients 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 the laying down of starch proceeds. During grain fill, yield gains can still be made from photosynthesis and carbohydrate accumulation that occurs during this time, however these are often offset by the senescence or leaching of nutrients from the lower leaves. The position of the milk line is closely related to the dry matter content of the crop, so indicates the crop’s progress towards harvest.

A scoring system is used to track the movement of the milk line. The milk line score (MLS) begins at 0 when the kernels are fully expanded but there is no visible line at the top of the kernel where starch deposition has commenced. It finishes at 5 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 4 days. The process can occur more rapidly in hot, dry conditions.

Physiological maturity

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

Severe moisture stress, hot temperatures or early frost during grain fill can cause premature setting of the black layer. 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 nitrogen, phosphorus and potassium required in fertiliser applications is dependent on previous cropping and fertiliser history, age of cultivation, fallow conditions and yield targets. The overall removal of nutrients is greater in silage compared to grain crops, particularly for potassium. The expected nutrient removal by maize grain and silage crops of varying yields is shown in Table 6. Continuous removal of these nutrients 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 4 weeks after planting when nutrient uptake rapidly increases. More than 90% of potassium uptake occurs between 4 and 7 weeks after planting, when less than half of the final above ground dry matter has been produced. Nitrogen uptake also increases rapidly with 55% of uptake occurring in the short window from 7 weeks after planting until the end of silking. Nitrogen uptake is virtually complete 2 weeks after flowering. Phosphorus uptake is complete 4 weeks after flowering.

The timing of fertiliser application is extremely important. Crop accumulation of nitrogen, phosphorus and potassium is rapid in the early stages of growth. Banding fertiliser at sowing 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 at a faster rate when sown with banded fertiliser. An added advantage of band applied fertiliser over broadcast fertiliser is that the nutrients remain in available forms for a longer time.

Banding fertiliser at sowing is possible with most modern precision planters. Apply mixed fertilisers (nitrogen, phosphorus and potassium) in a band 5 cm to the side of the seed and 5 cm below it. This placement prevents damage to the seedling by fertiliser burn which is a risk if the seed and fertiliser are in direct contact.

Nitrogen (N)

Nitrogen is the main nutritional limitation to yield in all maize producing regions. The challenge is to manage nitrogen fertilisers for maximum efficiency of utilisation. N supply must be adequate to meet daily uptake demands whilst minimising losses through processes such as 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.
Maize crop growth stages as they relate to crop agronomy

<table>
<thead>
<tr>
<th>Stage VE</th>
<th>V2</th>
<th>V5</th>
<th>V8</th>
<th>V12</th>
<th>V16</th>
<th>R1</th>
<th>R5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergence</td>
<td>2 leaves fully emerged</td>
<td>5 leaves fully emerged</td>
<td>8 leaves fully emerged</td>
<td>12 leaves</td>
<td>16 leaves</td>
<td>Pollination</td>
<td>20 leaves</td>
</tr>
<tr>
<td>Tassel and ear initiation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Height (cm) | 0 | 10 | 30 | 60 | 270 | 270 |
| Days        | –6 | –2 | 0  | 7  | 18  | 28  |

Critical periods for monitoring key insect pests of maize.

- Wireworms
- African black beetle
- Cutworms
- Armyworms
- Heliothis
- Monoleptra beetle
- Mites

Herbicide windows for weed control in maize.

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Post-emergent application</th>
<th>Avoid Spraying Pre-plant application</th>
<th>Harvest aid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atrazine</td>
<td>2-3 leaves</td>
<td>10-90 cm or 15 days prior to tasselling</td>
<td>2,4-D amine</td>
</tr>
<tr>
<td>Dicamba</td>
<td>10-20 cm</td>
<td>20 cm – before tasselling: drop nozzles only</td>
<td>2,4-D amine from dough stage</td>
</tr>
<tr>
<td>MCPA 250</td>
<td>3-5 leaves</td>
<td>6 leaves to tasselling: use droppers</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rate of water, nitrogen, phosphorus and potassium use by maize.

| % Water | 1 | 2 | 4 | 5 | 7 | 19 | 11 | 12 | 12 | 11 | 8 | 6 | 5 | 3 | 2 | 1 | 1 |
|---------|---|---|---|---|---|----|----|----|----|----|---|---|---|---|---|---|---|---|
| % N     | 1 | 1 | 1 | 2 | 7 | 11 | 14 | 15 | 16 | 12 | 10 | 6 | 4 | 2 | 1 | 1 | 1 |
| % P     | 1 | 1 | 1 | 1 | 2 | 4 | 7 | 10 | 11 | 15 | 13 | 11 | 9 | 8 | 5 | 2 | 1 |
| % K     | 1 | 1 | 1 | 3 | 9 | 16 | 21 | 20 | 16 | 8 | 5 | 1 | – | – | – | – | – |

Maize
N uptake by a crop comes 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 grain yield and protein content of the previous crop. Legume rotations and long fallows increase the availability of soil nitrate N, reducing the fertiliser requirement. Indicative N requirements for a range of target yields following various rotations are provided in Table 7.

For high yields in coastal areas, up to 200 kg N/ha as fertiliser may be needed. High yielding inland irrigated crops may need 250 to 350 kg N/ha, depending on the yield target and cropping history. Dryland crops in inland regions need about the same quantity of nitrogen as grain sorghum.

Irrespective of the form of nitrogen applied, the efficiency of nitrogen fertiliser use and thus its cost effectiveness can be enhanced through the adoption of a split application program. Fertiliser can be applied before sowing, at sowing 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 prior to sowing and the remainder is applied as 50 kg N/ha in each irrigation commencing with the third irrigation.

Approach 2 – apply a third of the N pre-plant, a third as a side dressing prior to 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 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 the nitrogen requirements of a crop by using the following calculations.

\[
\text{N removed in grain (kg/ha):} \\
\text{Target yield (t/ha)} \times \text{grain protein %} \times 1.6 \text{ (conversion factor)}
\]

\[
\text{N required for crop (kg/ha):} \\
\text{N removed in grain (kg/ha)} \times 1.6 \text{ (N use efficiency)}
\]

Example calculation:

\[
\left[ 10 \text{ (t/ha target yield)} \times 10 \times \text{(% grain protein)} \times 1.6 \text{ (conversion factor)} \right] \times 1.6 \text{ (efficiency)}
\]

= 256 kg N/ha required for 10 t/ha yield potential

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.

**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 may be as high as 30 to 50 kg P/ha on high yielding irrigated crops. The soil type, test strips and VAM fungi levels (in northern NSW) are guides to the phosphorus requirement of a crop. However a soil test is the only reliable method of determining 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.

P fertiliser can be broadcast and cultivated-in prior to sowing or banded at sowing. Early in crop development maize has a relatively high requirement for P but is inefficient at extracting it from the soil. Therefore at least some of the applied P should be banded at planting, 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 stubble burnt) up to 300 kg K is being removed, as shown in Table 6. This K will eventually need to be replaced to maintain high yield potential. K remaining in the roots and retained stubble is rapidly returned to the soil as K is readily leached from plant material.

**Table 7. Nitrogen rates (kg N/ha) for maize yield targets 4–12 t/ha, as influenced by crop rotation.**

<table>
<thead>
<tr>
<th>Previous crop</th>
<th>Dryland* yield target t/ha</th>
<th>Irrigated yield target t/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Sorghum, Cotton, Sunflower, Maize</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>Soybean</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Cowpea, Mungbean</td>
<td>70</td>
<td>120</td>
</tr>
<tr>
<td>Long fallow Wheat</td>
<td>80</td>
<td>120</td>
</tr>
<tr>
<td>Long fallow Faba bean</td>
<td>30</td>
<td>80</td>
</tr>
<tr>
<td>Long fallow Chickpea</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Lucerne</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

* Dryland maize N estimates are based Liverpool Plains climate and soils with cultivations older than 25 years.

**Table 6. Nitrogen, phosphorous and potassium removal by maize.**

<table>
<thead>
<tr>
<th>Yield potential tonnes/ha</th>
<th>Dryland</th>
<th>Irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grain</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>Mid</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>Mid</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>Mid</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>Mid</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>Mid</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>Mid</td>
</tr>
<tr>
<td>Nutrient removal kg/ha</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>9</td>
<td>17</td>
</tr>
<tr>
<td>Potassium</td>
<td>11</td>
<td>22</td>
</tr>
</tbody>
</table>

The amount of fertiliser K required depends on the level of available potassium in the soil. Plants absorb K directly from soil solution which is far smaller than the exchangeable and fixed pools of K in the soil. Particularly in clay soils with shrink-swell properties, K added as fertiliser may be fixed in the soil and yet not immediately available for plant uptake. Soil testing gives an indication of 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 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 the need 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 test strips with 60–125 kg/ha of muriate of potash.

**Zinc (Zn)**

Zinc fertilisers are needed for maize grown on heavy alkaline soils as deficiencies commonly occur. Zinc can be broadcast at 10–20 kg Zn/ha and incorporated at least 3 months prior to planting. This application rate should last for five to six years as zinc is relatively immobile in the soil. Lower rates are sufficient on lighter textured soils.

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

**Molybdenum (Mo)**

Molybdenum deficiency usually occurs on acid coastal soils. The deficiency should be overcome by a single application of molybdénised superphosphate every 5 years. More frequent applications may raise Mo to toxic levels. A seed dressing of molybdenum trioxide or a foliar spray of sodium molybdate or ammonium molybdate are alternative methods of preventing Mo deficiency.

**Subsoil constraints**

Maize is only moderately tolerant of saline soils or saline irrigation water. The critical limits for yield reductions and likely impact of salinity on maize production are shown below in Table 8.

The quality of irrigation water that can be used on the crop is dependent on soil texture. 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. Shandyng water to less than 0.6 dS/m where possible will reduce the problems of salinity building up in the soil profile. When assessing paddock suitability for maize, the depth to the watertable and its salt content should also be considered. Watertables could rise during the season in response to rainfall or irrigation.

### Table 8. The likely impact of salt on maize production.

<table>
<thead>
<tr>
<th>Average salt concentration</th>
<th>Likely impact on maize production</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 dS/m in irrigation water</td>
<td>above this critical limit, yield starts to decline</td>
</tr>
<tr>
<td>1.7 dS/m in the root zone</td>
<td>above this critical limit, yield starts to decline</td>
</tr>
<tr>
<td>2.5 dS/m in the root zone</td>
<td>up to 10% yield loss</td>
</tr>
<tr>
<td>3.8 dS/m in the root zone</td>
<td>at least 25% yield loss</td>
</tr>
</tbody>
</table>

**Soil moisture**

Knowledge of soil water holding capacity and starting moisture is essential 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, which will also affect yield.

Inland dryland crops require moisture to one metre at planting. Maize is less tolerant of moisture stress than other summer crops such as grain sorghum. It is particularly vulnerable to moisture stress just prior to flowering (tasselling) and through to three weeks after flower finish (silking).

Plant crops using no-till and stubble retention methods wherever possible to conserve soil moisture. While the ideal sowing depth is 4–5 cm, seed may be moisture sought down to 9 cm.

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

**Irrigation**

Well irrigated maize crops use water very efficiently, commonly yielding 16–18 kg grain/ha/mm of water. Trial work has recorded efficiencies in excess of 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. Yields achieved in irrigated maize trials conducted by the Department of Primary Industries are shown in Table 11.

**Water budgeting**

When planning a maize crop it is important to consider the area that can be fully watered as maize is less tolerant of moisture stress than other summer crops. At Gunnedah budgeting 7 ML of irrigation water applied to the field /ha will satisfy crop water requirements in four out of five years. In the Murrumbidgee valley, irrigation water use ranges from 6 to 10 ML 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 when using these methods. The higher system efficiencies of these methods, as shown in Table 9, are another significant advantage in maize production.
Table 9. Indicative efficiency of irrigation methods.

<table>
<thead>
<tr>
<th>Irrigation Method</th>
<th>Indicative System Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood or furrow</td>
<td>60–70%</td>
</tr>
<tr>
<td>Sprinkler – centre pivot, lateral move</td>
<td>85–90%</td>
</tr>
<tr>
<td>Drip</td>
<td>90–95%</td>
</tr>
</tbody>
</table>

**Peak water use**

High water use occurs from tassel appearance through to early dent grain maturity. Approximately 70% of the crop’s total water use will occur in this window between 5 and 12 weeks after planting. During this time cob initiation, flowering, pollination and kernel set occur.

Peak water use occurs during the 3 weeks following silking (weeks 10–12). The greater the canopy, the greater the water use during this period. Taller, denser crops will use more water as they intercept more light and are exposed to more wind.

**Scheduling irrigations**

The frequency of irrigation depends on the interaction between crop growth, stored soil moisture and the climatic conditions – temperature, rainfall, wind and humidity. Early in the season, when the root system is developing, it is recommended that irrigations are scheduled to occur 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. The daily water use of maize at key stages of growth, relative to both pan evaporation and the evapotranspiration of a ‘standard’ crop are presented in Table 10. A large proportion of the soil water is taken up by the roots from within the top 30 cm of the profile. Monitoring soil moisture conditions at 25 cm is also a useful guide to moisture availability.

**Timing the first irrigation**

Planting the crop into a full profile of soil moisture encourages rapid root growth and avoids waterlogging. This may require a pre-sowing irrigation. When starting with a full profile of moisture, 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 during the period 5–8 weeks after emergence. The first irrigation should be timed to ensure access to nutrients is not limited by water at this time and it is critical that nutrient uptake not be interrupted by waterlogging.

**Timing the last irrigation**

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

For grain crops, the last irrigation should be timed 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 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 prior, when the crop is at the milk line score of 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 3 weeks after silking) will result in a ~90 mm deficit by the time a 2.5 milk line score is reached.

**Irrigation scheduling tools**

Loggers that continuously monitor moisture at different depths throughout the profile (such as Enviroscans® and C Probes®) allow accurate and continuous soil moisture monitoring. This technology also allows users to access the information through wireless communication, so soil profiles can be monitored remotely. Neutron probes also measure available soil water, however logging is not continuous and only occurs as often as is manually possible. Other scheduling systems based on weather data (such as DPI WaterWatch service) are available in major irrigation areas.

**The impacts of stress**

Moisture stress in the first 4 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, whilst stress at tasselling (flowering) and silking (pollination) can result in unset kernels. Moisture stress following silking leads to reduced kernel size and increased risk of mycotoxin contamination in the grain sample. Four consecutive days of moisture stress between tasselling and silking can reduce yields by 30%. Grain yield declines by 6–8% per day of moisture stress during the peak water use period. After a period of moisture stress, the crop may take several days to recover regardless of soil moisture. If an irrigation is applied after a period of stress, increase the flow rate to minimise the period of inundation. Prolonged saturation increases the risk of lodging if conditions become windy. Ideally watering periods should not be more than 12 hours.
Maize is not tolerant of waterlogging. Root activity is restricted due to a lack of oxygen and nitrogen losses through denitrification and leaching can be significant. There are two stages of growth during which waterlogging are most damaging. The first is the seedling stage prior to the development of secondary roots. At this stage crop water use is low resulting in the soil drying slowly. Any marginal nutritional deficiencies are exacerbated; in particular zinc deficiency becomes much worse. Crop recovery is slow and quite commonly crops never ‘catch up’ from early waterlogging set backs. The second is the period from tasselling to silking. At this time the crop is highly sensitive to both the reduction in water uptake and the interruption in the flow of nutrients. When furrow irrigating, an irrigation is usually timed just prior to 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 prior to silking. When maize plants are moisture stressed leading into tasselling the development of silks lower down the plant may be slower than normal which can result in pollen being shed and wasted before the silks emerge resulting in very poor kernel set. If only one irrigation is possible, its application just prior to tasselling (~8 weeks after planting) will usually offer the greatest return. If two irrigations are possible, the second should follow the first avoiding stress in between. It should be remembered 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 stages of growth until the crop reaches 0.8 m in height, ~8 weeks after planting. Effective weed control through this period is essential for high yields, particularly in dryland crops. Maintaining weed control beyond this stage is important for harvestability and preventing contamination of the grain sample.

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

Herbicides

Due to the impact of 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 may have plant back restrictions that limit their suitability. The herbicides with registrations for use in maize are summarised in Table 12. For more detail, refer to the DPI Management Guide, Weed Control in Summer Crops 2012–13. Always read the label directions before using any agricultural chemicals.

Cultivation

Inter-row cultivation is widely used for the control of small, 2–4 leaf weeds and is very useful for controlling stressed weeds which herbicides may not control. The operation must be shallow to avoid damaging the crop’s root system. Straight beds with straight plant lines allow effective cultivation without loss of maize plants. Before crop emergence tined harrows are very 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 of herbicide. Later, inter-row cultivation can be used in conjunction with side-dressing fertiliser or preparing 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 emergence of weeds through the band of treated soil. This can occur despite the herbicide having been incorporated previously.

Clearfield® hybrids

The available herbicide options can be expanded by choosing to grow a Clearfield® hybrid with the I.T. or I.R. trait incorporated. These hybrids have tolerance (I.T.) or resistance (I.R.) to the imidazolinone family of herbicides. The herbicide registered for use on I.T. and I.R. hybrids is Lightning®. The Lightning® label has over 50 broadleaf and grass weeds listed for post-emergent control. This herbicide has residual soil activity and so plant-back periods to other crops must be observed. There is no yield penalty associated with hybrids carrying the I.T. or I.R. trait.

### Table 11. DPI irrigated maize hybrid evaluation trials.

*Sites at Liverpool Plains in 2002–2008.*

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>Seed brand</th>
<th>No. of trials</th>
<th>Mean yield t/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>32P55</td>
<td>Pioneer</td>
<td>1</td>
<td>10.61</td>
</tr>
<tr>
<td>Colossus</td>
<td>HSR Seeds</td>
<td>3</td>
<td>10.50</td>
</tr>
<tr>
<td>PAC 675</td>
<td>Pacific Seeds</td>
<td>3</td>
<td>10.49</td>
</tr>
<tr>
<td>31G66</td>
<td>Pioneer</td>
<td>2</td>
<td>10.45</td>
</tr>
<tr>
<td>3153</td>
<td>Pioneer</td>
<td>5</td>
<td>10.35</td>
</tr>
<tr>
<td>34N43</td>
<td>Pioneer</td>
<td>1</td>
<td>10.32</td>
</tr>
<tr>
<td>33V15</td>
<td>Pioneer</td>
<td>1</td>
<td>10.31</td>
</tr>
<tr>
<td>PAC 533</td>
<td>Pacific Seeds</td>
<td>1</td>
<td>10.30</td>
</tr>
<tr>
<td>Olympiad</td>
<td>HSR Seeds</td>
<td>3</td>
<td>10.30</td>
</tr>
<tr>
<td>PAC 424</td>
<td>Pacific Seeds</td>
<td>5</td>
<td>10.23</td>
</tr>
<tr>
<td>Hycom 675IT</td>
<td>Pacific Seeds</td>
<td>3</td>
<td>10.23</td>
</tr>
<tr>
<td>33T39</td>
<td>Pioneer</td>
<td>1</td>
<td>10.17</td>
</tr>
<tr>
<td>Hannibal</td>
<td>HSR Seeds</td>
<td>4</td>
<td>10.16</td>
</tr>
<tr>
<td>31H50</td>
<td>Pioneer</td>
<td>4</td>
<td>9.94</td>
</tr>
<tr>
<td>XL80</td>
<td>Pacific Seeds</td>
<td>1</td>
<td>9.74</td>
</tr>
<tr>
<td>34B28IT</td>
<td>Pioneer</td>
<td>1</td>
<td>9.72</td>
</tr>
<tr>
<td>Victory</td>
<td>Nuseed</td>
<td>2</td>
<td>9.38</td>
</tr>
<tr>
<td>PAC 345</td>
<td>Pacific Seeds</td>
<td>5</td>
<td>9.32</td>
</tr>
<tr>
<td>Maximus</td>
<td>HSR Seeds</td>
<td>2</td>
<td>8.85</td>
</tr>
<tr>
<td>LSD:</td>
<td></td>
<td></td>
<td>1.12 t/ha</td>
</tr>
</tbody>
</table>
**Herbicide application techniques**

For all herbicide use patterns in maize (pre-plant, post-plant pre-emergent and post-emergent herbicide) applications can be made using a conventional hydraulic boom sprayer. Water rates in the 50 to 100 L/ha range will ensure adequate soil and/or weed coverage. For herbicides used post-crop-emergence, nozzle configuration is also important to prevent crop injury. Drop nozzles are recommended for linuron at all times to avoid contact with the maize plants. 2,4-D should be applied through drop nozzles from when the crop has 4 fully emerged leaves through until tasselling. Drop nozzles avoid the accumulation of herbicide in the whorl of the plant, which may damage the developing tassel and cob. Drop nozzles also have the advantage of improving herbicide coverage on the weeds. Shielded sprayers can be used in place of drop nozzles to apply post-emergent herbicides.

**Table 12. Herbicides registered in NSW for use in maize.**

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Example product</th>
<th>Group</th>
<th>Maize use pattern</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2,4-D i.p.a.</td>
<td>Amicide® 625</td>
<td>I</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>atrazine</td>
<td>Atrazine 500 SC®</td>
<td>C</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>flumetsulam</td>
<td>Broadstrike®</td>
<td>B</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>dicamba</td>
<td>Kamba® 500</td>
<td>I</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>EPTC</td>
<td>Eptam®</td>
<td>E</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>fluroxypyr</td>
<td>Starane™ Advanced</td>
<td>i</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>imazethapyr + imazapyr*</td>
<td>Lightning**</td>
<td>B</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>linuron</td>
<td>Linuron®</td>
<td>D</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>pendimethalin</td>
<td>Rifle®440 D</td>
<td>D</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>s-metachlor + atrazine</td>
<td>Primextra® Gold</td>
<td>C</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>propachlor</td>
<td>Ramrod®</td>
<td>K</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>s-metolachlor</td>
<td>Dual® Gold</td>
<td>K</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>2,4-D amine + pidarom</td>
<td>Tordon 75–D®</td>
<td>I</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>tribenuron methyl</td>
<td>Express®</td>
<td>B</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>triclopyr</td>
<td>Garlon® 600</td>
<td>I</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>dicamba</td>
<td>Banvel® 200</td>
<td>I</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>fluroxypyr</td>
<td>Starane™ Advanced™</td>
<td>I</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>glyphosate</td>
<td>Roundup®PowerMAX™</td>
<td>M</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>paraquat + diquat</td>
<td>Spray Seed®250</td>
<td>L</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

* Registered for Clearfield® hybrids with the I.T. or I.R. trait only.

**Diseases of maize**

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 to maize production because of their potential to reduce yield, the marketing of grain can be severely restricted by the presence of disease, adding further to the need to choose hybrids carefully. Refer to Table 4 for details of disease reactions in current hybrids.

**Boil smut or Common smut (Ustilago maydis)**

**Symptoms**

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

**Conditions favouring development**

The fungus develops in temperatures over 25°C and dry conditions, however spreads in rain or high humidity. High soil nitrogen also favours the fungus and physical damage incurred by plants as a result of mechanical disturbance for example, can also increase infection. Spores are wind dispersed and through contact sources. Inoculum may remain viable in soil for many years. While losses are not usually significant, occasionally yield loss is severe.

**Management**

VARIETAL SELECTION may assist in reducing risk of infection however an integrated management program is necessary for greater effectiveness which involves; cleaning machinery and boots to reduce contamination, regularly inspecting crops, removal of infected plants, minimising plant injuries, careful rotations and applying seed treatments. Vitavax®200FF is currently the only registered chemical seed treatment available. Burning stubble may also be effective in reducing inoculum which may over-winter.

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

**Dwarf mosaic virus**

**Symptoms**

Maize dwarf mosaic appears as striping and mottling of leaves which may be confused with zinc deficiency symptoms. Sometimes there are dark green ‘islands’ surrounded by lighter coloured rings. An overall yellowing of plants is common and some may become stunted. The virus may cause husks to gape, which can result in 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 over-wintering of the virus 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 disease agronomically, through controlling weeds and volunteer maize plants and monitoring crops regularly.
**Cob and Stalk rots**

Cob and stalk rots are a particularly important group of diseases in maize. There are a number of fungal pathogens involved (Aspergillus, Fusarium and Gibberella spp.). Stalk rots are frequently responsible for crop lodging.

Such fungal diseases reduce yield directly and may contaminate grain with mycotoxins, released during the fungal life cycle which are toxic to pigs and horses and also linked to human conditions.

**Symptoms**

A variety of symptoms may present according to various types of fungi, which are outlined in Table 13. Fungal species may often be found within a plant, without causing symptoms, hence small amounts exist in crop unnoticed every season. White streaks or lines on grain are an indication of presence.

**Conditions favouring development**

Cob and stalk rots are commonly associated with high humidity or moisture, and some species require high temperatures also. Physical varietal characteristics may influence prevalence of infection, specifically pericarp thickness and the extent of husk coverage of the cob in reducing moisture infiltration. Similarly, insect damage and kernel splitting can also increase incidence of infection for the same reason. Again, specifics are listed in Table 13.

**Management**

Management of these diseases must aim to both reduce the opportunity for disease infections and the likelihood that mycotoxins will be produced when infections occur. Such strategies as careful varietal selection, crop rotation, pest management and assisting stubble breakdown are effective. Also the maintenance of good soil moisture from silking through to harvest will abate infection as well as prompt harvest of crops to reduce likelihood of kernel splitting.

**Rust (Puccinia sorghi)**

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

**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 may also occur leading to stunting and defoliation.

**Conditions favouring development**

Humid conditions coupled with mild temperatures favour disease development in susceptible hybrids. Late plantings tend to be at greatest risk. Maize volunteers, stubble and some winter crops host rust, however inoculum is also wind dispersed.

**Management**

Appropriate varietal selection, correct sowing time, crop rotations and control of hosts assist in preventative management of rust.

---

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

Leaf blight can have deleterious effects on crop yield, as 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 lesions on the leaves. As the lesions dry out they become black in the centre as masses of spores are produced by the fungus. The lesions are not confined by the leaf veins. As the disease progresses the lesions may coalesce causing large areas of leaf to wither and die.

**Conditions favouring development**

Leaf blight is particularly of concern in areas experiencing high rainfall, humidity and temperature such as coastal NSW where the disease is present most seasons. Specifically, 14 non-consecutive hours of temperatures over 20°C and one hour of leaf wetness are necessary for infection to occur. Dew conditions also promote disease growth. Late sown crops are also susceptible to infection. Inoculum over-winters on stubble and maize volunteers, as well as sorghum which should be accounted for in rotation plans. Inoculum is dispersed by wind and rain splash.

**Management**

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

**Wallaby ear**

The condition is the result of the plant’s reaction to a toxin injected by the jassid (leafhopper), Cicadulina bimaculata, when feeding. This particular jassid species mostly occurs in northern coastal areas of NSW, where significant damage may result, however the condition is not significant in most years.

**Symptoms**

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

**Conditions favouring development**

Seasonal conditions which promote the proliferation of jassid populations will see a greater incidence of the condition.

**Management**

There are no insecticides registered for the control of jassids in maize in NSW.

**Insect pests of maize**

The successful management of 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. Infestations of insect pests can occur at any time but crops are most susceptible to damage during establishment and from tasselling until harvest.
Table 13. Cob and stalk rots associated with mycotoxins of concern in NSW maize crops.

<table>
<thead>
<tr>
<th>Disease symptoms</th>
<th>Disease infection and spread</th>
<th>Mycotoxin characteristics</th>
<th>Conditions favouring mycotoxin development</th>
<th>Good agricultural practice to prevent grain contamination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fusarium cob and stalk rots</td>
<td>Powdery or cottony white to grey-green fungal growth on ear and stalk tissues. Fungi are best observed in the presence of high relative humidity and low light.</td>
<td>Fusarium spp., commonly A. flavus, enter the crop as wind-blown spores that are highly resistant to desiccation. Fungi access to the developing kernel via the ear from insects or birds. Once fungal growth has begun it continues until grain moisture content (MC) falls below 14%.</td>
<td>Fusarium spp., especially F. verticillioides, are tolerant of hotter conditions than many other fungal diseases (A. Don 13–45°C, optimum is 30°C).</td>
<td>Due to the high moisture and humidity requirements of Fusarium spp., development of fumonisins in stored grain is highly unlikely.</td>
</tr>
<tr>
<td>Gibberella cob and stalk rots</td>
<td>Greenish-grey mould growth affecting all parts of the crop is associated with the fungus Gibberella zeae.</td>
<td>A. flavus is also known as a 'storage fungus' as it grows at low moisture contents. Temperature fluctuations in grain stored at low moisture contents can cause growth to accelerate or decline.</td>
<td>Fusarium spp., especially F. verticillioides, overwinters in crop residues and spreads by wind-blown spores. Infections are systemic, so the infection can be spread throughout the crop.</td>
<td>Fusarium spp., especially F. verticillioides, are tolerant of hotter conditions than many other fungal diseases (A. Don 13–45°C, optimum is 30°C).</td>
</tr>
</tbody>
</table>
More detailed information about management options for the key insect pests of maize can be found in the DPI Management Guide, Insect and Mite Control in Field Crops 2013

### African black beetle (Heteronyx arator)

Adult beetles are stout-bodied, shiny black, 10–13 mm long with toothed front legs and are responsible for crop damage. The larvae are white or cream coloured with a hard brown head and are a common pest of lawn and turf. They are often referred to as 'curl grubs' as they rest in a c-shape 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 association with 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 may produce suckers, while older plants remain weak and will lodge.

#### Threshold

Spraying is effective on populations up to 5 beetles/m². If numbers exceed 10/m², damage will result in spite of 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 seed bed prior to planting is difficult but warranted if the risk is high. To estimate the soil population, dig and sieve soil from 10 randomly located quadrats (20cm × 20cm × 30cm in depth). The only insecticide treatment available is an in-furrow application is chlorpyrifos during planting. However this treatment is not effective when beetle numbers are high (≥10/m²) or when swarms of beetles fly into the crop after planting.

### Armyworm (Spodoptera spp.)

Larvae vary in colour and size but their bodies are usually distinctly striped, hairless and tapered at both ends. Armyworms hide in the soil or funnels of well grown plants during the day, and feed during overcast conditions, or late afternoon and night. Outbreaks often occur following heavy rain or flooding. Moths may lay their eggs in the crop or rain or flooding. Moths may lay their eggs in the crop or

#### 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 may outgrow the attack, however armyworms will feed on the tassels, husks, silks and cobs as well as the foliage. Silks may 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

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

### 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.

#### Management

Examine soil prior to sowing, earwigs are usually present in large populations and are favoured by moist soils.

#### Damage

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

#### Threshold

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 seed bed prior to 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 (Rhopalosipum maidis)

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

#### Damage

Aphids suck sap causing leaves to turn yellow and appear wilted. Heavy or prolonged infestations may see leaves become red and shrivelled. When infestations commence 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 will reduce aphid infestations.

**Cutworm (Agrostis spp.)**

Hairless worms, varying greatly in colour and size, from green to pale yellow or almost black and 25–50 mm in length 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 may be distributed throughout the field or confined to patches or strips along field edges.

**Threshold**

Spray at 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 the occurrence of weedy conditions prior to seedbed preparation. Cutworm are also known to move into crops from fencelines and adjoining pastures or weedy fallows. Control weeds at least 4 weeks prior to planting. During the first 4 weeks after planting monitor for damaged seedlings. Where damage occurs, inspect seedlings in the late afternoon and examine the soil around damaged plants to a depth of 10 cm to confirm the presence of cutworms.

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

**Heliothis or Corn earworm (Helicoverpa armigera)**

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

**Threshold**

Damage prior to tasselling does not warrant control measures, and spraying is unlikely to be economic. However, gittering maize crops should receive 1-2 sprays at tasselling and silking and processing maize, 1 spray during silking.

**Management**

Early planted crops usually have lower infestations than those planted later. Regular monitoring is required as early detection will allow control during egg lay or small larvae stages, while they are most susceptible to insecticides and before damage occurs. Natural enemies of heliothis may regulate the population below damaging levels. These include; Trichogramma, ladybirds and Micropilitis. There are a range of insecticides registered for heliothis control in maize; the biological insecticides Bt and NPV 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 likely to give much better control than aerial application. Alternatively target egg lays prior to 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/silking crops.

**Damage**

Beetles eat leaves, tassels and silks and husks at the top of the cobs. Injury to the silks may impair kernel set and leave the tops of cobs exposed to secondary attack by other insects and cob rots. 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 cream, yellow or tan in colour with three pairs of legs located behind the head. True wireworms are soft bodied with a darker, flattened head, growing up to 20 mm in length, while false wireworms have hard bodies with darker, rounded heads and can reach 30 mm in length. Adult beetles are dark in colour and the true wireworm is the larva of the click beetle, distinguished by the clicking noise it makes when flipped on its’ back.

**Damage**

Wireworm larvae consume roots and shoots below ground, and bore up into the stem, killing the growing point causing wilting and death of plants, 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 as they dig down into the soil as it dries out and venture near the surface only with moisture. Check under loose clods of soil prior to sowing, and treat seed or soil at 3 or more false wireworm larvae/m, and at >1 true wireworm larvae/m.

Management

As wireworms have a very wide host range, they can be present irrespective of crop rotation or weed control. However early plantings into retained stubble tend to be at greatest risk of wireworm attack. Control measures must be applied before or at sowing. Testing the seed for germination and vigour prior to planting is recommended by planting seed at normal depth in a section of the intended seed bed 2–3 weeks prior to planting to observe seedling mortality. Baited seed; soaked in sunflower oil and a small amount of chlorpyrifos, may also be used to observe wireworm mortality. Digging and sieving topsoil may also be conducted to observe 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, and are therefore better suited for use in low populations. Planting in warm conditions will assist in rapid growth of seedlings and reduce exposure to wireworm damage.

Two-spotted spider mite (Tetranychus urticae)

Adults and nymphs are yellow-green in colour, with a dark spot in the middle of each side of their body. Adults are 0.5 mm in length. Infestation usually commences late in the vegetative stage, increases after tasselling and dramatically increases again when the grain is at the soft dough stage. Hot dry conditions are favourable for rapid population increase. Mites colonise the under side 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 to be senescing prematurely. Mites normally commence 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 may assist in regulating populations. Synthetic pyrethroids are known to ‘flare’ mites, which is a 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 prior to physiological maturity when the maturing grain reaches the MLS of 2.5. When the milk line score is in the range 2–3, dry matter production is near to the maximum and moisture content is 63–67% which is ideal for fermentation, as shown in Table 14.

Feed quality declines rapidly if crops are held for more than 10–14 days past the optimum harvest time, as dry matter yield is lost and the chopped material becomes difficult to compact, resulting in poor fermentation and ineffective silage.

If harvest at the optimum time is delayed due to rain it may be preferable to hold the crop for grain. At MLS 2.5 the milk line is halfway down the grain. This often coincides with the cob husk turning from green to white and the drying off of lower leaves.

Frosted crops

After frost damage the crop will generally have a higher moisture content than is apparent 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% DM. When frost occurs early in grain fill, the moisture content will be too high for immediate harvest and ensiling and 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 prior to 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 nitrogen inputs becomes drought-stressed, there may be 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. Harvest should be delayed while plants have green leaf if there is a chance of rain.

Cutting height

Nominating an optimum cutting height is difficult due to variations in hybrids 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 assist or hinder the establishment of 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. However harvesting at low DM is not advised as poor fermentation and unacceptable effluent losses can result.
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, depending on location. Maize can dry at a rate of 0.5–1.0% each day in suitable weather conditions. Once conditions become cool, consideration should be given to 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 usually commences at 18% grain moisture content. Most harvesters perform best; losing and damaging less grain, when moisture content is between 18 and 24%. Aeration equipment 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 drying occurs too quickly, shrinkage is uneven leading to the formation of cracks. During milling grits break up along the cracks, making them unsuitable for products such as cornflakes. To reduce the occurrence of stress cracks:

- use lower drum speeds during harvest
- use large diameter augers (greater than 200 mm) operating at low speeds and maximum holding capacity
- use conveyor belts preferentially over augers
- reduce 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 re-wetting of grain from dew, condensation or rain
- minimise the number of times the grain is handled.

**Table 14. The relationship between MLS and forage yield and quality. Example based on dryland maize crops grown at Nowra.**

<table>
<thead>
<tr>
<th>Milk Line Score (MLS) at harvest</th>
<th>&gt; 0–1</th>
<th>&gt; 1–2</th>
<th>&gt; 2–3</th>
<th>&gt; 3–4</th>
<th>&gt; 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (t/ha)</td>
<td>57.5</td>
<td>56.7</td>
<td>50.3</td>
<td>46.0</td>
<td>36.4</td>
</tr>
<tr>
<td>DM content (%)</td>
<td>27.3</td>
<td>29.8</td>
<td>33.2</td>
<td>39.1</td>
<td>44.0</td>
</tr>
<tr>
<td>DM Yield (t/ha)</td>
<td>15.7</td>
<td>16.9</td>
<td>16.7</td>
<td>18.0</td>
<td>16.0</td>
</tr>
<tr>
<td>Grain content (% DM)</td>
<td>33.4</td>
<td>39.7</td>
<td>42.8</td>
<td>45.8</td>
<td>48.0</td>
</tr>
<tr>
<td>Crude protein (% DM)</td>
<td>7.2</td>
<td>7.1</td>
<td>6.9</td>
<td>6.7</td>
<td>6.6</td>
</tr>
<tr>
<td>ME (MJ/kg DM)</td>
<td>10.3</td>
<td>10.2</td>
<td>10.1</td>
<td>10.0</td>
<td>9.8</td>
</tr>
</tbody>
</table>


**Marketing**

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 is heavily reliant on domestic markets. All maize surplus to the requirements of human consumption markets must be valued against other feed grains such as wheat, barley and in particular sorghum. Proximity to markets has a major influence on profitability, particularly of silage.

The processors of maize grain for the human consumption markets have stringent guidelines that must be understood by growers entering the industry. Forward contracts are used extensively by processors to ensure reliability of supply and grain quality. Contracts may outline the hybrids to be grown which may not necessarily be the highest yielding lines for the region, however premiums may be offered based on quality. Traditional maize growers will tend to be offered contracts ahead of new growers, making initial contracts difficult to attain. In most irrigation areas it is considered high risk to plant a maize crop without a major portion under contract.

The popcorn market is especially small and volatile, and as such all product is bought domestically under contract.

Forward contracting is also common place in the dairy and feedlotting industries for the purchase of maize silage. Contracts will specify quantity and quality parameters and the date of delivery. Growers must consider the risk of crop contamination from spray drift when growing maize under contract as detection of residues will result in product rejection. Usually the grower organises harvest and transport, which is paid for by the buyer.

**Preventing mycotoxin contamination**

Mycotoxins are toxic chemicals that can be produced by some fungi 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 in generally of high quality in regard to mycotoxin contamination by comparison with other exporting countries.

A summary of the key information is given in Table 13.

**Further information**

**From DPI**

Other relevant DPI publications available through DPI district offices and at www.dpi.nsw.gov.au are;

- Weed Control in Summer Crops 2012-13
- Insect and Mite Control in Field Crops 2013
- Propcrop Maize Growth & Development guide
- Maize Growing – Agfact P3.3.3 2nd Edition 1992

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Scott F., Belfield S., Serafin L. (2007); Regional Maize and sunflower trials to improve crop performance and reliability, GRDC Update Moree.
Mycotoxins in Australian maize production: how to reduce the risk, www.maizeaustralia.com.au

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Mungbean
Kathi Hertel, Gordon Cumming, Leigh Jenkins and Loretta Serafin

Key management issues

- Assess starting soil water prior to 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% in these situations.
- Use high quality seed. Check the germination percentage, disease status and varietal purity of seed.
- Fertilise according to soil test analyses, VAM status, yield potential and paddock history.
- Inoculate seed using Group I inoculant (rhizobium strain CB 1015).
- Calculate the required seeding rate to achieve a plant establishment of 20–30 plants/m².
- Select row spacing to fit your farming system. Wide rows offer more flexibility in sowing, weed and insect management. Narrow rows offer higher potential yields and greater weed competition.
- Weed control options must be carefully planned (broadleaf options are limited). Assess potential weed problems.
- Do not grow mungbeans if there is a risk of herbicide residues from previous cropping history.
- Insect monitoring should commence from the late vegetative (bud initialisation) 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 drydown to avoid dust sticking to seed when harvesting.

Brief crop description

Mungbean is a short duration summer grain legume (pulse) crop, which flowers in approximately 45 days and reaches maturity in 90–120 days. Mungbean plants are branching, erect and self-pollinating. They have a rooting depth of between 60 cm and 100 cm.

Mungbean is suited to double cropping situations when sufficient refilling of the soil moisture profile has occurred prior to sowing. They are suitable for dryland or irrigation production.

Mungbean yields are more reliable when planted into a good profile of stored moisture.

Mungbean is typically grown in northern NSW and the irrigation areas of the central west and south west of the state.

As a relatively small summer crop more specialised marketing is required. Mungbeans supply a human consumption market so management for high grain quality is essential.

Paddock selection

Paddocks selected for mungbean should be fairly uniform in soil type, stubble cover and lack of harvest impediments such as sticks and stones. These are important considerations due to the low height of mungbean pods and to reduce the tendency for uneven crop maturity.

Paddock history

Mungbean is best included in the rotation after a cereal, either winter or summer. This may be as a double cropping option following the harvesting of a winter cereal, as a short fallow following sorghum or after a long fallow from a winter cereal.

When planning rotations be aware that volunteer mungbeans may occur in following crops and will need control.

As discussed further in the weed control section, mungbean is sensitive to several residual herbicides so caution needs to be exercised when selecting paddocks where residual products have been used.

Soil management

Mungbean prefer well drained soils with a medium to heavy texture. They do not tolerate soil compaction or waterlogging.

Mungbean is well suited to no-till situations and planting into standing cereal stubble often encourages them to grow taller, meaning additional height to the lowest pods for ease of harvest. No-till also increases the efficiency of storing moisture in the fallow, reducing the risk of crop failure.

Soil moisture

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 Plant Available Water (PAW) will often produce unprofitable crops. These paddocks may 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 percentages when sowing into hot soil conditions. Always refer to the products’ Directions for Use.

Mungbean seed should be sown as soon as possible after inoculation into moisture, to increase the survival of the rhizobia.

Nodulation should be checked 35 days after sowing for sufficient numbers of active pink nodules. A nodulation failure can lead to a significant yield reduction.

Inoculation may be carried out in several ways, such as through coating the seed with a peat slurry, granular products, or via water injection behind the sowing tynes or discs.
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Time of sowing

Mungbean offers two options for planting, a spring plant and a summer (main season) plant. The suggested sowing times for mungbean in northern NSW, southern and central Qld are outlined in Table 1.

Spring plant mungbean is less exposed to heatwave conditions during flowering and seed fill. However it also tends to produce plants with more vegetative material.

Spring plantings are predisposed to higher mirid and thrip pressure, so timely insect control is critical. In addition weed pressure is often higher as many of the summer weeds begin germination at similar soil temperatures to mungbean. However, spring plantings allow harvesting in December or January, which may allow time for the soil water profile to replenish sufficiently before the following winter allowing for a double crop option.

Summer plantings risk hotter conditions during establishment and flowering and will often be more subject to risk of powdery mildew infections during pod-fill. Very late plantings also risk slow drydown to harvest.

Planting time also has an effect on the number of days to flowering, with later plantings reaching flowering quicker.

Row spacing

Recent trends have been towards row spacings of 50 cm to 100 cm. This is largely due to the ease of configuration for machinery used on other crops. Mungbean is suitable for row spacings from 18 cm to 100 cm.

Narrow rows (< 50 cm) have been shown to have higher yield potentials where yields are likely to be greater than 1 t/ha. Data suggests the yield increase may be as much as 10–15% as yields approach 2 t/ha. A comparison of wide rows vs. narrow rows is included below.

Wide rows (50 cm–100 cm)
- Ease of checking for insect pressure.
- The ability to plant into heavy stubble residue in no-till situations.
- Row-crop planters can be used to provide more accurate seed placement, resulting in better establishment and more even plant stands.
- 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.
- Input costs can be reduced by band-spraying insecticides and defoliants.
- Ability to control weeds relatively cheaply by inter-row cultivation or shielded spraying.
- Improved likelihood of higher yields in moisture limited situations.

Narrow rows (18 cm–50 cm)
- Higher potential yields.
- Greater competition with weeds, particularly in late sowings when canopy closure will be more difficult to achieve.
- More even utilisation of moisture across the paddock.

Twin rows, single or double skip row configurations are alternative options, but mungbean has limited lateral root growth and thus yield potential is limited in these situations.

Plant population and sowing depth

Aim to establish 20–30 plants/m² in dryland crops and 30–40 plants/m² in irrigated situations. Consider re-sowing if less than 10 plants/m² establish, provided adequate time remains in the sowing window.

Establishing a uniform plant density is critical to achieve uniform plant maturity across the paddock. Ensure the planting depth across the width of sowing machinery is even to aid in the timing and consistency of crop emergence.

The number of seeds per kilogram (kg) in mungbean seed can vary widely. The range may be from 12 000 to 30 000 seeds per kg, depending on variety and season. It is recommended to calculate the sowing rate using germination test results, seed count per kilogram, target plant population and establishment %. Also take into account hard seed levels and planting conditions.

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

Calculating sowing rates

The following formula can be used to calculate sowing rates, taking into consideration:
- number of seeds/kilogram (seed size or seed weight)

---

Table 1. Suggested sowing times for mungbean.

<table>
<thead>
<tr>
<th>Region</th>
<th>Early plant</th>
<th></th>
<th>Late plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sept 1 2 3 4</td>
<td>Oct 1 2 3 4</td>
<td>Nov 1 2 3 4</td>
</tr>
<tr>
<td>Goondiwindi, Moree and Narrabri</td>
<td>&lt; &lt; * * *</td>
<td>* * &gt; &gt;</td>
<td>&lt; &lt; * * *</td>
</tr>
<tr>
<td>Gunnedah and Tamworth</td>
<td>&lt; &lt; * * *</td>
<td>* * &gt; &gt;</td>
<td>&lt; &lt; * * *</td>
</tr>
<tr>
<td>Warren and Narromine</td>
<td>&lt; * * *</td>
<td>&gt; &gt;</td>
<td>&lt; * * *</td>
</tr>
<tr>
<td>Darling Downs</td>
<td>&lt; &lt; * * *</td>
<td>* * &gt; &gt;</td>
<td>&lt; &lt; * * *</td>
</tr>
<tr>
<td>Western Downs</td>
<td>&lt; &lt; * * *</td>
<td>* * &gt; &gt;</td>
<td>&lt; &lt; * * *</td>
</tr>
<tr>
<td>Central Queensland</td>
<td>&lt; &lt; * * *</td>
<td>* * &gt; &gt;</td>
<td>&lt; &lt; * * *</td>
</tr>
</tbody>
</table>

< Earlier than ideal, but acceptable. * Optimum sowing time. > Later than ideal, but acceptable.
• target plant population
• germination % (e.g. 90% germination = 0.9 in the formula).
• establishment: usually 80%, unless sowing into adverse conditions (80% = 0.8 in the formula)

Sowing Rate (kg/ha) = \( \frac{\text{target plant population/m}^2 \times 10,000}{\text{germ.} \times \text{estab.} \times \% \text{seeds/kg}} \)

**Worked example of calculation**

To establish Crystal\(^\text{A}\) at 30 plants/m\(^2\) with a seed size of 15,000 seeds/kg:

Sowing rate (kg/ha) = \( \frac{30 \text{ plants/m}^2 \times 10,000}{0.9 \times 0.8 \times 15,000 \text{ seeds/kg}} \) = 27.8 kg/ha

**Seed quality**

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

Planting seed should ideally have germination percentages above 90%. Caution needs to be exercised with some varieties as hard seed levels may be included in the germination percentage above 90%. Hard seed levels may change over time, so any formal seed test (above 20% hard seed is not advisable for use as planting seed).

The main implication of high levels of hard seed is in terms of uneven germination and establishment. Hard seeds may not germinate until the next in-crop rainfall event after planting or even later.

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

Variatel purity is essential, as mixtures are unacceptable in both the sprouting and cooking trade. Mixed seed lines will often attract heavy discounts when being 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 quite significantly over a period of 2–3 years and off-types may be quite different in seed coat appearance to the main seed line. As such growers should purchase new AMA approved seed every two to three years.

Seed quality also relates to freedom from seed borne diseases such as bacterial blight and tan spot. It is recommended growers purchase seed through the Australian Mungbean Association (AMA) approved seed scheme, which inspects the seed crop for these seed borne diseases.

**Table 2. Characteristics of currently recommended mungbean varieties available in 2014–15.**

<table>
<thead>
<tr>
<th>Variety</th>
<th>Seed colour</th>
<th>Weathering resistance</th>
<th>Height</th>
<th>Powdery mildew resistance</th>
<th>Lodging resistance</th>
<th>Approximate no. of seeds/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berken</td>
<td>Green</td>
<td>Poor</td>
<td>Short</td>
<td>Very susceptible</td>
<td>Fair</td>
<td>15–20 000</td>
</tr>
<tr>
<td>Celera II-AU(^{\text{B}})</td>
<td>Green</td>
<td>Fair</td>
<td>Medium</td>
<td>Susceptible</td>
<td>Fair</td>
<td>27–30 000</td>
</tr>
<tr>
<td>Crystal(^{\text{C}})</td>
<td>Green</td>
<td>Fair</td>
<td>Tall</td>
<td>Moderately susceptible</td>
<td>Good</td>
<td>14–17 000</td>
</tr>
<tr>
<td>Green Diamond(^{\text{D}})</td>
<td>Green</td>
<td>Fair</td>
<td>Medium</td>
<td>Moderately susceptible</td>
<td>Good</td>
<td>27–30 000</td>
</tr>
<tr>
<td>Jade-AU(^{\text{E}})</td>
<td>Green</td>
<td>Fair</td>
<td>Tall</td>
<td>Moderately susceptible</td>
<td>Good</td>
<td>13–17 000</td>
</tr>
<tr>
<td>Satin II(^{\text{F}})</td>
<td>Green (dull)</td>
<td>Fair</td>
<td>Tall</td>
<td>Susceptible</td>
<td>Good</td>
<td>14–17 000</td>
</tr>
</tbody>
</table>

**Variety characteristics**

Mungbean varieties should be clearly separated at planting. Varietal mixtures are unacceptable in the markets for both cooking and sprouting grade beans, 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. Two new varieties were released since 2012.

Jade-AU\(^{\text{E}}\) (released 2013) is a large seeded bright green mungbean that is broadly adapted to the northern region.

It is suitable for both ‘spring planting’ (Sept/Oct) and ‘conventional summer planting’ (Dec/Jan). It has a demonstrated consistent yield increase of 12% when compared to Crystal\(^{\text{A}}\) across all regions of central and southern Queensland and northern New South Wales. It has grain quality equivalent to Crystal\(^{\text{A}}\) and is highly acceptable in the market place.

Jade-AU\(^{\text{E}}\) has the best available combined suite of resistance to powdery mildew [Moderately Susceptible (MS)], greater than Crystal\(^{\text{A}}\)], tan spot and halo blight [Moderately Susceptible (MS), equivalent to Crystal\(^{\text{A}}\)]. Jade-AU\(^{\text{E}}\) is of an equivalent plant type and has similar production agronomy to Crystal\(^{\text{A}}\) and other current varieties.

Crystal\(^{\text{A}}\) (released in 2008. Crystal\(^{\text{A}}\) has widespread regional adaptation and is suitable for both spring and summer plantings. It offers significant advances in grain quality, and has a low level of hardseededness. Crystal\(^{\text{A}}\) is a relatively tall, erect variety with similar lodging resistance to Emerald.

Berken 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. However Berken is susceptible to all three key diseases, and can also be prone to lodging, weather damage and cracking. These factors increase the difficulty of achieving a premium for sprouting grade quality.

Satın II\(^{\text{F}}\) Released 2008 as a replacement for Satın. Satın II\(^{\text{F}}\) is a dull-seeded mungbean which is grown for a niche market. Satın II\(^{\text{F}}\) has improved seed quality including increased seed size and offers both significant yield increases (20%) and disease advantages (powdery mildew and tan spot) over Satın. Satın II\(^{\text{F}}\) also offers improved lodging resistance and equal plant maturity compared to Satın. Note, however that Satın II\(^{\text{F}}\) is a niche variety with a limited market size; growers are advised to consult their marketer before planting.
**Celera II-AU** was released in 2014 as a replacement for Celera® and Green Diamond®. 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, splitters and millers also like small green mungbean. Note, however, that Celera II-AU® is a niche variety with a limited market size; growers are advised to consult their marketer before planting. Celera II-AU® is the first mungbean variety released with an improved resistance to halo blight [Moderately Resistant (MR)]. Under moderate to high halo blight pressure it is higher yielding than all other commercial varieties, reducing production risk. It is broadly adapted to northern New South Wales and southern Queensland and is suitable for both spring and summer plantings. In central Queensland, yields have been consistently lower than Jade-AU® and Crystal®.

**Green Diamond**® (released 1997) is a small seeded variety with very high levels of hard seed (70%). It is a relatively quick maturing variety. As such it often performs better under drier conditions and may be more suited to double crop situations and the drier western areas. It is moderately susceptible to all three key diseases.

### Growth stages

Mungbean germination, emergence, vegetative growth and rate of pod development are all influenced by temperature.

The base soil temperature for emergence is 10.5°C, and plant growth is maximised at ambient temperatures of 28–30°C. As such spring planted mungbean are slower to reach all growth stages.

Mungbean have 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.

Mungbean are branching, erect or sub-erect and usually stand 0.5–1.0 m high when they have finished vegetative growth.

Mungbean are determinate in their growth habit with vegetative growth ceasing when flowering commences, meaning this will be the final height of the crop. However, they have an indeterminate flowering habit meaning that they do not have a defined flowering period, and will continue to flower so long as there is sufficient soil moisture. Consequently a single plant can have flowers, green pods and black pods all present at the same time.

Mungbean plants progress from emergence to flowering in around 45 days. The time to flowering depends on photoperiod (day length) and temperature. Mungbean are sensitive to daylength and flowering is delayed moving further south. Variations in temperature can significantly affect flowering times. Generally warmer temperatures speed up the plant's development.

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 ever soil moisture 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.

Mungbean is both chilling and frost sensitive, with a critical temperature of 15°C required for adequate growth.

### Nutrition

Fertiliser recommendations need to be based on soil test results, fallow length, yield potential and paddock history. Mungbean nutritional requirements are summarised in Table 4.

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

**Table 4. Mungbean nutrient removal kg/ha.**

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Yield 1 t/ha</th>
<th>Removed in grain kg/ha</th>
<th>Total crop requirement kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>35–40</td>
<td>60–70</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>3–5</td>
<td>6–9</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>12–14</td>
<td>45–50</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>2–2.5</td>
<td>3–7</td>
<td></td>
</tr>
</tbody>
</table>


#### Nitrogen (N)

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

Application of starter fertilisers containing low rates of nitrogen as well as phosphorus, sulfur and zinc are often recommended.

#### Phosphorus (P)

Mungbean is responsive to high rates of phosphorus, so deficiencies should be avoided.

**Table 3. Grain Yields for commercial mungbean varieties expressed as t/ha and as % of cv. Crystal®.**

<table>
<thead>
<tr>
<th></th>
<th>Central Queensland</th>
<th>Southern Queensland</th>
<th>Northern NSW</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jade-AU®</td>
<td>1.19</td>
<td>1.14</td>
<td>1.18</td>
<td>1.16</td>
<td>1.10</td>
<td>1.30</td>
<td>1.13</td>
<td>0.95</td>
<td>1.13</td>
</tr>
<tr>
<td>Jade-AU®</td>
<td>112</td>
<td>114</td>
<td>108</td>
<td>119</td>
<td>115</td>
<td>111</td>
<td>108</td>
<td>105</td>
<td>112</td>
</tr>
<tr>
<td>Berken</td>
<td>86</td>
<td>83</td>
<td>55</td>
<td>80</td>
<td>95</td>
<td>67</td>
<td>84</td>
<td>59</td>
<td>77</td>
</tr>
<tr>
<td>Crystal®</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Satin II®</td>
<td>106</td>
<td>111</td>
<td>93</td>
<td>116</td>
<td>114</td>
<td>98</td>
<td>104</td>
<td>106</td>
<td>107</td>
</tr>
</tbody>
</table>

No of sites | 14                | 15                  | 9            | 3    | 8    | 14    | 9    | 4    | 38      |

Mungbean is a highly AM dependent crop, so their place in the rotation should be given careful consideration. Planting following a long fallow may increase the risk of phosphorus deficiency.

Soil testing will indicate if a deficiency is likely. On deficient soils 5–10 kg P/ha as a guide is commonly applied to dryland crops, with higher rates on irrigated crops.

Using a starter fertiliser containing phosphorus is recommended.

**Sulfur (S)**

Problems with sulfur deficiency are most likely in double cropped situations. Symptoms will first appear as yellowing of the upper leaves and petioles. Sulfur levels should be addressed through regular soil testing. Checking sulfur levels prior to sowing will indicate the potential for deficiency, which can then be addressed through the use of a starter fertiliser containing sulfur, or with gypsum or sulphate of ammonia.

**Zinc (Zn)**

Indicators of zinc deficiency are soil test levels below 0.8 mg/kg on alkaline soils. Mungbean is responsive to zinc, and deficiency symptoms will appear as stunted plants and dead tissue between the veins. Foliar sprays can assist with mild deficiencies in crop, or regular applications of fertilisers containing zinc are a longer term solution.

**Subsoil constraints**

Mungbean is not tolerant of 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 quickly wilt on hot days. Leaves may appear small and grey with older leaves being affected first. If severe, the plant will be killed, otherwise flower and seed production will be reduced. Electrical Conductivity (EC) is a measure of soil salinity levels. EC levels above 2 dS/m are sufficient to cause a yield reduction in mungbeans.

In situations where there is subsoil sodicity, the amount of plant available water will be limited, and as a result yield potential will also be limited. Sodicity is measured as Exchangeable Sodium Percentage (ESP) and levels above 3% ESP are considered to be sodic.

Subsoil acidity can also be a problem where the pH is below 5.5 (water 1:5), which can induce nutrient imbalances.

**Irrigation**

Mungbean does not tolerate waterlogging so irrigation management is critical. Waterlogging will reduce the ability of nodules to fix nitrogen, resulting in induced nitrogen deficiency as well. It is estimated that mungbeans require 3.5–4.5 ML/ha water for irrigation.

Spray irrigation is an option, which allows more frequent and smaller irrigation amounts to be applied. Approximately 50 mm of water per week is normally required during flowering and pod fill.

Flood irrigation can be used but field levelling is important to avoid low lying areas. The tail water system also needs to be able to quickly drain water away from the crop. Planting mungbeans onto hills or raised beds will assist drainage.

Irrigation water should be applied in 4–8 hours; hence fields with shorter runs are preferred. This may be assisted by the use of two siphons in each furrow and irrigating down alternate furrows.

The timing of irrigations is suggested as:

**Irrigation 1** – about 7 days prior to the start of flowering, which is usually around 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 may cause another flush of flowers to be produced, resulting in a split maturity in the crop, delayed harvest, and increased risk of downgrading quality.

**Weed management**

Mungbean are poor competitors 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-emergent in mungbean. Hence emphasis must be placed on selecting paddocks clean of broadleaf weeds. However there are a range of post-emergent options available for grass weed control.

Table 5 includes herbicides which are currently registered or permitted for use in NSW. Further information on selecting herbicides for specific weed control is available in the DPI publication, *Weed control in summer crops 2012–13*. Always read the label directions before using any agricultural chemicals.

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 do not tolerate sulfonylurea (SU) (Group B), triazine (Group C) or picloram (Group I) residues. Residues will 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 timeframe may need to be revised for longer if soil pH_{can} is above 8.5 or prolonged drought/dry conditions have been experienced.

Weed seed contamination in harvested mungbeans makes marketing more difficult and usually results in a lower price. While some weed seeds can be removed by grading, sorghum and thornapple 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 later section on Harvesting and desiccation).
Table 5. Herbicides registered for use in mungbean.

<table>
<thead>
<tr>
<th>Herbicide (active)</th>
<th>Example product</th>
<th>Group</th>
<th>Pre-plant</th>
<th>Post-plant</th>
<th>Post-emergent</th>
<th>Pre-harvest crop desiccation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,4-D amine</td>
<td>Surpass®</td>
<td>I</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dicamba</td>
<td>Cadence®</td>
<td>I</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tribenuron-methyl</td>
<td>Express®</td>
<td>B</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>trifluralin</td>
<td>TriflurX®</td>
<td>D</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>pendimethalin</td>
<td>Rifle®</td>
<td>D</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>imazethapyr</td>
<td>Spinnaker®</td>
<td>B</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>glyphosate</td>
<td>Roundup® Attack</td>
<td>M</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>paraquat</td>
<td>Gramoxone®</td>
<td>L</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>paraquat + diquat</td>
<td>Spray.Seed®</td>
<td>L</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>butroxydim</td>
<td>Factor®</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>clethodim</td>
<td>Status®</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>haloxyfop-r</td>
<td>Verdict®</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>quizalofop-p-ethyl</td>
<td>Targa®</td>
<td>A</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>acifluorfen</td>
<td>Blazer®</td>
<td>G</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>diquat</td>
<td>Reglone®</td>
<td>L</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Diseases

Several diseases affect mungbean and some varietal resistance is available to diseases such as tan spot, halo blight and powdery mildew (see Table 6). A range of other diseases may occur in mungbean depending on the occurrence of suitable conditions or inoculum levels.

**Charcoal rot (Macrophomina phaseolina)**

Charcoal rot is a fungal disease of high concern as it often causes downgrading of sprouting grade beans. However, it can also cause yield loss when it infects plants in the field.

**Symptoms**

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

**Conditions favouring development**

Charcoal rot appears to be very seasonally dependent and there is limited information on the conditions which favour its development.

The fungus is seed borne and survives in the soil for long periods, having a wide range of host crops and weeds. It may be particularly severe after sorghum or cotton crops.

Movement of soil and plant debris readily spreads the fungus. Seed infection is favoured by rainfall events during early pod fill.

**Management**

Charcoal rot is seed borne. It has a wide host range and can remain in the soil for many years. Rotation seems to impact on 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.

Movement of soil and plant debris can spread the fungus so hygiene is important.

Planting into good soil moisture and maintaining good growing conditions can help minimise the level of occurrence.

**Gummy pod (Gluconobacter spp.)**

Gummy pod occurs due to a bacterial infection which is a secondary process following an over-production of sugar by the flower nectaries in the plant.

**Symptoms**

The symptoms appear as pods, stems and pod stalks coated with a sticky foam and gum which exudes from flower nectaries and flowers. This may 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 of little consequence until ideal conditions prevail. Uneven flowering as a result of insect damage may encourage the bacteria to increase.

**Management**

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

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

Halo blight is a seed-borne bacterial disease. Stems, leaves, pods and seed are affected by this disease; severely affected plants may be stunted.

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 favours infection with symptoms appearing 7–10 days after infection. Wind, rain, movement of people and machinery 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 movement of people and machinery through diseased crops particularly when wet. Control volunteers and other crop hosts such as soybean and navy bean, as well as host weed species cowvine, bellvine and morning glory.

Legume little leaf / Witches broom
This disease is caused by a phytoplasma (extremely small bacteria).

Symptoms
Infected plants appear to have small, cupped leaves, be ill-thrifty and very erect. The flowers appear distorted with green petals and often pods are not produced or are empty. Pods may also appear curved, small and thin. Affected seed may turn brown and fail to develop.

Conditions favouring development
Phytoplasma is spread by leafhoppers and survives on weeds. Dry seasons often promote migration of leafhoppers into crops.

Management
Occurrence is usually very minor, but monitoring leafhopper numbers is recommended.

Powdery mildew (Podosphaera fusca)
Powdery mildew is a fungal disease. Yield reduction may result if infection occurs at or before flowering. Powdery mildew is more common in late sown crops.

Symptoms
The most common symptoms include a greyish–white fungal growth firstly appearing in circular patches that later spreads over the surface of leaves, stems and pods. Late infections may cause leaf drop.

Conditions favouring development
Favoured by cool (22–26°C), dry growing conditions. The disease is more critical if it infects plants prior to flowering or when crops are under moisture stress. The fungus survives on alternate hosts and is spread by wind.

Management
Select varieties with higher levels of resistance. A number of fungicides are currently registered for use as management options under permit, tebuconazole (PER13979), sulphur fungicides (PER13605) and carbendazim (PER13609). They act as protectants only so they must be applied early in the disease development to be effective. Minimise leaf burn from the sulphur by applying in late afternoon or at night. Use with high water volumes and ensure thorough coverage.

Puffy pod disorder
Symptoms
The 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.

Conditions favouring development
It is not known what causes puffy pod.

Management
It is recommended to harvest 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.

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 may disintegrate during high winds giving the leaves a ragged appearance.

Infection can occur at any stage from seedling to maturity. Seed may not be set and plants may 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
A major disease of mungbeans, development is often rapid following hailstorms, when temperatures are > 30°C and when the crop becomes moisture stressed. Spread may be helped by raindrop splash and wind but unlike most other plant pathogenic bacteria it can apparently also infect tissues in the absence of rain. The available evidence suggests that the pathogen is systemic within infected plants and that it moves from the site of infection throughout the plant.

Under favourable growing conditions the disease may go undetected.

Management
Do not retain seed from infected crops and use disease free seed where possible. Select varieties with better resistance levels, e.g. Crystal®, see Table 6.

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

<table>
<thead>
<tr>
<th>Variety description</th>
<th>Powdery mildew</th>
<th>Tan spot</th>
<th>Halo blight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berken</td>
<td>Very susceptible</td>
<td>Susceptible</td>
<td>Susceptible</td>
</tr>
<tr>
<td>Celera II-AU(©)</td>
<td>Susceptible</td>
<td>Moderately susceptible</td>
<td>Moderately resistant</td>
</tr>
<tr>
<td>Crystal®</td>
<td>Susceptible</td>
<td>Moderately susceptible</td>
<td>Moderately susceptible</td>
</tr>
<tr>
<td>Green Diamond®</td>
<td>Moderately susceptible</td>
<td>Susceptible</td>
<td>Susceptible</td>
</tr>
<tr>
<td>Jade-AU®</td>
<td>Moderately susceptible</td>
<td>Moderately susceptible</td>
<td>Moderately susceptible</td>
</tr>
<tr>
<td>Satin II®</td>
<td>Susceptible</td>
<td>Moderately susceptible</td>
<td>Moderately susceptible</td>
</tr>
</tbody>
</table>

Table 6. Varietal resistance to disease in mungbean.
Insect pests

Insects can significantly 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 mungbeans. Crops should be inspected weekly from the vegetative stage through to budding, and twice weekly from the start of budding-flowering through to the completion of pod fill. Crops which are producing buds, but not flowers, may contain damaging levels of sucking insects, causing the buds to abort before the flowers open.

The preferred method for insect checking is to use a beat sheet between rows to identify, monitor and count insect numbers.

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

Mungbean are not preferred hosts for silverleaf whitefly (SLW). While adults are often seen on mungbeans, the development of SLW nymphs is very poor in this crop.

A list of currently registered pesticides can be found on the AMA website (www.mungbean.org.au) or from the APVMA website (www.apvma.gov.au).

Cowpea bruchids (Callosobruchus maculatus (Fabricius))

Bruchids have become a common pest of stored grain and can also infest mature and dry pods in the field. They are 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 2 bruchids per tonne, in 4 months this could result in 100% of grains being damaged.

Management

Management in stored grain is provided through 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.

Thorough checking of crops and stored grains is required 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 remain at risk until pods are too hard to damage (i.e. very close to harvest). Damaging populations are typically highest in late summer crops during late pod-fill (when nymphs have reached or are near adulthood).

Damage

These sucking insects use their mouth part to suck nutrients from the seed.

Pods most at risk are those containing well-developed seeds. GVB also damages buds and flowers but mungbean can compensate for this early damage. Damage to young pods causes deformed and shrivelled seeds and reduced 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 as a result of tissue breakdown or water which may gain entry where pods are pierced by bugs.

Threshold

Green Vegetable bug spray threshold: 1 GVB per m².

Increasing the threshold to 0.3–0.6 GVB per m² may 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 beat sheet 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 plant parts of mungbeans.

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 thus 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 than late pod damage; however in dryland crops, where water is limiting, significant early damage may delay or stagger podding with subsequent yield and quality losses. Damage to well-developed pods also results in weather staining of uneaten seeds due to water entering the pods.

Threshold

The new reproductive threshold for late flowering/early podding to late pod-fill stages (see Table 7) is conservatively based on the rate of damage at late pod-fill, and varies from 1–5 larvae/m², depending on the cost of control and the price...
of mungbeans. This threshold allows for possible yield loss in drought-stressed crops damaged by Helicoverpa at flowering.

Management

Mungbeans should be monitored weekly during the vegetative stage and twice weekly from early budding until late podding.

A range of control options are available. Consideration needs to be given to the number and size of grubs and unhatched eggs in the crop. Knowledge of the level of resistance in H. armigera populations and the beneficial insect population will help in selecting the most suitable chemical for spraying.

**Mirids (Green: Creontiades dilatus; and Brown: C. pacificus)**

Mirids target buds and flowers causing them to abort and are considered one of the key pests of mungbean. Mirids are often in the crop and can be at the threshold prior to budding. It is very important to scout weekly, through the late vegetative stage to ensure the start of budding is NOT missed. The green mirid is responsible for the most damage.

Mirid numbers will develop rapidly so regular checking is essential, particularly as nymphs are considered to be as damaging as adults.

Mirid eggs are difficult to detect. Mirids have a lifecycle which takes between 19 and 23 days from egg laying to fertile adults.

**Damage**

Mirids pierce the plant with their mouth parts and release an enzyme which destroys the cells, resulting in blackening and death of the affected part.

Mirids target buds, flowers and pods and will cause abortion, which if left unchecked may result in almost total yield loss.

**Threshold**

Mirid spray threshold: 0.3–0.6/m² using beat sheet sampling.

<table>
<thead>
<tr>
<th>Cost of control = value of damage ($/ha)</th>
<th>$350</th>
<th>$400</th>
<th>$450</th>
<th>$500</th>
<th>$550</th>
<th>$600</th>
<th>$650</th>
<th>$700</th>
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<td>2.5</td>
<td>2.3</td>
</tr>
</tbody>
</table>


**Management**

Research conducted by Qld DAFF has suggested the following strategy:

- Begin monitoring prior to the onset of budding. Check once a week during the vegetative stages and then twice a week from the start of budding through to the completion of pod filling.
- Consider using low rates of dimethoate plus salt (0.5% NaCl) to control mirids early in the season. The low rate is recommended to assist with reducing the impacting 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 mungbeans.

**Damage**

Seedlings: 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.

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

**Threshold**

Seedlings: There are no thresholds for thrips at the seedling stage and it is unlikely that this pest reduces mungbean yields except under extreme circumstances.

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

**Table 7. Economic threshold chart for helicoverpa in podding mungbeans.**

This table is based on a measured yield loss of 35 kg/ha for every larva per square metre. Cross-reference the cost of control versus 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 which is the breakeven point.
Management

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

Harvesting and desiccation

Mungbean maturity across paddocks is often uneven creating a difficult decision for timing of desiccation to optimise yield and quality. Significant rainfall events later in the crops development will often mean additional flowering and pods.

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

Desiccation is strongly recommended and should be applied at the 90% yellow to black pod stage. Harvest should be delayed until maximum dry down of leaf moisture, which 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 seed and has a withholding period to harvest of 7 days which must be observed.

Mungbean crops which 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 staining of seeds can be more prevalent. Green sappy weeds may cause similar issues.

Staining of the seed coat is the most important issue reducing quality and profit due to the emphasis placed on visual appearance at the point of sale.

Conversely mungbean which are too dry when harvested can result in additional harvest losses, due to both the increased risk of shattering and moisture weight losses.

Mungbean are 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 to a greater extent. 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 which contain a lot of green material should be graded as soon as possible to prevent mould developing and downgrading the sample.

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 when compared with the main exporters of mungbean; 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 may fluctuate between seasons.

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.

Fumigation (to prevent insect contamination), drying or aeration if delivery moisture is above standard and sometimes storage may also need to be provided. Mungbean grading losses can account for between 8–20% of the crop yield.

Forward selling is extremely limited and hectare contracts are the main option available for marketing.

Mungbean buyers focus on visual appearance, a bright even green colour being a critical aspect, varietal purity and size. As such prices are usually based on the final graded quality, and not agreed to prior to grading.

The export standards are quite stringent with processing plants needing to be registered and maintaining AQIS standards, which focus on a high level of hygiene.

The Australian Mungbean Association receival standards are included at the end of this guide; however general comments are included below on the main attributes affecting grades.

Mungbean are sold into three main grades:

1. Sprouting – Premium or No.1 attracts the highest price. Strict specifications focus on colour, germination, purity (99% or over), charcoal rot, size and oversoaks.
2. Cooking – Classified on appearance, size, range and purity.
3. Processing – Classified on appearance, size, range and purity.

Currently approximately 80% of Australian mungbean production falls into the processing market so growers should budget on prices for this grade. Only very small proportions of the crop make the sprouting grade.

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, Fisheries and Forestry, (QDAFF): www.daff.qld.gov.au
Mungbean & Soybean Disorders: The Ute Guide (2003) DEEDI, Qld
References


Thompson, J. (1997) ‘VAM boosts crop yields’. Queensland Department of Primary Industries


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Visit: www.mungbean.org.au

For the latest information on:
- The latest research results
- Marketing of your mungbean crop
- Profitable mungbean production
- News and happenings in the mungbean industry
- Industry publications
- AMA members and traders.

For more information email: info@mungbean.org.au

AMA Approved Mungbean Planting Seed

Growers should replenish their planting seed every 3 years with AMA Approved Planting Seed to ensure:
- Greatest seedling crop vigour
- Freedom from off-types
- Freedom from seed-borne diseases such as Halo Blight & Tan Spot.

Contact your local AMA Member for your seed requirements today.
Introduction

This chapter is designed to assist insect identification of 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.

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:
  - Beat sheet for any grubs or pod-sucking bugs sheltering in crop foliage
  - Unfurl plant growing points for feeding larvae
  - Check the under side 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.
- Utilise Integrated Pest Management (IPM) to minimise pesticide use, increase beneficial insects and reduce environmental impact.

African black beetle (*Heteronychus arator*)

African black beetle larvae.
Source: NSW DPI

African black beetle adult.
Source: NSW DPI

Green peach aphid.
Source: NSW DPI

Cowpea aphid.
Source: Lowen Turton, NSW DPI

Cowpea aphid.
Source: Lowen Turton, NSW DPI

Armyworm (*Spodoptera spp.*)

Common armyworm.
Source: Lowen Turton, NSW DPI

Common armyworm moth.
Source: NSW DPI

Brown shield bug (*Dictyotus caenosus*)

Brown shield bug.
Source: Queensland Department of Agriculture, Fisheries and Forestry QDAFF
**Cutworm** (*Agrotis spp.*)

- Cutworm adults. Source: QDAFF
- Cutworm (Agrotis spp.) larva/caterpillar. Source: NSW DPI

**Heliothis** (*Helicoverpa spp.*)

- Heliothis larvae. Source: QDAFF
- Heliothis armigera adult. Source: QDAFF

**Green vegetable bug** (*Nezara viridula*)

- Green vegetable bug raceme. Source: Barry Haskins, formerly NSW DPI
- Green vegetable bug nymphs. Source: Barry Haskins, NSW DPI
- Green vegetable bug adult. Source: NSW DPI

**Grass blue butterfly** (*Zizina otis labradus*)

- Grass blue butterfly larvae. Source: QDAFF
- Grass blue butterfly adults. Source: QDAFF

**Australian plague locust** (*Chortoicetes terminifera*)

- Australian plague locust on a wheat stem. Source: Lowan Turton, NSW DPI
- Spur throated locust. Source: NSW DPI

**Lucerne seed-web moth** (*Etiella behrii*)

- Lucerne seed web moth caterpillar. Source: NSW DPI
- Lucerne seed web moth. Source: NSW DPI

**Lucerne crown borer adult** (*Zygrita diva*)

- Lucerne crown borer adult. Source: Natalie Moore, NSW DPI
POWERFUL DUAL PURPOSE HYBRIDS

FEED CORN - 114 CRM

PAC 606

GRIT/FEED CORN - 123 CRM

PAC 727
LEADING HYBRIDS
Mirids

Red-banded shield bug (Piezodorus hybneri)

- Green mirid (Creontiades dilatus).
  Source: NSW DPI

- Brown mirid (C. pacificus).
  Source: QDAFF

Mites

- Red-legged earth mites (Halotydeus destructor).
  Source: Barry Haskins, NSW DPI

- Two-spotted spider mite (Tetranychus urticae).
  Source: NSW DPI

Sorghum midge (Contarinia sorghicola)

- Sorghum midge (Contarinia sorghicola).
  Source: QDAFF

Soybean moth (Stomopteryx simplexella)

- Soybean moth caterpillar.
  Source: NSW DPI

- Soybean moth adult.
  Source: Lowan Turton, NSW DPI

Western flower thrips (Frankliniella occidentalis)

- Western flower thrips (Frankliniella occidentalis).
  Source: NSW DPI

Rutherglen bug (Nysius vinitor)

- Rutherglen bug (Nysius vinitor).
  Source: Bob Colton, formerly NSW DPI

- Rutherglen bug (Nysius vinitor).
  Source: QDAFF

- Rutherglen bug (Nysius vinitor).
  Source: Bob Colton, formerly NSW DPI

- Rutherglen bug (Nysius vinitor).
  Source: QDAFF
Whitefly

Silverleaf whitefly (Bemisia tabaci). Source: NSW DPI

Greenhouse whitefly (Trialeurodes vaporariorum). Source: Max Hill, NSW DPI

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

Wireworm larvae (Agrypnus spp.). Source: NSW DPI

False wireworms (Pterohelaeus spp.) or Pie dish beetle. Source: NSW DPI

Further information

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

Publications


Good Bug Bad Bug?: An identification guide for pest and beneficial insects in summer pulses, peanuts and chickpeas. Hugh Brier, et al. (2012), GRDC and QDAFF.

Insect and mite control in field crops 2013, NSW Department of Primary Industries. Available at: www.dpi.nsw.gov.au/agriculture/broadacre/guides/insect-mite-crops

Websites

The Beat Sheet (QDAFF): http://thebeatsheet.com.au


NIPi and GRDC CESAR (Pest Facts) website: http://cesaraustralia.com/sustainable-agriculture/pestfacts-southeastern

Beneficial insects and IPM

Australasian Biological Control: www.goodbugs.org.au

Biological Services: www.bioresources.com.au

Bugs for Bugs: www.bugsforbugs.com.au

Ecogrow: www.ecogrow.com.au

Acknowledgements

The author would like to acknowledge the contributions of Barry Haskins, formerly NSW DPI; Loretta Serafin, NSW DPI, Tamworth; Merydyn Davison, NSW DPI, Orange; Kate Charleston, Queensland QDAFF, Toowoomba; Natalie Moore, NSW DPI, Grafton; Lowan Turton, NSW DPI Menangle; Bob Colton, formerly NSW DPI Orange.
Soybean
Natalie Moore, Luke Gaynor, Leigh Jenkins and Don McCaffery

Key management issues

- Plant at the optimum time to maximise yield potential and grain quality, by taking full advantage of daylight/heat units and to avoid damage from early frosts.
- Dryland soybean 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.
- Always inoculate seed correctly using the soybean-specific strain of Group H inoculant (strain CB 1809).
- Plan weed control measures carefully selecting appropriate herbicides (pre-emergent and/or post-emergent) and/or use inter-row cultivation.
- Remember that seed size varies widely between varieties and seasons. Check each bag for seed size and use the formula to calculate sowing rates based on seed size and target plant population (not on bags of seed/ha).
- Establish and maintain a uniform plant stand at recommended plant populations for your climatic and soil conditions.
- Correct any nutritional deficiencies of phosphorus, sulfur, potassium and trace elements (in particular zinc on heavy grey clay soils or molybdenum on acid soils of the tablelands and coastal areas).
- Inspect crops for insect pests and beneficials 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.
- Harvest soybeans as soon as possible to maximise grain quality by reducing the risk of weather damage or harvest losses from over-dry grain.

Significant premiums are paid for grain suitable for these markets, making the crop more attractive where high yields are also achieved. The expansion into human consumption markets is relatively new and is a result of improved Australian varieties with better grain quality.

While the areas currently grown are indicative of the strong competition from other summer crops, many producers have retained soybean in their crop rotations. Dryland soybean crops have been shown to have a beneficial role in mixed livestock and crop-farming systems. Benefits include:

- increased cash flow;
- potential contribution to the soil nitrogen balance, since soybean is a legume crop;
- improved soil structure, resulting in improved establishment of following crops or pastures;
- stubble and the occasional failed crop provide valuable grazing;
- expanded options for hay and silage in the Northern Tablelands and in mixed farming/grazing systems.

Paddock selection

Paddock history

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 farming systems, a double cropping rotation of soybean and winter cereal is considered a profitable system and offers growers opportunities to:

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

Under irrigation, quicker maturing varieties are harvested before the autumn break, allowing timely sowing of winter cereals into a seedbed with some stored moisture. The stored moisture and nitrogen residue can be utilised 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’ alternate crops of winter cereal and soybean, or two to three years of winter cereal followed by a similar period of soybean. However, these crops should be closely monitored for any sign of disease, weed population shifts and chemical resistance.

Soil management

Soils should be managed to maintain adequate groundcover through both fallow and cropping phases. This is beneficial for

Brief crop description

Soybean is a profitable crop for irrigated and dryland farming systems in NSW. Irrigated soybean production is centred on two main regions, the Riverina in the south and river valleys from the Macquarie Valley north to the Queensland border. Dryland soybean production is centred on the North Coast and the milder areas of the North-West Slopes, Liverpool Plains and Northern Tablelands. North Coast soybean crops are grown mainly in the Clarence, Richmond and Tweed valleys, but also as far south as the Manning Valley.

Soybean crops are particularly profitable where the quality standards for human consumption markets are attained.
both soil health (soil biology and soil structure) and to minimise soil erosion. With a build up of soil organic matter, soil structure improves with the soil becoming softer for easier disc or tine penetration resulting in more even sowing depth and easier root penetration to depth. Minimum- or no-tillage systems are used to maximise groundwater and conserve soil moisture. However, no-till systems can limit the use of some pre-emergent herbicides and the control of certain perennial weeds.

In the Riverina and in high rainfall areas such as the North Coast, soybean crops yield well on raised bed systems. Better soil structure, improved irrigation efficiency, and the ability to double-crop with successive crops are the major advantages of raised beds. Raised beds are compatible with controlled traffic systems and GPS guidance to reduce soil compaction.

On the North Coast of NSW, soybeans are grown mainly on better class alluvial soils, on mixed soil types in rotation with sugarcane, on lighter textured hill soils in pasture development programs and in rotation with winter and summer cereal crops.

**Soil salinity**

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

**Soil acidity and liming**

Soybean plants are adapted to acid soils and prefer pH_{ca} levels from 5.2–6.5. As pH_{ca} levels drop below 5, increasing amounts of toxic aluminium enter the soil solution. This effect is common in the soils of the North Coast of NSW and is greatest in soils that are low in organic matter as indicated by an organic carbon soil test. Soils with pH_{ca} levels of 4.5 or less are unsuitable for growing soybeans.

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 a nitrogen rich residue which breaks down to nitrate and becomes available to the following crop. When nitrates are leached, the zone of leaching becomes more acid. In general terms, for maintenance programs and in rotation with winter and summer cereal crops.

**Plant available water**

Dryland (rainfed) soybean crops should be planted into a full profile of soil moisture where possible. 100–120 cm of wet soil is ideal. This is rarely achieved on the North Coast due to the large proportion 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 to 80 cm wet soil at sowing is a realistic target.

Dryland yield and rainfall

The former NSW DPI soybean breeding program at Narrabri planted early indeterminate types in late November–early December for 24 seasons. In all seasons, full moisture profiles were used on a heavy clay soil with 100 cm row spacing and the recommended dryland plant population. This allowed the relationship between rainfall over the 120 days following planting and the resulting yield to be described. Figure 1 illustrates the relationship: each point represents the actual yield obtained (vertical axis) for the rainfall measured (horizontal axis) at Narrabri.

Growers can use this relationship as a guide to the dryland yield expectation at their site. 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 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. However, the yields should be discounted by about 10% to allow for the difference between experimental plot yields and commercial crop yields.

**Irrigation**

High yielding soybean crops have been shown to use six to eight 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, furrow, full flood and sprinkler irrigation. Pressurised water systems (pivots and laterals) are increasing in number in NSW and provide flexibility and timeliness for soybean growers. Regardless of the type of irrigation system, soybean crops have a peak water demand during flowering and early pod filling. For a crop planted in late November–early December in southern NSW, this means the peak water demand is from mid January to late March. This equates to 50–110 days after emergence.

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 border check layout. In the Riverina region of NSW, soybean crops are typically grown on...
raised beds using furrow irrigation on slopes of 1:1500 or flatter with run lengths of 400–800m. This allows better drainage around the root zone, less water-logging problems and disease and minimal establishment difficulties. Raised beds facilitate the sowing of the soybean crop 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 sowing but that is not too wet for machinery access. Often the soil surface dries out too quickly before, during and after sowing resulting in uneven and low plant population and patchy crop establishment.

Pre-irrigating fields one to three weeks prior to planting and conducting sowing operations as soon as the soil is dry enough to work is the recommended practice for irrigated soybean crops. Watering up (irrigating after sowing 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, as dry and hot summer conditions can quickly kill the rhizobia on inoculated planting seed resulting in poor nodulation. It is also not recommended in border check systems as seed can become waterlogged and rot or burst due to a lack of drainage.

Grain yield and protein content are dependent on timely irrigations throughout the life of the crop, and avoiding small moisture stresses. Intermittent moisture stress should be avoided as it may reduce protein content. When the plants start to become moisture stressed, they shutdown the rhizobium nodules first until they are watered again; once the crop is watered it can take a few days for the rhizobium nodules to become fully functional and active again. The cumulative effect over the season can have a negative effect on the total N content of the plant and ultimately seed protein content. High grain yields may also limit protein content of the grain.

The number and amount of irrigations applied will vary depending on season, soil type, irrigation equipment and target yield. Implementing a scheduling system to help identify when the crop is approaching water stress is recommended.

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

As soybeans are often flowering and filling pods during the hottest part of the year any moisture stress can reduce yield by reducing the number of retained pods and by reducing seed weight. Some moisture stress before flowering can help the crop develop a deeper root system, providing a buffer for times of unexpected moisture stress. This strategy will work best on well structured grey clay soils that allow the crop to develop a larger root system.

Inoculation

To capture maximum crop growth, grain yield and benefits of residual soil N from soybean crops inoculate planting seed with Group H soybean inoculant (strain CB 1809) every time a soybean crop is sown. Whilst some soybean rhizobia (spores of the bacterium *Rhizobium japonicum*) may survive in fields previously sown with inoculated soybean seed, distribution will not be uniform particularly if waterlogging or soil disturbance has occurred. Therefore, to achieve an even plant stand, maximum crop vigour and grain with a high protein content, inoculation of every soybean crop is recommended. 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 just prior to sowing
- 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.

Refer to the GRDC Publication *Inoculating legumes: A practical guide* by Drew *et al.* (2013) for more information.

Soybean grain is high in protein and the soybean plant has a high nitrogen requirement, but when inoculated correctly soybean crops will fix far more nitrogen than their own needs. Studies by NSW DPI on the North Coast of NSW showed that on average well-nodulated soybean crops fixed around 80 kg of N per tonne of soybean grain produced. Per 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 and left behind around 70 kg of residual N/ha after the grain was harvested.

Refer to the GRDC publication *Managing legume and fertiliser N for northern grains cropping*, by David Herridge, 2013, for an extensive review of N fixation studies and tools for calculating N budgets.

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 inoculant in a cool but not frozen 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 prior to sowing soybean.

However, too much starter N should be avoided as it will interfere with timely nodulation of the soybean seedlings and N fixation for the duration of the crop.

Growers are encouraged to dig up plants after six weeks to check on the success of their inoculation procedures. Check 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, firm and a whitish colour on the outside with a pink — orange
Unlock the potential in your soil, seeds and crops.

Growers most pressing challenges today centre on improving yield while managing resources: doing more with less. Through its new Functional Crop Care business, BASF is broadening what it means to produce better crops. One way we are doing this is by harnessing innovations in chemistry with high performing seed solutions.

### Nodulaid® NT
*For superior nodulation and yield performance.*

<table>
<thead>
<tr>
<th>The only dual benefit inoculant on the market that will take yields higher.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advanced features:</strong></td>
</tr>
<tr>
<td>– Contains a Nodulating Trigger (NT) with Plant Growth Promoting Rhizobacteria (PGPR), <em>Bacillus</em> spp., in addition to nitrogen-fixing rhizobia.</td>
</tr>
<tr>
<td>– Enhances root growth and improves nitrogen fixation.</td>
</tr>
<tr>
<td>– More vigorous plant growth.</td>
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<tr>
<td>– Greater yield potential.</td>
</tr>
</tbody>
</table>

### Nodulator® Clay Granules
*For better flow and better performance.*

<table>
<thead>
<tr>
<th>Providing a superior level of seed performance.</th>
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</thead>
<tbody>
<tr>
<td><strong>Advanced features:</strong></td>
</tr>
<tr>
<td>– Dust and lump-free formulation.</td>
</tr>
<tr>
<td>– Uniform size and smooth surface for superior flow.</td>
</tr>
<tr>
<td>– High counts of live rhizobia.</td>
</tr>
<tr>
<td>– Ideal for ‘dry seeding’.</td>
</tr>
</tbody>
</table>

**ALWAYS READ AND FOLLOW LABEL DIRECTIONS.**

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colour on the inside. Nodules that are very small in size, not firm or that have a green, grey or white colour inside are not functional and you should seek the advice of your local agronomist.

In addition to inoculating correctly, good agronomic practices that promote vigorous, high biomass soybean crops will ensure maximum nitrogen fixation.

**Time of sowing**

Sowing windows and varieties vary widely across the soybean production regions of Australia. Refer to Table 1 to ensure the correct variety is planted in the correct window for your region.

In southern NSW aim to sow mid November to mid December so that crops can mature as early as possible, preferably by late March/early April. Sowing in this 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 reduces total plant dry matter considerably. This reduces yields and results in plants maturing in cooler overnight temperatures, which delays harvest. It also reduces the flexibility in the timelines of farming operations, and often crops are exposed to greater insect pressure. Planting in early January in southern NSW is not recommended.

In northern inland NSW the planting window for maximum yield potential commences in mid November. Yield potential declines with late 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 yield potential declines by 30% and other crop options are preferred.

In the Manning, Hastings and Macleay Valleys, the recommended sowing times range from early November to the end of December.

In the North Coast districts of NSW, current varieties allow sowing from late November to the end of January. Within this range each variety has an optimum sowing period of two to three weeks.

Soybean plants flower and mature in response to increasing length of darkness, that is, shortening daylight hours. Current commercial soybean varieties are photosensitive and in general the later they are sown the fewer days until flowering. If the same variety is sown on the same day at Casino and Wauchope, it will experience longer daylight hours during summer in Wauchope and so flowering begins a little later.

Sowing times are recommended for each variety to achieve the optimum balance between vegetative growth and yield potential. Varieties sown later than their recommended sowing time will likely have shorter plants with pods set closer to the ground. This can be compensated for by increasing plant population by up to 20% in later sowings. Conversely, varieties sown earlier than recommended can spend too long in the vegetative phase, grow too tall and lodge.

Sowing in the early part of the window is recommended where early growth is likely to be slower, such as where soil fertility is low, or where crops are direct drilled.

### Table 1. Suggested sowing times for soybean in NSW.

<table>
<thead>
<tr>
<th>Region</th>
<th>Variety</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 2</td>
<td>3 4</td>
<td>1 2</td>
</tr>
<tr>
<td>Northern Inland – dryland</td>
<td>Moonbi</td>
<td>&lt;</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Hale, Ivory</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Northern Inland – irrigation (Macquarie Valley and north)</td>
<td>Moonbi, Richmond, Bunya, Cowrie, Soya 791, Hale, Ivory,</td>
<td>&lt;</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Northern Tablelands and Slopes</td>
<td>Hayman (for silage or hay)⁴</td>
<td>&lt;</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Moonbi, Richmond, Soya 791, Intrepid, Hale</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Far North Coast – Clarence, Richmond and Tweed Rivers</td>
<td>Hayman (for silage or hay)⁴</td>
<td>&lt;</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Moonbi, Soya 791</td>
<td>&lt;</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Cowrie</td>
<td>&lt;</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Zeus</td>
<td>&lt;</td>
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<td>*</td>
</tr>
<tr>
<td></td>
<td>Richmond, Manta, A6785</td>
<td>&lt;</td>
<td>*</td>
<td>*</td>
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<tr>
<td></td>
<td>Poseidon, Surf</td>
<td>&lt;</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Hayman (for grain)⁴</td>
<td>&lt;</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Mid North Coast – Manning, Hastings and Macleay Rivers</td>
<td>Hayman (for silage or hay)⁴</td>
<td>&lt;</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Moonbi, Cowrie, Soya 791</td>
<td>&lt;</td>
<td>*</td>
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<tr>
<td></td>
<td>Zeus</td>
<td>&lt;</td>
<td>*</td>
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</tr>
<tr>
<td></td>
<td>Manta</td>
<td>&lt;</td>
<td>*</td>
<td>*</td>
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<tr>
<td></td>
<td>Poseidon</td>
<td>&lt;</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Macquarie Valley</td>
<td>Moonbi, Snowy, Soya 791, Djakal</td>
<td>&lt;</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Lachlan Valley – irrigated</td>
<td>Djakal, Snowy, Bidgee</td>
<td>&lt;</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Southern NSW Riverina</td>
<td>Djakal, Snowy, Bidgee</td>
<td>&lt;</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Murray Valley</td>
<td>Djakal, Bidgee</td>
<td>&lt;</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

< Earlier than ideal, but acceptable.  * Optimum sowing time to achieve full yield potential.  ▷ Later than ideal, but acceptable.

⁴ Note: On the North Coast Hayman has two different recommended sowing times depending on the objective of the crop. For silage or hay production, sow mid Nov to early Dec. For grain production sow early-late Jan.
**Row spacing**

Soybean has a large seed size relative to other crops and a delicate, thin seed coat. Therefore, broadcasting through a spreader and discing in is not ideal. Soybean is best grown in defined rows using a seeder to achieve uniform seed depth and placement along the row and to better achieve target plant populations. Row cropping allows more options for weed control including the use of banded sprays, shielded sprayers and inter-row cultivation. It also allows easier access into the crop for bug-checking and facilitates the use of directed sprays for insect control (eg. angled delivery of sprays to target the underside of leaves).

In humid coastal environments wide rows aligned to the direction of the prevailing winds can reduce the incidence of Sclerotinia (white mould) infection by reducing humidity in the crop. Improving aeration in the crop can also delay the development of soybean leaf rust, which is favoured by leaf wetness.

Soybean is successfully grown on a wide range of row spacings associated with the diverse cropping systems in NSW. 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 row spacing of 50 cm.

Dryland crops on the slopes and plains should be sown on a 100 cm row spacing, which conserves more moisture for pod-fill. In high yielding situations, row spacings less than 75 cm out-yield wider row spacings.

In the more favoured rainfall areas of the Northern Tablelands and North Coast, crops are normally planted on 18–53 cm rows. 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 may be more limited as the crop canopy closes more quickly.

In cultivated seedbeds, seed is generally sown in 18 or 36 cm row spacing using conventional seed drills. With minimum- or no–till systems, specialised direct drills (preferably disc openers) or precision planters are necessary to ensure uniform seed placement and clearance of 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 farming system, stubble loads, time of sowing and inter-row sowing capability. Sowing an additional row of plants in the middle of the raised bed requires good lateral movement of soil water to ensure that adequate moisture is available to plants in the centre row. Sowing more than two rows per bed requires more water (to fill to the middle of the bed to field capacity) than two plant rows per bed.

**Plant population and sowing depth**

Potential yield is determined by the ability to establish and maintain a uniform plant stand. The desirable plant population densities are listed in Table 2.

With late sown varieties higher populations are recommended as yield steadily declines as population density is reduced to below 30 plants/m².

Growers planting varieties for the tofu market such as Moonbi, Richmond, Bidgee, Snowy, Bunya, Cowrie and Hayman will need to adjust sowing rates to account for the larger seed size of these varieties. Likewise, sowing 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 sowing rates' below.

Lower plant populations are acceptable when sowing is early, while higher densities are preferred for sowing later in the recommended sowing window.

**Calculating sowing rates**

The following formula can be used to calculate sowing 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 sowing into adverse conditions (80% = 0.8 in the formula)

Sowing Rate (kg/ha) = \( \frac{\text{target plant population/m}^2 \times 10,000}{\text{germ.} \times \text{estab.} \times \text{seeds/kg}} \)

Experience has shown that dryland soybean crops yield best when sown at lower seed rates than irrigated crops, particularly in the hotter, drier regions. However, plant populations lower than 15–20 plants/m² on the northern slopes and plains may increase harvesting problems because the pods are set too close to the ground, especially in the early-maturing varieties.

**Table 2. General recommendations for soybean plant populations for regions of NSW.**

<table>
<thead>
<tr>
<th>NSW Region</th>
<th>Target Plant Population - established plants/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Inland</td>
<td></td>
</tr>
<tr>
<td>Irrigation/mild dryland areas</td>
<td>25–30</td>
</tr>
<tr>
<td>Dryland/Slopes and Plains</td>
<td>15–20</td>
</tr>
<tr>
<td>Tablelands</td>
<td>35–40</td>
</tr>
<tr>
<td>Coastal</td>
<td></td>
</tr>
<tr>
<td>Narrow rows (&lt; 75 cm)</td>
<td>30–40</td>
</tr>
<tr>
<td>Wide rows (&gt; 75cm)</td>
<td>28–32</td>
</tr>
<tr>
<td>Southern</td>
<td></td>
</tr>
<tr>
<td>Mid Nov–Mid Dec</td>
<td>35–40</td>
</tr>
<tr>
<td>Mid Dec–Late Dec</td>
<td>45–50</td>
</tr>
</tbody>
</table>

Seed should be sown into moist soil to a depth of no more 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. The use of rollers is generally not advised. Planters with press wheels which 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 sowing (2–3 cm) is preferred when crops are sown dry and watered up. This is often the case in double-crop situations.

**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. This is exacerbated by high moisture levels and high temperatures.

Prolonged wet weather before harvest reduces seed quality by the alternate wetting and drying of 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 sowing 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 storage conditions over winter. Germination tests typically cost around $70 per sample.

Soybean seeds have a thin seedcoat, making them more susceptible to damage than other crop species. Incorrect seed handling, the use of spiral augers, and long drops of seed onto hard surfaces can damage the thin seedcoat and split seed. Belt conveyers are preferred for seed targeted at 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 at very low moisture content, for example 8%, can increase damage compared to harvesting at the optimum moisture content of 13%.

**Variety characteristics**

Select a preferred 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 through the occurrence of new races.

Information is provided with emphasis on recent releases. Recommendations are based on extensive testing.

**Southern NSW varieties**

In the Murrumbidgee and Murray Valleys, the preferred human consumption varieties are Djakal and Snowy. Under optimum conditions growers should be targeting over 4 t/ha yields with Djakal and Snowy. Long term (6 years) yield averages for both varieties at Leeton Field Station is 4.19 t/ha and 3.9 t/ha respectively. Although 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 and Bidgee. All are indeterminate types. Higher yielding, early maturing human consumption varieties have largely replaced older oilseed crushing types. Older varieties now superseded due to lower yield and/or lower human consumption quality include Curringa, Empyle and Bowyer.

**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 sowing time without lodging,
- tolerance to high soil manganese levels, common in soils with low pH and 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, Moombi, 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 NSW and Queensland respectively) have a greater risk of not performing to their full potential.

**Northern inland NSW varieties**

The preferred varieties for the human consumption market are Moombi, 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**

The © symbol indicates that a variety is covered by the Plant Breeder’s Rights Act (1994) and an End Point Royalty (EPR), including breeder royalties, is payable at the first point of sale of the grain from these varieties. Growers are allowed to retain seed from production of such 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 Factsheet End Point Royalties (EPR) and visit the Variety Central website at http://varietycentral.com.au/end-point-royalties/growers/epr-industry-collection-system

**A6785 (Asgrow)**

A6785 (Asgrow) has a brown hilum and is suited mainly to the crushing market and to soylfower production. It is sometimes used in soymilk manufacturing, although seed size (approx. 17 g/100 seeds or 5800 seeds per kg) is smaller than is preferred for this market and grain protein levels often fall below 40% dry matter basis. It produces high yields if sown at the correct time. It has tolerance to races 1 and 15 of Phytophthora, and has moderate weathering tolerance. On the North Coast of NSW A6785 can lodge if sown too early or at too high a plant population.
Table 3. Characteristics of soybean varieties available in NSW 2014.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Growth habit</th>
<th>Colour</th>
<th>Resistance or tolerance to</th>
<th>Seed size (seeds per kg @ 12% moisture)</th>
<th>Area of adaptation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flower</td>
<td>Pod hair</td>
<td>Hilum</td>
<td>Manganese toxicity (1–10, where 10 is highly tolerant)</td>
<td>Weathering (1–10, where 10 is highly tolerant)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(seeds per kg @ 12% moisture)</td>
<td>race 1</td>
</tr>
<tr>
<td>A6785</td>
<td>Determinate</td>
<td>white</td>
<td>grey</td>
<td>brown</td>
<td>3</td>
</tr>
<tr>
<td>Bidgee</td>
<td>Determinate</td>
<td>white</td>
<td>grey</td>
<td>clear</td>
<td>–</td>
</tr>
<tr>
<td>Bunya</td>
<td>Determinate</td>
<td>white</td>
<td>grey</td>
<td>clear</td>
<td>8</td>
</tr>
<tr>
<td>Cowrie</td>
<td>Determinate</td>
<td>white</td>
<td>grey</td>
<td>clear</td>
<td>7</td>
</tr>
<tr>
<td>Curringa</td>
<td>Indeterminate</td>
<td>white</td>
<td>grey</td>
<td>clear</td>
<td>–</td>
</tr>
<tr>
<td>Djakal</td>
<td>Indeterminate</td>
<td>white</td>
<td>grey</td>
<td>buff</td>
<td>–</td>
</tr>
<tr>
<td>Hale</td>
<td>Indeterminate</td>
<td>white</td>
<td>brown</td>
<td>black</td>
<td>–</td>
</tr>
<tr>
<td>Hayman</td>
<td>Semi-determinate</td>
<td>white</td>
<td>grey</td>
<td>clear</td>
<td>7</td>
</tr>
<tr>
<td>Intrepid</td>
<td>Indeterminate</td>
<td>purple</td>
<td>brown</td>
<td>black</td>
<td>–</td>
</tr>
<tr>
<td>Ivory</td>
<td>Determinate</td>
<td>white</td>
<td>grey</td>
<td>clear</td>
<td>–</td>
</tr>
<tr>
<td>Manta</td>
<td>Determinate</td>
<td>purple</td>
<td>brown</td>
<td>black</td>
<td>6</td>
</tr>
<tr>
<td>Moonbi</td>
<td>Indeterminate</td>
<td>white</td>
<td>grey</td>
<td>clear</td>
<td>7</td>
</tr>
<tr>
<td>Poseidon</td>
<td>Determinate</td>
<td>purple</td>
<td>brown</td>
<td>black</td>
<td>6</td>
</tr>
<tr>
<td>Richmond</td>
<td>Determinate</td>
<td>white</td>
<td>grey</td>
<td>clear</td>
<td>8</td>
</tr>
<tr>
<td>Snowy</td>
<td>Indeterminate</td>
<td>white</td>
<td>grey</td>
<td>clear</td>
<td>–</td>
</tr>
<tr>
<td>Soya 791</td>
<td>Determinate</td>
<td>white</td>
<td>grey</td>
<td>brown</td>
<td>3</td>
</tr>
<tr>
<td>Surf</td>
<td>Determinate</td>
<td>purple</td>
<td>grey</td>
<td>clear</td>
<td>7</td>
</tr>
<tr>
<td>Zeus</td>
<td>Determinate</td>
<td>purple</td>
<td>brown</td>
<td>black</td>
<td>6</td>
</tr>
</tbody>
</table>

- 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
- Indicates that this variety is covered by the Plant Breeder’s Rights Act (1994)
- Indicates disease assessments and field observations by Dr Malcolm Ryley, Plant Pathologist formerly of QDAFF, Queensland
This table was updated by Natalie Moore and Mr Luke Gaynor (NSW DPI) based on replicated, multi-season NSW DPI research data and field observations to 2014
Bidgee

Bidgee (Line L023B-23) is a clear hilum, high yielding, high protein variety for southern NSW and is currently licensed to Soy Australia. Bidgee was released by the Australian Soybean Breeding Program as a higher yielding, higher protein and shorter season alternative to Djakal. Bidgee’s quicker maturity can reduce the number of in-crop irrigations. As with all varieties in southern NSW, growers are encouraged to sow as early as possible in the sowing window (mid November to mid December) to maximise yield potential. With Bidgee’s quicker maturity, growers need to be prepared to harvest on time as this variety can shatter in some years. Bidgee 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, compared to Djakal which has only single-gene resistance.

Bunya

Bunya is 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. Bunya is currently licensed to Soy Australia. It is resistant to Phytophthora including race 15 but susceptible to powdery mildew. Seed size (approx 25 g/100 seed or 4000 seeds per kg) can be up to 15% larger than Cowrie. This increases the risk of seedcoat damage at harvest. Germination checks and attention to careful seed handling during planting are essential. Achieving high grain protein content (i.e. over 40% protein dry matter basis) in coastal environments with Bunya can be difficult and it is better suited to inland irrigated production environments.

Cowrie

Cowrie was released 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 (approx. 23 g/100 seeds or 4350 seeds per kg), making it very acceptable to the soymilk, tofu and soyflour markets. Weathering tolerance is moderate (70% of Zeus). Cowrie is tolerant to Phytophthora race 1 but not to race 15.

Curringa

Curringa superseded Bowyer for the premium human consumption, yellow hilum market. It had better yield, lodging and disease resistance than Bowyer. It is resistant to Phytophthora races 1 and 15, and has field tolerance to races 4 and 25. It has similar growth habit, maturity and seed size to Bowyer, but has higher yield potential in the MIA and Lachlan Valley. Curringa has been accepted into tofu and soymilk markets. Weathering tolerance is moderate (70% of Zeus). Curringa is tolerant to Phytophthora race 1 but not to race 15.

Djakal

Djakal is the current industry standard in southern NSW for yield stability and maturity. Djakal is a high yielding variety and is a robust plant over a range of season types. On average Djakal matured 6 days earlier than Snowy and about 3 days later than Bidgee. On average it matured 11 days earlier than Curringa and 6 days earlier than Snowy. Djakal performs consistently over a wide range of sowing times within the recommended sowing window and is suited to all central/southern irrigation areas in NSW and irrigation areas in Northern Victoria.

Limited trials have been conducted north of the Lachlan Valley. Djakal is a strong performer, providing growers with consistent high yields, early maturity, lodging resistance and generally good agronomic package.

Djakal carries resistance to Phytophthora races 1 and 4 but lacks resistance to the newer race 25, which is present in parts of the Riverina but is not widespread. Commercial experience indicates Djakal has field tolerance to race 25. Whilst this is a risk, good grower management can reduce the likelihood of this disease. Testing to date has shown Djakal to be equivalent to Curringa for tofu and soymilk. Protein content of Djakal is slightly lower than Snowy.

Hale

Hale was bred by NSW DPI at Narrabri, and released in 2000. It has improved yield potential and disease resistance. It has shown excellent yields under both irrigated and dryland conditions and has immunity to races 1, 4 and 15 of Phytophthora.

In northern NSW, Hale has out-yielded Valiant under irrigated conditions by 8.5% averaged over nine trials and across 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.

Hale is a preferred variety for dryland situations. It is also promoted along with Moonbi to irrigated cotton growers in northern river valleys as an early maturing alternative to the traditional full season varieties.

Hayman

Hayman (Line NK55C-32) is a new variety from the Australian Soybean Breeding Program, released in 2013 and currently licensed to Seednet. Hayman produces large pale seed with a clear hilum and readily produces protein levels above 43% dry matter basis. These traits provide growers with wider market options including the higher value human consumption markets as well as crushing markets. Hayman also possesses the 11sA4 protein null (like Bunya) that is valued by tofu processors. Hayman is resistant to powdery mildew, and has high tolerance to manganese toxicity, which is common in coastal soils. Hayman has similar weathering tolerance to A6785. Due to its large biomass and longer growing season on the North Coast it is recommended for grain production only at late season sowing dates (mid-late January). On the North Coast Hayman provides a superior option to Warrigal or A6785 for very late sowing dates.

Hayman is the best option for hay and silage production for sheep and dairy producers in the North Coast and Northern Tablelands regions of NSW and in southern Queensland. Hayman produces up to 25% greater biomass per hectare than Asgrow A6785, whilst maintaining the same feed values and less lodging. When sown on the same date Hayman takes around 12 days longer to mature than A6785, giving hay and silage producers a longer window of opportunity to cut the crop.

Intrepid

Intrepid, bred by NSW DPI at Narrabri, is a dryland variety recommended for northern inland NSW. It has less tolerance to Phytophthora races 1 and 15 than Hale and Valiant. 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 Valiant and Hale. Intrepid is highly regarded by growers in the Northern Tablelands region but due to its black hilum it 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 Cowrie, Moonbi or Richmond. Growers seeking a high biomass variety to produce hay or silage are strongly encouraged to try Hayman.

Ivory

Bred by NSW DPI at Narrabri, Ivory has been widely grown by irrigators 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. Ivory is resistant to races 1 and 4 of Phytophthora with field tolerance to race 15. It also has resistance to bacterial pustule and bacterial blight. It is recommended for all irrigated and late dryland sowings.

Manta

Manta was released in 1991 by NSW DPI for coastal environments. This variety combines high yield, tolerance to manganese, Sclerotinia and race 1 of Phytophthora. It also has a good level of weathering tolerance. Manta produces grain with above average protein content, but is only suitable for the crushing market due to its dark coloured hilum. Manta has good resistance to lodging and is recommended for coastal growers seeking to supply the crushing market.

Moonbi

Moonbi (Line 98053-3) was released by the Australian Soybean Breeding Program in 2010 and is currently licensed to Soy Australia. As a short season variety (ready to harvest 12 days earlier than Soya 791 at the same planting date), it is particularly suited to double cropping systems on the North Coast, northern tablelands and slopes where timeliness of planting winter crops or pastures is critical. It is also suited to dryland production on the Liverpool Plains. Moonbi is suited to the early season planting window from late November to early December.

Moonbi has excellent grain quality with a clear hilum, high protein, attractive round seed and better weathering tolerance than Cowrie and Soya 791. Moonbi is resistant to powdery mildew. It is a compact plant type with a much lower tendency to lodge than Soya 791 and has clean leaf drop and even ripening for ease of harvest. The grain quality is well suited for higher value human consumption markets such as soy milk and tofu. Seed size is around 22 g/100 seed or 4550 seeds per kg.

Poseidon

Poseidon was 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. Tolerance to Sclerotinia is less than in Manta and Zeus. Poseidon has good tolerance to race 15 of Phytophthora. It has a black hilum, which makes it suitable only for the crushing market.

Richmond

Richmond (Line NF246-64) is a new variety from the Australian Soybean Breeding Program, released in 2013 and currently licensed to Seednet. Richmond is suited to production on the North Coast, northern tablelands and slopes and the Liverpool Plains. Richmond provides a clear hilum, high protein, large seeded alternative to A6785 and is suited to a mid season sowing window on the coast (mid-late December).

Richmond has the highest weathering tolerance of any currently available clear hilum variety, but is not quite as high as Zeus the dark hilum benchmark for weathering tolerance. Richmond has a compact plant type to minimise lodging, clean leaf drop and even ripening for ease of harvest.

Snowy

Snowy is a mid maturing, high yielding, human consumption variety. It was the first clear hilum culinary quality soybean combining good tofu making qualities with good agronomic traits and is currently licensed to Soy Australia.

Snowy is resistant to all commonly found races of Phytophthora in the Riverina, including race 25.

Snowy has yielded slightly less then Bidgee and Djakal, but significantly out-yields older varieties. It matures slightly later than Djakal. Snowy has slightly larger seed size and higher protein than Djakal and Bidgee and significantly larger seed size than Empyle. A premium may be available in the culinary market for this variety. Snowy is susceptible to lodging and powdery mildew.

Soya 791

Soya 791 has a brown hilum and is suited to soylflower production. It is also used for soymilk, although seed size (approx. 21 g/100 seeds or 4760 seeds per kg) is a little smaller than is preferred for this market. It can produce high yields if sown at the correct time and has good protein content. Soya 791 is tolerant to race 1 of Phytophthora but not race 15, and has poor tolerance to the white mould fungus Sclerotinia. It is susceptible to manganese toxicity and has very poor weathering tolerance in coastal environments.

Surf

Surf was released as a public variety by NSW DPI in 2004. It has a clear hilum, large seed size (approx. 22 g/100 seeds or 4550 seeds per kg) and good protein content, making it suitable for the culinary market. As it is suited to the late planting window on the North Coast (end Dec to mid Jan), Surf extends the planting window for culinary soybean varieties in this region, which is currently served by Moonbi, Cowrie and Soya 791 at earlier sowing dates. Surf has a similar weathering tolerance to Cowrie and is tolerant to races 1 and 15 of Phytophthora.

Zeus

Zeus was bred by NSW DPI for northern coastal NSW environments and was released in 1999 as a higher yielding and more weathering tolerant replacement for Dune. Zeus has the highest level of weathering tolerance of all the current commercially available varieties and useful tolerance to the fungus Sclerotinia (white mould), which makes it a popular choice for areas with high rainfall and high humidity. Zeus has a dark coloured hilum and is therefore suitable only for the crushing market.
Growth stages

Soybeans commence flowering in response to lengthening hours of darkness, which has an effect on the time to maturity, mature plant height and yield. Selection of an appropriate variety and a suitable sowing time are important factors for a high yielding crop. If a variety is sown 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 sown later than recommended, yield will be reduced and the crop may be too short and therefore difficult to harvest. Varieties have been bred and selected for their adaptation to specific regions.

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 was not achieved by the optimum time for maximum yield potential.

In southern NSW flowering should commence approximately 40–55 days after sowing in the Murrumbidgee Valley and southwards to achieve full ground cover by mid flowering for indeterminate varieties.

Eight critical stages of crop development and management targets are provided below and in Figure 2:

1. Planting – Sow appropriate variety at the correct planting time, 5 cm deep into good soil moisture.
2. Emergence usually occurs 5–10 days, but more often 7 days after planting. Establish a uniform stand of 30–40 plants per square metre dependent on recommendations for your area. Check for insects, weeds and diseases.
3. Early vegetative stage is between 1 and 5 weeks after emergence. Check weekly for weeds, 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. Late vegetative stage is weeks 5–6. During this stage, 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 nitrogen to make up the shortfall in fixed nitrogen.
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 commences check every 3 days for insects and for leaf and stem disease. Visually assess 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 commence 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. Poddng commences at weeks 8–10. The first pods appear 10 to 14 days after the start of flowering. Each pod usually contains two or three seeds but may range from one to four. It is critical to monitor and control insects now. Check every 3 days for insects, also 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 commences 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 the range of 15% to 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, sowing date and extreme environmental conditions.

Nutrition

Soybeans has a high demand for plant nutrients, in particular nitrogen, phosphorus and potassium. When deciding how much fertiliser to apply to a soybean crop it is important to know the nutrient status of the soil and the critical level of soil nutrients, particularly phosphorus and potassium that are needed to give the maximum economic yield. A soil test is the best way to determine soil nutrient status.

The approximate quantities of major nutrients utilised by a soybean grain crop are shown in Table 4.

Figure 2. Soybean Crop Growth Targets (adapted from SoyCheck 1997).
Nitrogen (N)

When inoculation of planting seed is carried out correctly the nitrogen fixing bacteria (rhizobia) in the root nodules will supply soybean plants with all their nitrogen requirements. A small amount (up to about 20 kg of N per hectare) of ‘starter’ nitrogen may be beneficial in certain situations. For example, for late sown crops it helps to ensure good early growth of seedlings and adequate height to the lowest pod. Small amounts of starter N may also be beneficial where soybean is sown into dense sugar cane stubble. Care must be taken not to apply too much starter N as this will have a detrimental effect on the formation of nodules that supply nitrogen to the plant later in its growth cycle. See the Inoculation section above for important information.

Sulfur (S)

Soybean is a high protein legume and insufficient sulfur limits yield. Generally, single superphosphate applications supply adequate sulfur. On high phosphorus testing soil, inadequate sulfur can frequently limit yields, especially with direct drilled crops. The KCl-40 soil test is a good guide for sulfur fertiliser requirements – it is suggested if KCl-40 S test levels are below 10 mg/kg, apply fertiliser containing sulfur at rates up to 15 kg S/ha.

Phosphorus (P)

Soils predominantly derived from sedimentary and granitic rocks are extremely low in phosphorus and high rates of phosphatic 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 (that fixes phosphorus). In these types of soils, a large proportion of the phosphorus applied in fertiliser can be fixed in a form that is unavailable to the current crop. 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 phosphorus buffering indices.

On podsolic soils where large amounts of single superphosphate are required, apply some phosphorus fertiliser before sowing and up to a maximum of 200 kg/ha with the seed.

For practical and economic reasons, most growers with medium to high phosphorus soils broadcast and incorporate the entire fertiliser requirement prior to sowing.

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 5 as a guide to soybean crop phosphorus fertiliser requirements.

Zinc (Zn)

Zinc deficiency is widespread on the grey clays of inland irrigation areas. Although it is a well-known problem with soybeans, zinc deficiency is still occasionally found. Some varieties may be more sensitive than others.

Zinc can be applied either to the soil or to the foliage. Apply 30 kg/ha of zinc oxide to the soil every 5–7 years or apply zinc sulfate heptahydrate at 4 kg/ha as a foliar spray 6–8 weeks after planting.

Molybdenum (Mo)

In acid soils (pH< 5.0), molybdenum deficiency is likely and can be corrected by applying 70 g/ha of molybdenum oxide every 2 years. Molybdenum is commonly applied as molybdenum 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 molybdenum trioxide are not toxic to rhizobia. Sodium molybdate can be applied with trifluralin before sowing.

Root nodule bacteria require molybdenum as part of an enzyme to convert atmospheric nitrogen 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 molybdenum.

Potassium (K)

Soybean yields may be limited by potassium deficiencies on some coastal and tableland soils, particularly on sandy soils and those with a long history of intensive cropping where heavy export of K in hay, silage, grain or sugarcane has occurred.

Table 5. Guide to phosphorus fertiliser requirements for soybean crops on North Coast NSW soils.

<table>
<thead>
<tr>
<th>Colwell Test</th>
<th>Bray No 1 Test</th>
<th>Phosphorus recommendation (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PBI* &lt; 280 e.g. sandstone/shale/granite</td>
<td>PBI &gt; 280 e.g. basalt/clay alluvials</td>
<td>All soils</td>
</tr>
<tr>
<td>0–10</td>
<td>0–30</td>
<td>0–5</td>
</tr>
<tr>
<td>11–15</td>
<td>30–40</td>
<td>5–10</td>
</tr>
<tr>
<td>26–40</td>
<td>50–60</td>
<td>15–25</td>
</tr>
<tr>
<td>Over 40</td>
<td>Over 60</td>
<td>Over 25</td>
</tr>
</tbody>
</table>

* Phosphorus Buffering Index (Burkitt et al. 2002)

Table 6. Potassium fertiliser recommendations for soybean crops on North Coast NSW soils.

<table>
<thead>
<tr>
<th>Exchangeable potassium levels. K recommendation as Muriate of Potash</th>
<th>C mol+/kg</th>
<th>K (kg/ha)</th>
<th>Muriate of Potash (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–0.1</td>
<td>50–75</td>
<td>100–150</td>
<td></td>
</tr>
<tr>
<td>0.1–0.2</td>
<td>25–50</td>
<td>50–100</td>
<td></td>
</tr>
<tr>
<td>0.2–0.4</td>
<td>10–25</td>
<td>20–50</td>
<td></td>
</tr>
<tr>
<td>Over 0.4</td>
<td>Nil</td>
<td>Nil</td>
<td></td>
</tr>
</tbody>
</table>

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.
Table 6 gives a guide to potassium 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 potassium value.

When sowing, never place any potassium fertiliser in contact with the seed, as plant establishment will be impaired by the salt effect of the fertiliser.

Manganese (Mn)
Where manganese problems are likely to occur management strategies are:

- improve drainage,
- incorporate lime to raise soil pH,
- grow manganese tolerant soybean varieties.

Moderately acid soils can release potentially toxic soluble manganese after a waterlogging event. Also, the heating effect on exposed soils releases soluble manganese. Improved drainage and liming to raise the pH, reduces the intensity and duration of the soluble manganese pulse.

Other trace elements
Except for molybdenum on the North Coast and Tablelands, and zinc on the grey clays of inland irrigation areas, fertiliser trace elements are generally not required for soybean crops. Copper and zinc deficiency may occur in pastures and sugar cane on sandy Wallum soils in coastal areas.

Weed management

Good weed management relies on timeliness, crop rotations, herbicide rotations and specific management strategies targeted at reducing the seed banks of problem weeds. Summer growing weed species generally proliferate in the irrigation and coastal regions. Herbicides are therefore an important tool in the cost-effective management of weeds. The range of herbicides registered for weed control in soybeans is shown in Table 8.

Weeds compete with soybeans for moisture, nutrients and light; and can create difficulties at harvest. Weed contamination of the crop can drastically reduce grain yield and increase harvest costs. Additional costs may 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, prolific growth of troublesome weeds such as Apple of Peru (Nicandra physalodes), Jute (Corchorus spp.), Bellvine (Ipomoea plebeia), or Sesbania pea (Sesbania cannabina) can even prevent harvest. Blackberry nightshade is a particular weed problem in crops destined for human consumption as the berries of the weed can stain the seed coats of soybean.

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 allows the use of a range of herbicides to control the difficult-to-kill broadleaf weeds of soybean crops.

A weed-free fallow is essential for weed control and conservation of moisture. With conventional cultivation a weed-free seedbed is best achieved with an early working and follow-up cultivations to help 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 sowing and follow-up later with a post-emergent grass and/or broadleaf herbicide. A double-knock strategy that involves the application of a systemic herbicide followed by a contact herbicide with a different mode of action will reduce weed seed set and delay the development of herbicide resistance.

Development of a dense canopy 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.

Development of a dense canopy is encouraged by:

- a good seedbed with adequate moisture, good seed-soil contact and even crop establishment,
- the use of high germination/high vigour seed, along with adequate fertiliser,
- sowing the recommended soybean variety on time.

Sowing 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 sowing in narrow rows. The effects of row spacing on the presence or absence of weeds on soybean yield are shown in Table 7.

Table 7. The effect of row spacing in the presence or absence of weeds, on soybean yield (Felton 1976).

<table>
<thead>
<tr>
<th>Row spacing (cm)</th>
<th>Soybean yield (kg/ha)</th>
<th>Reduction in yield %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>– weeds</td>
<td>+ weeds</td>
</tr>
<tr>
<td>25</td>
<td>3084</td>
<td>3065</td>
</tr>
<tr>
<td>50</td>
<td>3018</td>
<td>2419</td>
</tr>
<tr>
<td>75</td>
<td>3078</td>
<td>2288</td>
</tr>
<tr>
<td>100</td>
<td>2964</td>
<td>1861</td>
</tr>
</tbody>
</table>

Where weeds are likely there are distinct advantages of growing soybeans at the higher range of the recommended plant densities and reducing the row spacing. However, increasing plant population beyond the recommended range is not a sensible strategy for weed management and is likely to 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 2.
Weed competition is greater in wide row crops, where control has been delayed. In narrow row crops, any delay in herbicide application may result in poor coverage of the target weed. Wide rows allow inter-row cultivation and low cost band spraying of rows.

Establishing the targeted plant population will achieve maximum crop competition with weeds, and avoid gaps in the established crop which allow weeds to flourish.

Soybeans are most sensitive to weed competition in the first four to seven 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.

Herbicides registered for weed control in soybeans are shown in Table 8.

**Pre-emergent herbicides**

Under conventional cultivation, with a good 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).

Metolachlor products such as Dual Gold® are best 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 prior to planting or 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 spraying to thoroughly wet the top 3–4 cm of soil.

Some broadleaf weeds such as nut grass and barnyard grass can be controlled with a pre-emergence application of Spinnaker® 700 WDG herbicide, surface applied immediately after planting. To activate Spinnaker®, rain is required prior to weed emergence to wet the soil to a depth of 5 cm.

**Post-emergent herbicides**

Grasses and broadleaf weeds can also be controlled post-emergence, preferably in the fourth week after emergence. A delayed spray may result in greater yield loss through reduced coverage of the weed by herbicides. Best results are obtained on weeds less than four leaf stage.

Broadleaf weeds may be controlled post-emergence with Spinnaker®, Basagran® or Blazer®. Mixtures of Basagran® and Blazer® are permitted.

Raptor® herbicide is a post-emergent herbicide for the control of certain annual grass and broadleaf weeds when applied at early post-emergence. Raptor® has a shorter plantback interval than Spinnaker®.

Post-emergent grass herbicides are most effective on actively growing grasses at the three to five leaf stage, before tillering commences.

Table 8 includes herbicides which are currently registered or permitted for use in NSW. Further information on selecting herbicides for specific weed control is available in the NSW DPI publication, *Weed control in summer crops* 2012–13. www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/publications/summer

Always read the label directions before using any agricultural chemicals.

**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 with the use of inter-row cultivators, hooded (shielded) sprayers, and knockdown herbicides. Knockdown herbicides are applied between the rows of soybeans to achieve cost-effective weed control. There is a range of selective herbicides also available for broadcast applications. Early weed control ensures that weeds can be controlled before they get too big.

**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 primarily because of the ability to apply higher water rates and the boom is closer to the weed target.

- Read the herbicide label carefully for details on optimum application methods and optimum conditions for spraying.

- Be aware that weeds can become resistant to herbicides if they are not used as recommended and as part of an overall weed management strategy. 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 of the more common and important diseases of soybean 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, although it has been recorded throughout the North Coast of NSW.

**Symptoms**

The most striking symptom is the blighting of the leaves. Large irregular grey to brown spots with a yellow margin develop on the leaves. The centre of these spots may 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. Disease development and spread is favoured by warm wet weather and poor ventilation in crops.
**Management**

Control is by using seed from disease-free crops, rotation with non-host crops, burning or burying trash, growing well ventilated soybean crops and minimising spread of infected material on boots, clothing and machinery. Iprodione products are registered for the control of 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.

**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 external surface of the stem, by peeling back under the bark an orange – caramel discoloration can be seen. Once dead, the surface of the lower stem and taproot eventually turns an ashen grey colour with charcoal grey coloured flecks also developing in stem tissue.

**Conditions favouring development**

Infection occurs when seedlings are actively growing but symptoms may 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**

Regular irrigation of the crop to avoid moisture stress where possible and rotation 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.

**Damping-off (Pythium spp.)**

**Symptoms**

Pythium is a water mould that infects roots of seedlings under wet soil conditions causing damping-off. This pathogen is common in soybean growing regions.

**Conditions favouring development**

Cool seedbed temperatures (below 18°C), wet soils and sowing too deep places establishment at risk due to infection by Pythium.

---

**Table 8. Herbicides registered for use in soybean.**

<table>
<thead>
<tr>
<th>Herbicide (active)</th>
<th>Example product</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,4-D ipa*</td>
<td>Surpass®</td>
<td>I</td>
</tr>
<tr>
<td>dicamba</td>
<td>Cadence®</td>
<td>I</td>
</tr>
<tr>
<td>tribenuron-methyl</td>
<td>Express®</td>
<td>B</td>
</tr>
<tr>
<td>trifluralin</td>
<td>TriflurX®</td>
<td>D</td>
</tr>
<tr>
<td>pendimethalin</td>
<td>Rifle®</td>
<td>D</td>
</tr>
<tr>
<td>metribuzin</td>
<td>Sencor®</td>
<td>C</td>
</tr>
<tr>
<td>metolachlor</td>
<td>Bouncer®</td>
<td>K</td>
</tr>
<tr>
<td>S-metolachlor</td>
<td>Dual®Gold</td>
<td>K</td>
</tr>
<tr>
<td>flumetsulam</td>
<td>Broadstrike®</td>
<td>B</td>
</tr>
<tr>
<td>imazethapyr</td>
<td>Spinnaker®</td>
<td>B</td>
</tr>
<tr>
<td>imazamox</td>
<td>Raptor®</td>
<td>B</td>
</tr>
<tr>
<td>glyphosate</td>
<td>Roundup® Attack</td>
<td>M</td>
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<tr>
<td>parquat</td>
<td>Gramoxone®</td>
<td>L</td>
</tr>
<tr>
<td>parquat + diquat</td>
<td>Spray.Seed®</td>
<td>L</td>
</tr>
<tr>
<td>acifluorfen</td>
<td>Blazer®</td>
<td>G</td>
</tr>
<tr>
<td>bentzone</td>
<td>Basagran®</td>
<td>C</td>
</tr>
<tr>
<td>butoxydim</td>
<td>Factor®</td>
<td>A</td>
</tr>
<tr>
<td>clethodim</td>
<td>Status®</td>
<td>A</td>
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<tr>
<td>haloxyfop-r</td>
<td>Verdict®</td>
<td>A</td>
</tr>
<tr>
<td>fluazifop-p</td>
<td>Fusilade®</td>
<td>A</td>
</tr>
<tr>
<td>sethoxydim</td>
<td>Sertin®</td>
<td>A</td>
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<tr>
<td>quinalofop-P</td>
<td>Targa®</td>
<td>A</td>
</tr>
<tr>
<td>diquat</td>
<td>Reglone®</td>
<td>L</td>
</tr>
</tbody>
</table>

* Use of 2,4-D HVE formulations is restricted. See the APVMA website for full details.

**Soybean Use Pattern**

<table>
<thead>
<tr>
<th></th>
<th>pre-plant</th>
<th>post-plant</th>
<th>post-emergent</th>
<th>pre-harvest crop desiccation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**Residual activity – check plant backs**

**Knockdown activity**
Management
Control is by sowing 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 stages of growth. Growers should be aware of their paddock susceptibility and implement management strategies that minimise losses.

In the irrigated soybean production regions of southern NSW and northern Victoria, this disease has become a major problem with seven new races found since 2000.

Seventeen races of *Phytophthora sojae* have been recorded in commercial soybean crops in Australia to date.

Race 1. Prior to 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 at Gunnedah, where one grower suffered some losses, 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 very isolated and the impact of these races, if any is being monitored.

However, the increasing number of races in those areas serves as a reminder that *Phytophthora* deserves constant attention.

A native *Phytophthora* species (*Phytophthora macrochlamydospora*) has also been recorded on the North Coast of NSW. It infects native legumes but generally has low virulence to soybeans.

**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 discolouration. Dead plants are usually found in continuous sections of rows.

**Conditions favouring development**

Disease development is favoured by poorly drained soils, warm temperatures and wet weather; either through excessive irrigation or rainfall.

**Management**

Control is achieved through growing tolerant varieties in well-drained fields, practising crop rotation and preventing the introduction of the disease 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 soybeans 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 3). The Australian Soybean Breeding Program is breeding in resistance genes to counteract the development of new races of the disease.

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 even 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 with their agronomist to have the race(s) identified and to develop a control strategy. This will allow incidences of disease to be monitored and will also assist in the early detection of changes in race patterns.

**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**

The disease becomes noticeable late in the season, causing premature yellowing of the top of the plant and early maturation of pods. 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 of seed quality when harvest is delayed by wet weather. The seedcoat may 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.

**Powdery mildew (Erysiphe diffusa)**

Powdery mildew developed in many crops throughout northern NSW and southern Queensland in the mild and wet 2012–2013 season. 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. Difficulties occur at harvest as infected leaves remain attached to the plant and infected crops ripen unevenly.
Symptoms
Areas of white powdery fungal growth develop on the leaves. Spores, which develop on the white powdery growth, can be spread many kilometres by wind. Affected plants do not ripen as normal, and as leaves become covered by fungal growth they cannot function normally, reducing grain fill.

Powdery mildew should not be confused with downy mildew (caused by the fungus *Peronospora manshurica*), which produces pale yellow blottches on the upper leaf surface with small areas of downy, pale grey fungal growth on the underside of the leaf. Downy mildew is common and widespread in soybean crops in Australia, particularly in coastal production areas and during mild, wet conditions. Yield loss from downy mildew is considered insignificant.

**Conditions favouring development**
The disease is most serious in mild, wet summers such as those of 2011–2012 and 2012–2013. Anecdotal evidence suggests that widespread development of this disease in eastern Australia was last seen in the mid 1970’s when similar rainfall patterns occurred. Growth of this fungus is favoured by mild (18–24°C) and wet conditions when photosynthesis and transpiration in the soybean plant are reduced. Disease development stops at 30°C.

**Management**
The use of resistant varieties, including Moonbi, Richmond and Hayman is recommended in areas where this disease is known to occur. The pathogen likely survives from season to season on volunteer soybean plants or alternative hosts, but little is known about the host range of this fungus. This fungus can also infect bean, mungbean, pea, cowpea, some wild species of Glycine as well as some non-leguminous plants. Folicur® 430 SC (tebuconazole) is available under permit PER14645 (expires 30-06-2016) for control of powdery mildew in soybean.

**Purple seed stain (Cercospora kikuchii)**
Purple seed stain is caused by a fungus.

**Symptoms**
The disease causes a characteristic pink to dark purple discoloration of the seed and sometimes cracking of the seed coat. Seeds, pods, stems and leaves can also be infected (Cercospora blight and leaf spot). Leaf infections are characterised by small dark red to 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 usually occur 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 matter, 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.

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**Rhizoctonia seedling blight (Rhizoctonia spp.)**
Rhizoctonia seedling blight is caused by a soil-inhabiting fungus. There is also a stem canker caused by a fungus (*Rhizoctonia* spp.).

**Symptoms**
Sunken, brick-red areas on the lower stem and roots. The lesions may extend up the stem. Stem canker is most evident during pod filling.

Some plants may die, while others remain stunted but may 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 proceeds at a slow rate.

**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 from flowering to early pod fill stage. Affected plants are characteristically bright yellow and stand out clearly in the crop. Closer examination will reveal 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 and is favoured by extended periods of plant surface wetness, moist soil, humid conditions in the crop canopy, and moderate temperatures (12–24°C). Later flowering and dense crops are more subject to infection, particularly where lodging has occurred 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, use of disease-free seed, selection of varieties with tolerance to Sclerotinia, planting by direct drilling, establishing well ventilated crops, and avoiding lodging. The varieties Zeus and Manta have useful tolerance to Sclerotinia.

**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.

**Symptoms**
Grey-brown pustules on the lower leaf surfaces release masses of minute rusty brown coloured spores, which can be spread by
air and then germinate on leaves. Pod formation, seed size and yield are affected.

**Conditions favouring development**

This disease is favoured by humid conditions and temperatures between 22–28°C. Build-up and spread of the fungus usually occurs 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 development of this disease and significant yield losses were recorded, particularly in late planted crops. On the positive side, rust infections that occur late in the crop can assist in leaf drop, hastening harvest and reducing the risk of damage to grain from wet weather.

**Management**

Until severe outbreaks occurred 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 senescing. However, when conditions of continual leaf wetness and maximum temperatures below 28°C are experienced earlier in the season, a leaf rust outbreak is possible and severe yield loss can result. If the disease develops in the crop prior to mid pod fill and control measures are not taken, green leaf area is rapidly lost and seed is not able to fill. Yield losses of up to 1 t/ha can result. In affected crops seed size can typically be reduced by up to 20%.

The disease tends to develop on the lower leaves first. Early detection of the disease, followed by the application of fungicides will halt development and protect green leaves and grain yield. Folicur® 430 SC (tebuconazole) is available under permit PER14413 expires 30-06-2016 and can help to minimise rust damage and protect the green leaf required to fill pods if applied early and correctly. Rust resistant breeding lines have been identified by the Australian Soybean Breeding Program and are being used to develop new varieties, particularly for coastal regions. Current commercial varieties do not have resistance to the rust pathogen. Refer to the GRDC Factsheet on managing soybean leaf rust for more information (see link at the end of this chapter).

Other diseases that have been recorded in soybean crops in Australia but are thought to have little 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 (Colletotrichum), and downy mildew (Peronospora manshurica). There are soybean varieties with tolerance to bacterial blight and downy mildew.

**Insect pests**

**Integrated pest management (IPM)**

IPM is a term used to describe the modern approach to insect control whereby many strategies are integrated to minimise pesticide use and to reduce deleterious effects on the environment, whilst maintaining profitability (yield and quality). It aims to maximise and use the controlling influence of beneficial insects and to utilise pest-specific agents, such as viruses and fungal sprays, to control the pest species.

IPM does not preclude the use of chemical methods of pest management, rather it encourages the decision to use chemical sprays to be taken in consideration of other impacts and with full understanding of which pest and beneficial insect species are present and the stage of crop development.

All soybean growers should consider adopting IPM practices in soybean cropping as soybean is an ideal host crop for a wide range of beneficial insects that predate on pest insect species. It is not wise to consider the control of one pest in isolation, as this can easily lead to increasing the population of another pest through a reduction in beneficial insects that may be keeping other pests in check. The concept of IPM is extremely important when dealing with pests such as silverleaf whitelly, mites and aphids as these pests can be flared easily when broad spectrum pesticides are used in the crop.

**Non-chemical methods for insect pest management**

The range of commercially available non-chemical methods for insect pest management is increasing in Australia. Whilst producers of organic crops are already familiar with many of these options, they are becoming increasingly sought after in ‘conventional’ soybean production. Many of the developments in insect pest control aim to target the pest species whilst minimising the non-target impacts of the treatment, in particular to beneficial insect species in the crop.

Non-chemical practices include monitoring levels of both the pest and beneficial insects and the management (including release) of parasites, predators and biological agents of insect and mite pests. Sequential flowering of trap crops and the release and management of Trichogramma wasp and other agents can mitigate *Helicoverpa* populations. Knowledge of the ecology and life cycles of pest species 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 an understanding of 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 zea* (e.g. ViVus® Max) for controlling *Helicoverpa* caterpillars. No products are registered or permitted for green vegetable bug control in organic soybean production. Some control of green vegetable bugs may be gained by three introduced parasitic Tachinid flies of the genus Trichopoda.

**Monitor and identify insects in the crop**

No season is identical in respect to the development of insect populations in crops. Different insects reach different population levels each season and may not appear at all in some seasons. The range of factors for this are not completely understood. Regular checking of the crop is crucial to understand the changing populations of insects that develop throughout the season, to become familiar with pest management thresholds, and to enable early detection and identification of new pests before significant damage occurs.
It is strongly recommended that growers become familiar with the few 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 and ants. These insects cause no economic harm to the soybean crop but rather bring benefits as they 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* by Brier et al. (2012), the new IPM website for grains [http://ipmguidelinesforgrains.com.au](http://ipmguidelinesforgrains.com.au) and the Cotton CRC Pest and Beneficial Insect Guide (available on-line at [www.cottoncrc.org.au/industry/Publications/Pests_and_Beneficials/Cotton_Insect_Pest_and_Beneficial_Guide](http://www.cottoncrc.org.au/industry/Publications/Pests_and_Beneficials/Cotton_Insect_Pest_and_Beneficial_Guide)) provide a wealth of photographs and information to assist 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 lower insect damage thresholds in grain for these markets.

Check crops every week prior to flowering and once every three days from flowering until pods turn yellow. 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 top of the crop canopy.

Before flowering soybeans can tolerate up to 33% loss of leaf area without any yield penalties. However, once flowering commences soybean is less tolerant of leaf loss and damage can occur to growing points, flowers and pods. Loss of growing points can dramatically restrict plant growth and reduce yield potential. This can often occur well before visual damage can be seen. Leaf-feeding pests such as Helicoverpa, soybean moth, soybean looper caterpillar and grass blue butterfly are most likely to cause this damage.

The incidence of insect infestation 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 they were not present in the previous year.

All growers need to be aware of the withholding period (WHP) as specified on the insecticide product label. Harvest WHP for insecticides can vary from 2 to 28 days prior to harvest, depending on product choice. This may preclude certain products from use at a critical stage of crop management for insect control. Further information on selecting pesticides for specific insect control is available in the NSW DPI publication, *Insect and mite control in field crops 2013*. Always read the label directions before using any agricultural chemicals.

Some of the more common and economically important insect pests found in soybean crops in NSW is given below and summarised in Table 9. Thresholds are based on the beat sheet crop sampling technique and expressed in pests/m².

### Black and Brown cutworm
*(*Agrostis epsilon 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 first sign of damage.

**Management**

Inspect crops late evening or night for the caterpillars feeding. During the day they remain hidden in the soil. Treat late in the afternoon.

### Grass blue butterfly
*(*Zizina otis labradus*)

**Damage**

The caterpillars eat into the leaves, growing points and even stems on plants. 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 impact on yield as low-set pods are more difficult to harvest. Infestations can develop suddenly during dry spells and damage may 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.

### Heliothis caterpillars
*(*Helicoverpa spp.*)*

**Damage**

The caterpillars feed on leaves and growing points. They also feed on developing flowers, pods and seeds.

**Threshold**

Vegetative soybeans: 6 larvae/m². Note: this new economic threshold (Brier et al., 2012) replaces the previous 33% defoliation threshold and/or 25% terminal loss (tipping) threshold. The new threshold is based on the maximum number of larvae that can be tolerated before there is an economic reduction in yield. Lower threshold in early vegetative crops or where terminal loss exceeds 25%.

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 per 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 per m².

**Management**

Target larvae from 5 to 7 mm for best results (size dependent on product choice). During the vegetative stage, biopesticides such as *Helicoverpa nucleopolyhedrovirus* (NPV) are preferred to chemical insecticides. The use of ‘soft’ chemicals helps conserve beneficial insects for the more susceptible reproductive stages, and avoids flaring of other pests such as silverleaf whitefly and mites.
### Table 9. Insect pests of soybean.

<table>
<thead>
<tr>
<th>Pest</th>
<th>Comments</th>
<th>Threshold for action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seedling Pests</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cutworms</td>
<td>Sprays late afternoon or evening. Small uniform seedling losses of up to 15% can be tolerated for early sown crops.</td>
<td></td>
</tr>
<tr>
<td>White fringed weevil</td>
<td>Larvae eat roots. Adults can defoliate seedlings.</td>
<td>Sporadic occurrence. No threshold determined.</td>
</tr>
<tr>
<td><strong>Foliage feeding caterpillars</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cluster caterpillar</td>
<td>A sporadic foliage feeder.</td>
<td>Vegetative threshold: 33% defoliation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Budding to podding threshold: 3 larvae/m²</td>
</tr>
<tr>
<td>Helicoverpa spp. ('heliothis')</td>
<td>Damage foliage, flower buds, flowers and pods. Vegetative threshold: 8 larvae/m² (NB. replaces the previous 33% defoliation threshold).</td>
<td></td>
</tr>
<tr>
<td>Loopers</td>
<td>Feed only on foliage.</td>
<td>Vegetative threshold: 33% defoliation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Budding to podding threshold: 15–20% defoliation</td>
</tr>
<tr>
<td>Soybean moth larvae</td>
<td>Blister, roll and web the leaves — plague numbers can build-up in dry years.</td>
<td>Based on defoliation:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 33% pre-flowering</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 15% flowering — early pod fill</td>
</tr>
<tr>
<td><strong>Pod feeders</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helicoverpa spp. ('heliothis')</td>
<td>A closed canopy crop is less favoured by egg laying Helicoverpa moths. Eggs laid at the top of plants suffer higher levels of mortality.</td>
<td>Budding to late pod fill: 1–3 larvae/m², based on yield loss model. About 2/m² pod feeding caterpillars during pod filling on the north coast. In the Riverina, &gt; 3 per m² for human consumption and &gt; 6 per m² for crushing or stockfeed.</td>
</tr>
<tr>
<td><strong>Pod-sucking bugs and other sap-suckers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green vegetable bug (GVB), brown bean bug, red-banded shield bug, brown shield bug</td>
<td>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 up until pods are too hard to penetrate. Hence bug thresholds are based on seed quality impact, not yield loss.</td>
<td>For calculating GVB thresholds in individual soybean crops refer to the on-line calculator at The Beatsheet at: <a href="http://thebeatsheet.com.au/economic-threshold-calculators">http://thebeatsheet.com.au/economic-threshold-calculators</a> General thresholds are based on GVB Adult Equivalents per metre² as follows: For green vegetable bug (GVB) 0.33 GVB/m² for human consumption beans 1.0 per m² for crushing or non edible beans For large and small brown bean bug (= 1.0 GVB) 0.33 per m² for human consumption 1.0 per m² for crushing For red-banded shield bug (= 0.75 GVB) 0.44 per m² for human consumption 1.3 per m² for crushing For brown shield bug (= 0.2 GVB) 1.7 per m² for human consumption 5.7 per m² for crushing</td>
</tr>
<tr>
<td>Silverleaf whitefly (SLW)</td>
<td>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.</td>
<td>There are no pesticides registered for silverleaf whitefly in soybeans. Conserve beneficial insects during the crops vegetative stage and use ‘soft’ insecticides during the reproductive stage</td>
</tr>
<tr>
<td>Spider mites</td>
<td>Piercing and sap-sucking pests. Check under surface of leaf. Can become troublesome in dry weather or after use of broad-spectrum insecticide sprays.</td>
<td>During the flowering to pod fill stage treatment may be warranted if there is an average of 5 mites/cm² on the leaf undersurface, provided natural enemies are not active.</td>
</tr>
<tr>
<td><strong>Stem-borers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lucerne crown-borer</td>
<td>Larvae bore down through the pith of the main stem. Near the base of the stem 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.</td>
<td>No action threshold has been determined. Control is by deep burial of crop residue; by crop rotation and eradication of Sesbania pea, Budda pea and Rattlepod weeds. Monitor the presence of adult beetles.</td>
</tr>
<tr>
<td>Soybean Stemfly</td>
<td>Larvae of this small (2mm long) black fly tunnel in the tissues of petioles and stems disrupting translocation of water in the plant. This tropical pest is favoured by extreme wet weather as occurred in the summers of 2011-2012 and 2012-2013.</td>
<td>No action threshold has been determined for this pest. Control of legume weeds is recommended. Control of legume weeds and IPM strategies to conserve natural predators is recommended.</td>
</tr>
</tbody>
</table>

Looper caterpillars including soybean (Thysanoplusia orichalcea) and tobacco (Chrysodeixis argentifera)

Damage
Loopers predominantly eat leaves and consequently higher numbers can be tolerated in soybean crops than Helicoverpa, which feed on leaves, flowers and pods. Loopers move in a looping motion and can be distinguished from Helicoverpa larvae by their 2 pairs of ventral prolegs (‘back legs’) compared to 4 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
The larval tunnel inside the stems of soybean plants. The larvae once hatched tunnel down stems and damage leaf petioles.

Threshold
No established thresholds.

Management
There are no control methods for plants which have become infested. Harvest early at the highest moisture content possible, then cultivate to 50 mm to bury the stems, which will reduce larval survival and adult emergence in the following spring. Rotate crops.

Lucerne seed-web moth (Etiella behrii)

Damage
The caterpillars attack the crop from vegetative stages through to flowering killing growing points. They tunnel into stems and pods causing small pods to shrivel and die. The caterpillars develop inside larger pods, eating the grain. This pest appears more prevalent in hot dry seasons and can cause significant damage to young, moisture stressed plants.

Threshold
None established.

Management
There are no registered pesticides for control. However, minor use permits have been secured for chlorantraniliprole (Altacor®) @ 70g/ha to control etiella (and bean podborer) in soybeans and mungbeans (PER14592).

Pod sucking bugs (PSB)

Green vegetable bug, red-banded shield bug, small and large brown bean bugs and the brown shield bug commonly occur in soybean crops throughout NSW. Collectively referred to as pod sucking bugs (PSB) they cause damage from early pod development by piercing the pod and damaging the seed as it develops inside the pods. Damaged seed fail to develop properly and can result in significant downgrading of quality. The threshold for damaged seed for the edible market is 3%. With this in mind, the action thresholds for PSB have been set at 2% to allow for another 1% of non-PSB damage in grain destined for the higher value edible markets (Brier et al., 2012).

Green vegetable bug (Nezara viridula)

Green vegetable bug (GVB) is a major pest of soybean.

Damage
Green vegetable bugs can severely reduce both yield and quality by feeding on young pods and developing seed. They are by far the most damaging of the sucking pests, due to their abundance, widespread distribution, rate of damage and rate of reproduction.

All pod-sucking bugs cause shrivelled and distorted seed, and can severely reduce yield and seed quality. Late bug damage reduces seed quality but not yield. For this reason, bug thresholds are based on seed quality impact, not yield loss, as only 2% seed damage is tolerable in soybean grain for edible markets.

Threshold
For updated information and charts to calculate GVB action thresholds for particular crop sizes and growth stages refer to the publication Good Bug Bad Bug?: An identification guide for pest and beneficial insects in summer pulses, soybeans, peanuts and chickpeas by Brier et al. (2012), which is available from GRDC, QDAFF or Soy Australia. Using the charts in this publication for example, for a crop of 1500 seeds/m², the action threshold is 0.38 GVBAEQ/m² for edible standard, expressed as green vegetable bug adult equivalents (GVBAEQ). This threshold is based on a rate of damage of approximately 80 harvestable seeds per adult bug per square metre (Brier et al., 2012).

An on-line threshold calculator has also been developed by the QDAFF entomology group and is available through The Beatsheet at: http://thebeatsheet.com.au/economic-threshold-calculators

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 as well as the 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 is in development. Generally, the GVB action thresholds for the crushing market are roughly twice that of those for the edible market.

Management
Examine crops twice per week from just prior to flowering through until harvest. Control at or above threshold numbers. Brier et al. (2012) recommend not spraying young nymphs of GVB 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.
All pod-sucking bugs cause shrivelled and distorted seed, and can severely reduce yield and seed quality, especially when damage occurs during the mid to late pod-filling stage.

**Threshold**

0.33 GVB/m² for human consumption and 1.0 GVB/m² for crushing, expressed as green vegetable bug adult equivalents (GVBAEQ).

**Management**

Examine crops twice per week from just prior to flowering through until harvest. Control 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. Whilst 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) by Brier *et al.* (2012). All pod-sucking bugs cause shrivelled and distorted seed, and can severely reduce yield and seed quality, especially when damage occurs during the mid to late pod-filling stage.

**Threshold**

0.44 GVB/m² for human consumption; 1.3 GVB/m² for crushing; expressed as green vegetable bug adult equivalents (GVBAEQ).

**Management**

Examine crops twice per week from just prior to flowering through until harvest. Control at or above threshold numbers. Brier *et al.* (2012) found that deltamethrin alone gave little to no control of Red-banded shield bug, however, up to 66% control was achieved by the addition of a 0.5% salt (NaCl) adjuvant to the deltamethrin spray.

**Brown shield bug (Dictyotus caenosus)**

**Damage**

Brown shield bugs are considered to be only 20% as damaging as GVB. The damage potentials are calculated as 0.2 of GVB (i.e. 1 BSB = 0.2 GVB) by Brier *et al.* (2012). All pod-sucking bugs cause shrivelled and distorted seed, and can severely reduce yield and seed quality, especially when damage occurs during the mid to late pod-filling stage.

**Threshold**

1.7 GVB/m² for human consumption; 5.7 GVB/m² for crushing; expressed as green vegetable bug adult equivalents (GVBAEQ).

**Management**

Examine crops twice per week from just prior to flowering through until harvest. Control at or above threshold numbers. Brier *et al.* (2012) found that adding common salt (NaCl) as an adjuvant to a deltamethrin spray achieved greater control of brown shield bug than using deltamethrin alone. The rate of salt used was 0.5%.

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**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 of 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 nymphs of the Silverleaf whitefly are small (1.5 mm long) and 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 by sucking sap from the plant and damaging green leaf tissue. SLW also secretes ‘honey dew’, 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**

Since its introduction to Australia, the first strain of whitefly (*Bemisia tabaci* B-biotype) has spread into many cropping regions. It presents particular problems for control since it is resistant to many common pesticides and can develop resistance to new synthetic chemicals very quickly in part to its rapid breeding cycle. Population explosions (billions of individuals per hectare of crop) have resulted where inappropriate insect management has been followed. For example, where ‘hard’ broad spectrum pesticide sprays have been used early in the crop to control other pests this subsequently flares the SLW population. These flares are caused primarily because ‘hard’ broad spectrum insecticides kill many of the natural predators that keep SLW numbers in check.

The primary management tool for SLW is the adoption of Integrated Pest Management (IPM) practices to maximise beneficial insect populations during the crop and between seasons. Other management strategies include weed control to remove host plants especially during winter (e.g. maintenance of clean fallows), awareness of control strategies in other broad acre host crops (e.g. cotton) and planting unsprayed refuges that allow beneficial insects to build up. Currently there are no pesticides registered for use against SLW in soybean. Spirotetramat (Movento® 240 SC) is permitted for use in soybean (APVMA Minor Use Permit 13850, expires June 2015). It is considered to be a ‘soft’ selective pesticide but it is a relatively expensive option and is only recommended to suppress low populations of SLW.

Fortunately there are many naturally occurring insects that predate and parasitise the nymphal stages of SLW. These include several microscopic wasp species (*Encarsia* spp. and *Eretmocerus* spp.), ladybird beetles, lacewing larvae and big-eyed bugs. Maximising the populations of these beneficial insects in a crop
Soybean moth (Aproaerema simplexella)

Soybean moth is a very common pest of soybeans but is usually only present in very low numbers. Control will rarely be required.

Damage
Soybean moth larvae initially feed inside leaves for about four days (i.e. 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 fold together to form cocoons for pupation. In low numbers the larvae only cause cosmetic damage that most crops will readily grow out of. However, extremely high populations can graze on the surface of pods, after they have eaten all the leaves, causing severe defoliation that retards plant development. Infestations are favoured by hot, dry weather, with crops under severe moisture stress most at risk.

Threshold
Based on defoliation, i.e. 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, treatment of the young caterpillar must occur before it rolls the leaflet together. Abamectin (e.g. Wizard® 18) is permitted for use against soybean moth (APVMA Minor Use Permit 14288, expires June 2017).

Soybean Stemfly (Melanogromyza sojae)

Damage
Activity of this fly is increased by high rainfall, warm temperatures and high humidity. 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 2 days and the larvae (white coloured maggots about 4 mm long) cause damage by tunnelling in the pith tissues of the petioles and stems. 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 coloration and can be easily seen on stems and petioles of affected plants.

Threshold
No thresholds have been developed for this pest.

Management
A small parasitic wasp was confirmed parasitising the larvae of soybean stemfly in outbreaks in NSW in 2013. Growers are encouraged to preserve beneficial insects via IPM strategies. As some legume weeds (e.g. Sesbania and Buddah pea) and volunteer soybean plants can host this pest, weed control is recommended. Presently no chemical control measures registered for use against this pest in soybean. For more information go to www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-107-NovDec-2013/Alert-for-new-stem-fly-outbreak

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 discolor and eventually die. They hasten plant maturity, reducing yield and seed size. Mites can be flared by the use of broad spectrum, non-selective pesticides.

Threshold
Five mites per cm² on the leaf undersurface.

Management
Control when thresholds are reached, particularly to protect green leaf tissue during flowering to pod fill stages.

Harvesting and desiccation

Harvest-aid herbicides
Consider desiccation if you have a weed problem, intensive insect pressure or for edible quality in varieties that may have green stems and retain some leaves. Desiccation will result in easier harvesting and better quality grain.

- Reglone® (a.i. diquat) is applied when 80% of pods are yellow/brown and seeds are ripe, yellow and pliable. Harvest four to seven days after spraying.
- Roundup® Attack (a.i. glyphosate) 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.

Harvest
Harvest soybeans as early as possible to minimise harvest delays caused by wet weather. The problem of wet weather at maturity is more frequent in southern irrigation areas and in coastal NSW.

- Harvest at 15% moisture content – normally 10 days after physiological maturity, if seed is being kept for planting.
- 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 cheap insurance.
- 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.

Efforts in preparing an even paddock and eliminating obstructions such as stumps, large sticks and rocks will be repaid at harvest time, when ease of access of the header to the ripe pods is critical.

Sowing the correct variety at the optimum time for the region will also maximise harvest yield as the variety will set pods well above the ground and ripen in a timely manner.
Uniform, high plant populations assist in minimising harvest losses as the crop produces an even closed canopy. This in turn minimises weed development, assists the crop to stand up without lodging and to feed into the harvester more efficiently.

All these factors enable the cutter bar on the header to be set low enough to access as many pods as possible without picking up soil or other contaminants, which degrade the quality of the grain particularly where it is targeted at culinary or export markets.

Correct grain moisture

The optimum moisture level for storage of soybean grain is 11–12%. Because of the high risk of autumn rain on the North Coast of NSW, which weathers and degrades ripe seed, crops are usually harvested at 15–18% moisture content and then fan-forced 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 with increased shattering of the pod and seed splitting at harvest.

Grain receival standards applying to soybean can be obtained through Grain Trade Australia (formerly known as NACMA) at www.graintrade.org.au

Incorrect header settings result in grain losses. To minimise unnecessary losses of grain during harvest ensure that:

- the cutting height is low enough to gather low set pods into the header and to minimise the impact of the cutter bar higher up the plant, which increases pod shattering and grain loss;
- the correct header front is chosen for the crop height and topography. For example, a wide-front header may not be the best option if the crop is on very uneven or sloping land. A floating cutter bar, ‘flexi-front’ header, or narrow front may be needed to overcome variability in crop height, low pods or sloping ground;
- if using an open-front header with a pick-up reel, the correct positioning and reel speed is obtained. A pick-up reel is preferable to a ‘bat’ reel;
- the position of the reel is 30 cm forward of the cutter bar;
- the speed is set at 1.25 to 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 is only a small producer of soybeans by global standards with annual production of around 280 million tonnes. Production has declined in recent years largely due to the impacts of drought and floods. Globally, in excess of 217 million tonnes of soybeans are produced annually. The USA, Brazil and Argentina are key players in the production and export of soybeans and soybean products.

Australia is a net importer of soy based products, with this primarily driven by demand for meal. This is unlikely to change significantly in the short to medium term.

Soybean offers a number of marketing opportunities, but these will fall into two broad market end uses, namely crushing for oil and meal, and edible quality beans for human consumption. A potential emerging market is for biodiesel with a large crushing facility planned for Port Kembla. 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 encouraged to consider what particular benefits 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. Examples of gross margin calculations for soybean are available at the NSW DPI website: www.dpi.nsw.gov.au/agriculture/farm-business/budgets/summer-crops

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 buyers now provide fax and email services covering this information. Independent sources include newsletters and the ABARE Crop Report.

Growers should understand contracts, including the legal obligations and what is expected of both the buyer and the seller.

**Currency**

As Australia is an importer of all three products (oil, meal and beans) in the soy complex, the value of the Australian dollar plays a significant part in the value of Australian soybeans 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 soybeans lower. The reverse will support and raise the value of imports and consequently the value of Australian soybeans.

**Crushing market**

Soybeans are crushed to produce oil and meal. Soybeans are referred to as a ‘low oil’ seed as they are approximately 80% meal and 20% oil. In contrast, high oil seeds like canola and sunflowers are 60% meal and 40% oil.

The demand for soybeans is a derived demand, that is, it is derived from the demand for oil and meal. There is some use of whole beans to produce full fat meal.

Australia is a net importer of soybean products and thus, local soybean prices are based on import parity. Soybean meal is regularly imported from South and North America.

Whole soybeans for crushing are generally imported from North America. The volume of imports varies considerably from year to year depending on local production, price relativities of seed, oil and meal and the requirements of domestic crushers. Due to quarantine restrictions imported soybeans must be crushed at port locations.

**Meal**

Australian produced soy meal competes with imported meal (48% min. protein) from North and South America. The Australian intensive livestock industry has been growing rapidly and was estimated to consume in excess of 800,000 tonnes of protein meal in 2004–05. The sector uses a wide variety of protein meals from both local and imported sources. In recent years, imported meals have accounted for more than 50% of usage, with imported soy meal accounting for around 30%–40% of meal consumed.

Australian soy meal competes with imported meal with adjustment for quality differences i.e. imported soy meal generally trades at 48% and local meal at 44% or 46% depending on the processing method.

As soybeans are 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 recent years, much of the soy oil used in blended vegetable oils has been substituted by canola oil in Australia.

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 and there is increasing demand in both export and domestic markets. Premiums are usually paid over beans grown for crushing. Organically produced grain also attracts a premium. Varieties with a clear or light coloured hilum, high protein content and large seed size such as Moonbi, Richmond, Hayman, Cowrie, Bunya, Surf, Snowy, Djacal, Soya 791, and to a lesser extent A6785, currently supply the human consumption markets.

Growers should contact end-users and buyers when making variety choices.

Soybean is used in the manufacture of a wide range of products which include soy flour, soy milk, soy grits, tofu, tempeh, spreads, soup, confectionery and other Asian foods.

Human consumption markets generally prefer beans with good seed size (20–24 g/100 seeds or 4100–5000 seeds/kg), high protein and high germination percentages. Beans should be free from stains, soil, mould and damage to the seed coat. There is very low tolerance for admixture and dark hilum seeds. Seed grading is normally required.

There are no genetically modified (GM) soybeans grown in Australia and this presently benefits high value export markets for human consumption including Japan, Korea and Taiwan.

AOF publishes delivery standards for crushing and edible soybeans. A copy of the standards is generally available from marketers or from producer organisations. AOF makes their standards available to Grain Trade Australia (formerly NACMA) who publish standards for all crops. Grain Trade Australia has a producer package available for purchase which provides access to standards, contracts and dispute resolution.

**Further information**

**Useful websites**

- Australian Oilseeds Federation: www.australianoilseeds.com
- Australian Pesticides and Veterinary Medicines Authority: https://portal.apvma.gov.au/pubcris
- The Beat Sheet (an excellent on-line IPM resource produced by the QDAFF entomology research group): http://thebeatsheet.com.au
- Grain Trade Australia (previously National Agricultural Commodities Marketing Association Inc.): www.graintrade.org.au
- Grains Research and Development Corporation: www.grdc.com.au
- National Oilseed Processors Association: www.nopa.org
- NSW Department of Primary Industries: www.dpi.nsw.gov.au/agriculture/broadacre/summer-crops
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Sunflower
Loretta Serafin, Don McCaffery and Sue Thompson

Key management issues

- Determine the amount of stored water in the soil profile prior to sowing by soil coring or using a push probe. If there is less than 80 cm of wet soil (less than 135 mm plant available water), consider not sowing sunflowers.
- Use no-till for dryland crops as more soil water is stored than in cultivated fallows, increasing the probability of higher yields.
- Double cropping is an option in dryland areas, where there is a positive seasonal outlook and good starting soil water.
- Apply nitrogen fertiliser based on a nitrogen budget using your target yield, soil test results and plant available water at sowing. Previous crop yield and protein content can be used if soil test results are not available.
- 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 in the soil. Sunflowers are particularly sensitive to sulfonylurea (SU) herbicides.
- Select high yielding hybrids that have the desired traits for your growing conditions.
- Monitor and, if necessary, control insects especially wireworm at or prior to crop establishment and Rutherglen bug and heliothis from budding through seed fill. Assess the potential for mice and bird damage.
- Familiarise yourself with the main diseases of sunflower, their lifecycle and alternative plant hosts, to assist with rotation planning and to limit the impact of diseases.
- Do not sow too late as the risk of disease, particularly Sclerotinia, is higher in the cooler areas, e.g. south of Gunnedah.
- Crops sown in late January are more likely to be slow drying down. Be prepared to harvest at higher moisture contents and use aeration where necessary.

Brief crop description

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

Sunflowers are a good rotation crop, highly suited to sowing into standing cereal stubble. Sunflowers are most often sown after a long fallow following a winter cereal. Sunflowers are also suitable for use in a short fallow following sorghum, or as a double crop option provided the soil moisture profile is near full. Sunflowers do not leave behind much stubble following harvest so planting into paddocks with existing cereal stubble helps to prevent soil loss through erosion.

Sunflowers are grown for three main markets; monounsaturated and polyunsaturated oil, and the confectionary/birdseed market.

The main sunflower production region is in northern NSW between Quirindi and Moree. Smaller areas are grown under full irrigation in the southwest around Griffith and Hillston, mainly for seed production. Opportunity planting of sunflowers occurs mainly in the northwest of the state, west of the Newell Highway, and less frequently in the central west.

Paddock selection

Paddock history

Select paddocks that were previously sown to a rotation crop. Paddocks in long fallow from wheat or barley, or a short fallow following sorghum, are preferred.

Previous crop history in a paddock can impact on the likelihood of disease having a major impact on the current sunflower crop. For example, many broadleaf crops host Sclerotinia and can increase inoculum levels for the following sunflower crop (Refer to the disease section for more information).

Sowing sunflowers following a cereal is preferred as broadleaf weed control will usually have been carried out in the cereal crop and the fallow, thus reducing the weed seed bank.

Consider previously applied residual herbicides and their plant-back periods. Sunflowers can be affected by herbicides such as the sulfonylureas and atrazine.

Crops of monounsaturated hybrids should be isolated from other types of sunflower crops by about 80–100 metres to reduce the risk of cross pollination, which lowers the oleic acid content. Do not sow adjoining crops of monounsaturated and polyunsaturated sunflowers where flowering may coincide.

Soil management

Sunflowers are best suited to deep soils in a no-till system. No-till relies on effective weed control in the previous crop and fallow. Combined with stubble cover no-till improves moisture retention, leading to consistently higher yielding sunflower crops. No-till also provides a wider sowing window and stores more soil water by reducing runoff. This enables a shorter fallow with more efficient water use, less runoff and less erosion. However, no-till can encourage the build-up of mice compared to conventional cultivated paddocks and limits some broadleaf weed control options due to the inability to incorporate pre-emergent herbicides.
Be aware that stubble can aid survival of both sunflower and other crop disease pathogens. Familiarise yourself with the pathogens of sunflower as well as the crops in your rotational sequences.

**Soil moisture**

*Plant available water*

Sunflowers should not be sown unless the soil profile is wet to a depth of at least 80 cm (>135 mm plant available water) to minimise the risk of crop failure or uneconomic yields.

A soil corer or push probe can be used to determine how much starting soil water is in the profile. If soil coring is used, crop lower limits can be applied to determine the exact amount of available soil water. Final sunflower yield will still be a reflection of the starting soil water and ‘in-crop’ rainfall. Starting with a full profile of moisture minimises the risk of crop failure.

The amount of starting soil water also has an impact on management decisions such as row configuration, with skip row or wide row configurations sometimes used when starting soil water is less than 80 cm.

**Sowing time**

Sunflower is adapted to a wide range of sowing times. Sowing times are grouped into an early and a late sowing window. Aim to sow at the times shown in Table 1.

The early sowing or spring planting window commences 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 the northern region. The late planting window begins at the start of December and finishes at the end of January.

Sunflower is tolerant of light frosts in the early and late stages of growth, and of high temperatures; except during the critical stages of flowering and seed-filling.

For early sowings, the soil temperature at 10 cm depth should exceed 10–12°C at 8.00 am (Eastern Standard Time) and the period of heavy frosts should be over. While 10°C is the minimum, it is important to plant on rising soil temperatures. Sunflower establishment will be best when 7–10 days of favourable growing conditions follow immediately after planting. Extremes of heat or cold may result in patchy plant stands.

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

Polysaturated sunflowers (> 62% linoleic acid) are best suited to the late planting window (December–January) so that crops are filling seed in the cooler autumn months. If sown in spring the oil quality of polysaturated hybrids 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.

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

**Row spacing**

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

Research at Moree has shown sowing on a 100 cm solid plant or a single skip row spacing will achieve similar yields to 75 cm single skip. In contrast, sowing on 75 cm solid plant or single skip at Gunnedah; or 100 cm solid plant, will achieve similar yields.

Double skip or wide row (150 cm) spacing’s, while a sound risk management strategy, carry a yield penalty in the main sunflower growing regions.

Single skip row configurations are an option if there is limited stored soil moisture or when planting in marginal dryland environments e.g. Walgett although they usually incur a yield penalty. In these situations weed control is more critical and hybrid height should be considered to avoid lodging problems.

**Plant population**

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

Aim for a plant population based on the depth of wet soil at sowing, the likely ‘in-crop’ rainfall and growing conditions in your area, as shown in Table 2.

---

**Table 1. Suggested sowing times for sunflowers.**

<table>
<thead>
<tr>
<th>Region</th>
<th>Early plant</th>
<th>Late plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aug</td>
<td>Sep</td>
</tr>
<tr>
<td>1 2 3 4 1 2 3 4 1 2 3 4</td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>Goondiwindi, Moree, Narrabri</td>
<td>&lt;&lt;&lt;</td>
<td>&lt;&lt;&lt;</td>
</tr>
<tr>
<td>Gunnedah, Quirindi</td>
<td>&lt;&lt;&lt;</td>
<td>&lt;&lt;&lt;</td>
</tr>
<tr>
<td>Southern irrigation areas</td>
<td>&lt;&lt;&lt;</td>
<td>&lt;&lt;&lt;</td>
</tr>
</tbody>
</table>

< Earlier than ideal ★ Optimum sowing time ★ Later than ideal
Table 2. Target plant population guide (plants/m²).

<table>
<thead>
<tr>
<th></th>
<th>Polyunsaturated/</th>
<th>Confectionary/ Birdseed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dryland</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marginal</td>
<td>2–2.5</td>
<td>2</td>
</tr>
<tr>
<td>Favourable</td>
<td>2.5–3.5</td>
<td>2.5–3.5</td>
</tr>
<tr>
<td>Irrigation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limited</td>
<td>3.5–5.0</td>
<td>3.0–4.0</td>
</tr>
<tr>
<td>Full</td>
<td>5.0–7.0</td>
<td>3.5–4.5</td>
</tr>
</tbody>
</table>

Seed for sowing averages 15,000 seeds/kg but can vary from 10,000 to 22,000 seeds/kg, depending on seed size (Table 3). Always check the seed count on the bag. The minimum germination percentage is usually greater than 90% but check the percentage on the bag or consult with seed merchants.

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

Table 3. Approximate number of seeds/kg.

<table>
<thead>
<tr>
<th>ASA* seed sizes</th>
<th>Description</th>
<th>Seeds/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/7</td>
<td>Very small seed</td>
<td>18000–25000</td>
</tr>
<tr>
<td>7/8</td>
<td>Small seed</td>
<td>15000–22000</td>
</tr>
<tr>
<td>8/10</td>
<td>Medium seed</td>
<td>12000–16000</td>
</tr>
<tr>
<td>10/14</td>
<td>Large seed</td>
<td>10000–14000</td>
</tr>
<tr>
<td>14/18</td>
<td>Very large seed</td>
<td>8000–11000</td>
</tr>
</tbody>
</table>

* 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 establishment losses can range from 20–50%.

To determine the planting rate (kg/ha):

\[
\text{Target plant population/m}^2 \times 10,000 \\
\text{Seeds/kg} \times \text{germination } \% \times \text{establishment } \%
\]

Example calculation:

\[
3.5 \text{ (Required number of plants/m}^2) \times 10,000 \\
15,000 \text{ (Seeds/kg)} \times 0.93 \text{ (germination )} \times 0.75 \text{ (establishment )}
= 3.35 \text{ kg/ha}
\]

To determine the number of bags of seed required:

\[
\frac{\text{Planting rate (kg/ha)} \times \text{area (ha)}}{\text{bag weight (kg)}}
\]

Sowing depth and crop establishment

Sowing depth is dictated largely by available moisture, the planter, temperatures at sowing, and the soil type. Sowing depth may range from 2.5–7 cm, but most commonly is 3–5 cm.

Press wheels are essential for obtaining good seed-soil contact. Press wheel selection is also important to ensure cracking of soil down the seed row does not occur. Where this occurs, seed beds 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 sowing moisture is marginal or temperatures are hotter.

Seed used for sowing is often treated with insecticide to provide protection against soil-dwelling insects. A list of registered seed treatments and the insects controlled is included at the back of the guide.

Planting speed has an impact on establishment. Sowing too fast will cause seed bounce and result in uneven seeding depth; sowing too slow allows dry soil to fall in on top of the seed.

Hybrid characteristics

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

Select hybrids based on end use requirement, yielding ability (seed and oil), disease tolerance, head inclination, height and good agronomic type. Hybrids and their characteristics are described in Table 4. Additional information can be found in the section 'Diseases of sunflower'.

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 (see Table 5) but always try the hybrids on your farm and grow those that produce the best results for you.


<table>
<thead>
<tr>
<th>Company</th>
<th>Hybrid</th>
<th>Maturity</th>
<th>End use</th>
<th>Height</th>
<th>Head inclination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuseed</td>
<td>Ausigold 4</td>
<td>Medium–slow (early plant)</td>
<td>Mid oleic (suitable for dehulling)</td>
<td>Medium–tall</td>
<td>Pendulous</td>
</tr>
<tr>
<td></td>
<td>Ausistripe 14</td>
<td>Medium (late plant)</td>
<td>Confectionary/Birdseed</td>
<td>Medium–tall</td>
<td>Semi-erect</td>
</tr>
<tr>
<td></td>
<td>Ausigold 62</td>
<td>Medium</td>
<td>Monounsaturated</td>
<td>Medium</td>
<td>Semi-erect</td>
</tr>
<tr>
<td>Pacific Seeds</td>
<td>Hyoleic 41</td>
<td>Medium–slow</td>
<td>Monounsaturated</td>
<td>Medium–tall</td>
<td>Semi-pendulous</td>
</tr>
<tr>
<td></td>
<td>Sunbird 7</td>
<td>Medium</td>
<td>Confectionary/Birdseed</td>
<td>Medium–tall</td>
<td>Semi-pendulous</td>
</tr>
</tbody>
</table>
Generally the medium-slow maturing hybrids have the highest yield potential. Monounsaturated hybrids yield equal to or slightly less than the best polyunsaturated hybrids. However, monounsaturated hybrids usually have a higher oil percentage and attract a price premium.

Table 5. Dryland sunflower hybrid* performance across sites and seasons 2004–09.

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

* Shaded lines are commercially available in 2014–15.

Oil percentage

High oil percentages give growers a premium of 1.5% of price for each 1% of oil above 40% (use Table 5 as a guide to oil contents). Birdseed and confectionary hybrids such as Sunbird 7 have low relative oil percentages, as oil content is not a requirement for these end uses.

Maturity

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

Head inclination and stem curvature

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

Growth stages

The time taken for a sunflower plant to develop through the various growth stages is affected by planting time and temperature, but also photoperiod and soil moisture. The sowing location and hybrid maturity also have an effect on the length of the growing season. Table 6 shows average times for each of the growth stages for a crop planted at Gunnedah.

Table 6. Development times for a sunflower hybrid at Gunnedah.

<table>
<thead>
<tr>
<th>Crop Stage</th>
<th>Time for each stage (days) when planting in;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting to emergence</td>
<td>Early October</td>
</tr>
<tr>
<td>Emergence to head visible</td>
<td>8</td>
</tr>
<tr>
<td>Head visible to start of flowering</td>
<td>45</td>
</tr>
<tr>
<td>Flowering to Physiological Maturity (PM)</td>
<td>27</td>
</tr>
<tr>
<td>Stage length</td>
<td></td>
</tr>
<tr>
<td>Planting to start of flowering</td>
<td>80</td>
</tr>
<tr>
<td>Planting to PM; – slow maturity hybrid</td>
<td>120</td>
</tr>
<tr>
<td>– medium maturity hybrid</td>
<td>110</td>
</tr>
<tr>
<td>PM to harvest</td>
<td>20–30</td>
</tr>
</tbody>
</table>


Germination and emergence

The speed of emergence can vary but usually takes between 5 and 10 days, however it may be up to 30 days in certain situations. The speed of germination is dependent on soil temperature, moisture and oxygen.

The preferred soil temperature for planting is 10–12°C; however germination will occur as low as 4°C. Planting in cold conditions will result in a longer time for germination and establishment. At these temperatures the risk of insect damage or disease is higher. Planting into warmer soils results in quicker emergence but soil moisture around the seed will decline faster.

Sunflowers have 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.

Sunflowers are reasonably tolerant of frost at certain stages. Newly emerged seedlings are frost tolerant up until 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

Sunflowers can tolerate temperatures ranging from 8°C to mid to high 30°C’s during growth but grow best between 25°C to 28°C.
Leaf formation and development is initially controlled by sunlight, but 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 taproot which, as a general rule, is equivalent to or greater than the plant height in rooting depth. For example, when the plant has 8–10 leaves (~25 cm to 30 cm tall) the taproot is about 40 cm to 50 cm deep. The taproot reaches its maximum depth at flowering. Sunflowers taproot allows the crop to extract more water than sorghum or maize.

Wilting in the middle of the day in summer is common as sunflower does not have the ability to close the stomates in its leaves and reduce transpiration losses. However if plants do not recover at night, then moisture stress is occurring.

**Bud initiation to start of flowering**

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

During leaf development, the plant is responsive to day length, with photoperiod affecting the speed of development. This effect is reduced during the reproductive stages. The response to photoperiod also varies between hybrids.

The plant will begin developing the bud, and finally ray petals will become evident. At this stage the bud is usually at least 10 cm in diameter. The ray petals, which are the bright yellow petals which surround the head, will then begin to unfold prior to the commencement of flowering. (Note: For chemical control of powdery mildew, 5% ray floret emergence is the cut-off for application of TILT® 250EC – refer to the disease section.)

**Start of flowering to physiological maturity**

Once the ray petals are fully open, flowering will commence.

Sunflower heads turn to follow the sun during the day, referred to as heliotropism, which increases photosynthesis by 9%. This will cease at flowering, at which point most of the heads remain facing northeast.

The sunflower head consists of the yellow ray petals which are highly attractive to bees and other insects. The disc flowers which 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. Individual disc flowers complete flowering in 3 days, however between 1 and 4 rings of flowers open each day, usually over a period of 5 to 10 days. There are between 800 and 3,000 disc flowers per head, each of which is capable of producing 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 which remain upright after the end of flowering are more prone to sunburn. Many commercial varieties have semi-pendulous heads to avoid this.

Temperature at this stage is critical. High temperatures during flowering and seed-fill affect oil quality and quantity as well as reducing seed yield, while a frost will damage the flowers and reduce seed set.

Moisture stress is also important at two critical stages, head formation to the start of flowering (which affects seed yield), and grainfill 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 can also impact on seed set, as the pollen is washed off the heads preventing fertilisation.

At the end of flowering the ray petals will wilt and fall off; this is referred to as petal drop. The disc flowers will also fall off just prior to 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 the start of flowering.

At this point 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 if needed.

**Nutrition**

Sunflowers require adequate nutrition yet have a significantly lower requirement for several of the major nutrients when compared to other crops. Table 7 shows the amount of each nutrient contained in the seed, stover (all other parts of the plant) and as a total.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Yield 1 t/ha</th>
<th>Yield 2.5 t/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Seed</td>
<td>Stover</td>
</tr>
<tr>
<td>N</td>
<td>26</td>
<td>14</td>
</tr>
<tr>
<td>P</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>K</td>
<td>8</td>
<td>22</td>
</tr>
<tr>
<td>S</td>
<td>1.7</td>
<td>3.0</td>
</tr>
</tbody>
</table>

NI = No Information

**Nitrogen (N)**

Sunflower has a lower requirement for nitrogen compared to sorghum and winter cereals. However nitrogen is the nutrient required in the greatest quantity by a sunflower crop having an influence on many crop characteristics including the size and number of leaves, seed size and weight, yield and oil content. Cropping history, years of cropping, fallow conditions and yield potential determine the quantity of nitrogen fertiliser needed.

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

Nitrogen budgeting is the preferred method for determining the nitrogen requirements of a crop by using the following calculations.

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.
Potassium (K)

Potassium (K) is required for stalk strength and general tissue strength in sunflowers. A 1 t/ha crop requires 30 kg of K/ha as sunflowers are a relatively high user of potassium. This is removed as 8 kg K/ha in the seed and the remaining 22 kg K/ha in the stover. Responses to potassium are unlikely if soil test levels are greater than 0.25 meq/100g. Several NSW DPI research trials have shown no significant responses to potassium on yield or oil content.

Zinc (Zn)

Fertiliser responses to zinc often occur on heavy alkaline soils. Zinc can be broadcast at 10–20 kg Zn/ha and incorporated into the soil well before sowing. Banding zinc compound fertilisers (rather than zinc-blended fertilisers) with the seed at planting is an effective way of applying zinc. Alternatively, when crops have 8–10 leaves, apply two foliar sprays of zinc sulfate heptahydrate solution (1 kg/100 L of water) at 150–200 L/ha, 7–10 days apart.

Safe rates of fertiliser sown with the seed

Suggested rates of fertiliser which can be safely sown with sunflower seed are shown in Table 8. The safe rate is affected by the row spacing. The wider the row spacing the lower the safe amount of nitrogen and phosphorus.

Table 8. Safe rates of fertiliser sown with sunflower seed.

<table>
<thead>
<tr>
<th>Row spacing cm</th>
<th>N kg/ha</th>
<th>P kg/ha</th>
<th>Fertiliser product kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>8</td>
<td>22</td>
<td>Urea 52</td>
</tr>
<tr>
<td>60</td>
<td>6</td>
<td>17</td>
<td>DAP 39</td>
</tr>
<tr>
<td>75</td>
<td>5</td>
<td>13</td>
<td>MAP 60</td>
</tr>
<tr>
<td>100</td>
<td>4</td>
<td>10</td>
<td>Urea 23</td>
</tr>
</tbody>
</table>


Subsoil constraints

Sunflowers are not tolerant of acidic soils, particularly those containing toxic levels of aluminium and manganese. Soils with a pH<sub>c</sub> of 5.0 or less are not suitable for sunflowers. Sunflowers do not tolerate salinity well, being less tolerant than wheat or sorghum but more tolerant than soybean or maize. Sunflowers are affected by soil salinity levels of 4–5 dS/m (ECE). Paddocks with salinity as a subsoil constraint should be identified and the depth to the subsoil constraint noted and the reduction in plant available water calculated. Subsoil constraints effectively reduce the amount of soil water available to the crop.

Irrigation

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

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

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

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

Water stress between flowering and maturity has the biggest impact on grain yield. As a rule of thumb, in self-mulching clay soils a water depletion of 75–90 mm can be used to schedule irrigations, however this is dependent on soil type and root zone structure.

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

The recommended times for surface irrigations are:
1. Prior to sowing – pre-water fields
2. Budding – first irrigation
3. Start of flowering – second irrigation
4. Early seed fill – third irrigation.

Caution should be exercised if using overhead irrigation to try and avoid irrigation during the period of flowering to ensure seed set is not affected pollen being washed off the florets. In addition irrigating too late into seed fill will increase the risk of paddocks remaining wet at harvest, reducing trafficability and potentially causing compaction.

**Weed management**

Good weed control is essential for high yielding crops. The first 7 weeks after emergence is the most critical period for weed competition. Research conducted by QDAFF has shown that early sunflower growth can be reduced by as much as 39% without effective weed control. Weeds may also harbour pests and diseases of the crop.

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 of Stomp® or Stomp Xtra® (pendimethalin) is an option for controlling several grass and broadleaf weeds in sunflower.

Herbicides are available for post-emergence control of grass weeds. Several Group A herbicides are registered for use in sunflowers, including Verdict®, Shogun® and Fusilade®.

Due to the increasing incidence of resistance to Group A herbicides these options should be used as part of an integrated weed management strategy. The identification of glyphosate resistant barnyard and liverseed grass in northern NSW is another complication for weed management. Rotation of herbicide groups is difficult with many crops, including sunflower, so an integrated system that combines a number of tactics should be used for weed control. The double knock strategy of glyphosate followed by paraquat (e.g. grammoxone) is the main resistance management tactic for grass weed control pre-sowing and in fallow.

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

### Table 9. Herbicides registered for use in sunflower.

<table>
<thead>
<tr>
<th>Herbicide (active)</th>
<th>Example product</th>
<th>Group</th>
<th>Sunflower use pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,4-D *</td>
<td>Baton®</td>
<td>I</td>
<td>✓</td>
</tr>
<tr>
<td>trifluralin</td>
<td>TriflurX®</td>
<td>D</td>
<td>✓</td>
</tr>
<tr>
<td>dicamba</td>
<td>Dicamba®</td>
<td>I</td>
<td>✓</td>
</tr>
<tr>
<td>pendimethalin</td>
<td>Stomp®</td>
<td>D</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>S-metolachlor</td>
<td>Dual®Gold</td>
<td>K</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>tribenuron -methyl</td>
<td>Express®</td>
<td>B</td>
<td>✓</td>
</tr>
<tr>
<td>glyphosate</td>
<td>Roundup®</td>
<td>M</td>
<td>✓</td>
</tr>
<tr>
<td>paraquat</td>
<td>Nugquat®</td>
<td>L</td>
<td>✓</td>
</tr>
<tr>
<td>paraquat + diquat</td>
<td>Sprayseed®</td>
<td>L</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>butoxydim</td>
<td>Factor®WG</td>
<td>A</td>
<td>✓</td>
</tr>
<tr>
<td>propanaquizafop</td>
<td>Shogun®</td>
<td>A</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>fluazifop-p</td>
<td>Fusilade®</td>
<td>A</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>haloxyfop-r</td>
<td>Verdict®</td>
<td>A</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>sethoxydim</td>
<td>Serin®</td>
<td>A</td>
<td>✓ ✓</td>
</tr>
</tbody>
</table>

* Use of 2,4-D HVE formulations is restricted. See the APVMA website for full details.

### Diseases

The main diseases of sunflower are usually related to seasonal conditions. In order to minimise field losses from diseases, select disease-resistant hybrids where possible, control volunteer and wild sunflower, and rotate crops to include non-susceptible hosts. The main diseases of sunflower in recent years are powdery mildew; Alternaria and Sclerotinia, with increased incidence of both Phoma black stem and Phomopsis stem canker.

**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 may be surrounded by yellow halos. If the disease infects a leaf vein, a long black lesion may develop following the vein and lead to more rapid necrosis of the leaf. Severe infection may cause leaf blighting which leads to premature senescence displayed as shrivelled leaves with a dark brown appearance.

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 incidence has 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°C – 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 yet available, so planting more than one hybrid and varying planting time is recommended. Tolerance levels in some hybrids may be reflected in the size and number of lesions and halos produced. Avoid planting near standing sunflower stubble which may be harbouring 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 with an ashy or silvery grey appearance as the stems dry down. In conditions of 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 impact on oil composition.

#### 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 infection until the crop becomes stressed. Microsclerotes (which cause the pepper appearance in the pith) are survival structures which can survive in the soil for many years infecting both monocotyledons and dicotyledons.

**Management**
Avoid any management practices that will stress the crop – water stress, excessive nitrogen, low potassium or herbicide injury.

Stress of irrigated crops can be reduced by irrigating to avoid moisture stress during seed fill. Crop rotations with sorghum or corn following sunflower help limit build-up of this disease. Rotating with more susceptible crops such as mungbeans, soybeans and navy beans can build-up inoculum.

Fungicides can act as effective seed treatments.

### Rhizopus head rot (Rhizopus spp.)

Rhizopus head rot is a common disease in sunflowers and has been more prevalent in recent years.

#### 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. Generally, the mushy, water soaked appearance of the head is characteristic of Rhizopus often with dark greyish fungal threads giving a cotton-wool type of 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 which tend to hold water in the back of the head as the head become pendulous during seed fill are also particularly vulnerable during periods of wet weather. If water collects for a significant length of time, Rhizopus may invade the stressed tissues without pre-existing damage to the head.

**Management**
Limiting insect, mouse or bird damage will reduce the risk of infection.

### Rust (Puccinia helianthi)

Rust incidence has been very low over the past few years. This is most likely due to both unfavourable weather conditions and good resistance levels in most of the hybrids. Generally, incidence is higher in the more susceptible birdseed and confectionary lines as well as on inbred and breeding lines in nurseries.

Currently there are more than 115 rust races characterised. 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**
Look for small reddish-brown pustules of dark brown dust-like spores that will rub off onto the end of your finger. This is a good check to limit confusion with early Alternaria infection. 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, 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 pathogens of sunflower.

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.

Management
Serious losses are normally avoided by growing resistant hybrids. Take note of planting times of neighbouring crops. Consider planting more than one hybrid to limit build-up of any specific rust races or avoid successive plantings of the same hybrid. Be aware that birdseed varieties such as Sunbird 7 are particularly susceptible to a number of specific rust races and will more likely carry rust during the season, especially if planted late. Additionally, many of the older sunflower varieties may not be resistant to current dominant rust races. Ask your seed company representative about the rust resistance levels of your hybrids.

Sclerotinia stem and head rot (Sclerotinia minor, Sclerotinia sclerotiorum)

Sclerotinia species have an extensive host range of broadleaf crops and weeds including canola, chickpeas, soybeans, vegetable crops, legumes and sunflowers. A build-up of Sclerotinia is often the result of inappropriate rotational choices although floods 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.

Symptoms
Basal and mid-stem lesions usually do not appear before budding. A light-brown lesion will develop either at the base or along the stem (S. minor) eventually girdling the stem causing the plant to either lodge or senesce early. Dark orange bands may stripe the basal lesion and a darker edge may develop as the lesions age. S. sclerotiorum can also cause head infection. The pith inside the stem and head becomes filled with a white cottony fungal growth, sometimes extending outside the stem. Both species produce sclerotes; small, black irregularly shaped survival structures that develop in the infected tissue and can survive many years in the soil. The sclerotes of S. minor 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.

Conditions favouring development
Sclerotinia minor will infect during warmer conditions whereas S. sclerotiorum is favoured by cool, wet weather (less than 18°C, 15–17°C is ideal) which allows germination of the sclerotes 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.

Management
Stem and head rots are reduced by sowing before mid January especially in the cooler areas, and by 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 many weeds are major hosts – weed control is essential.

Sclerotes can be difficult to sieve out of seed samples so it is important to keep seed production areas free of sclerotinia to avoid spread.

Sclerotonia are also easily transported on machinery, boots, plant debris and water – good farm hygiene will help limit spread.

White blister (Albugo trogopogonis)

White blister rarely causes economic damage in Australia 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.

Symptoms
Leaf symptoms appear as raised pustules on the top of the leaf with whitish spores on the underside of the leaf. 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 may occur in spring sown crops. Cool, wet conditions (<20°C) aid the spread and severity of the disease. Warm conditions slow disease development and spread.

Management
White blister has caused only small yield losses, even when leaf damage is severe. However, if petiole and stem infection occurs, lodging and significant yield loss could result. Controlling wild and volunteer sunflowers is an important management strategy. Many Australian hybrids have high levels of resistance.

Powdery mildew (Golovinomyces cichoracearum)

Previously considered a minor disease, powdery mildew has become a significant problem for many sunflower growing areas, particularly in late planted crop due to 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 which 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 the build-up of powdery mildew within a crop can be very rapid. Regular crop inspections are essential if conditions favour powdery mildew.
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 an emergency use permit for Tilt® 250EC (250 g/L propiconazole) under permit 14777 (expires 30/6/2016). This permit allows 1–2 applications at a rate of 250–500 mL/ha to be applied no later than 5% ray floret emergence.

Check the permit for additional application requirements.

**Trial Results – TILT®250EC rates and timing:**

Trials have indicated that one application of 500 mL/ha applied between the stages of 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, middle third of canopy with colonies dotted to half way at 5% ray floret emergence, 30–80% leaf area of top third infected by physiological maturity in the untreated.

For further information contact Sue Thompson, Plant Pathology, QDAFF, Toowoomba, Qld. (Contact details at the end of the chapter).

**Phomopsis Stem Canker (Phomopsis spp., not Phomopsis helianthi)**

Phomopsis stem canker is an emerging disease of Australian sunflowers with the potential to cause severe economic losses. Overseas, Phomopsis helianthi causes losses of up to 50% – the species identified in Australia to date are not P. helianthi but display almost identical symptoms.

**Symptoms**

Characteristic brown lesions dot the stems at the nodes. The lesions are similar to those of Phoma Black Stem (*Phoma spp.*) which displays black lesions dotted at the nodes and is less damaging. Yield losses are caused by pith deterioration behind the lesions and throughout the stem as the disease progresses. Lesions extend above and below the node as the plant ages and often develop a darker edge. Mid-stem lodging may occur. Dark coloured fruiting bodies (pycnidia) may be seen as a speckle of dots at the site of the lesion as the stems dry out.

**Conditions favouring development**

Warm wet conditions favour the disease with optimal temperatures for infection of 23–25°C. Infection occurs via the leaf margin, progresses down the petiole to the node where the characteristic brown lesion becomes evident on the stems from flowering onwards.

**Management**

*Phomopsis* spp. can survive on stubble – stubble management is essential to limit disease build-up. Overseas recommendations suggest burial to 15 cm. Strategic burial or processing of stubble should be considered to control spread and survival of this pathogen. Rotation away from sunflower for a minimum of 3–5 years is recommended overseas. Good farm hygiene will limit the spread of the pathogens 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 and several other crops have been found to be alternative hosts to *Phomopsis* spp. which infect sunflower in Australia.

Phomopsis species may 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, Plant Pathology, QDAFF, Toowoomba, Qld. (Contact details at the end of the chapter).

**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 heliothis 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 may 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 sunflowers do not have a compensatory mechanism such as tillering to recover from any stand losses. Typically 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 roots and underground stems of plants. False wireworms are hard bodied, shiny and cream or yellow in colour. False and True wireworms both have three pairs of legs just behind the head. In contrast True
wireworms are soft bodied but are also shiny and cream or yellow in colour.

**Damage**

The larvae may also bore into germinating seed. Activity is more common in heavier, wetter soils and damage is often more common when crop emergence is slowed by cool, wet conditions.

False wireworm damage is similar to that caused by the wireworm, however it is more prevalent in dry seedbeds. Wireworms are usually found at the interface between dry and wet soil.

**Threshold**

The threshold for False wireworm control is one larva 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 adults wireworms are not encouraged to breed up using this food source. Check the seedbed prior to sowing and use treated seed. Insecticide application is an option. Check the insecticide seed dressings table 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 may 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 whitefly populations. As whitefly populations can occur as mixed species, aim to retain natural predator populations for as long as possible. Another biotype of silverleaf whitefly Q-biotype has also recently been identified.

**Bemisia tabaci (Australian native, Silverleaf whitefly or B-biotype and Q-biotype)**

**Bemisia tabaci** species includes three biotypes; Australian native, silverleaf whitefly 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 silverleaf whitefly or B biotype was first discovered in Australia in 1994. Silverleaf whitefly (SLW) poses a greater threat than Greenhouse whitefly to broadacre crops. It caused significant damage to a wide range of broadleaf crops including sunflower, mungbean, soybean, peanut and cotton in the 2001–2002 season in the Emerald Irrigation Area. A new biotype named Q-biotype was discovered in 2009 in Queensland and northwest NSW.

**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 may be damaged by severe infestations. Caterpillars bore holes into the backs of heads and predispose the plant to Rhizopus head rot, which is a major problem.

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 warrant 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 made difficult by the fact that 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 have potential to 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 may be distorted, stunted or killed; and flowering through 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
Sunflower crops as higher prevailing temperatures promote more rapid Rutherglen bug development.

The thresholds proposed in Table 10 are based on field experience and knowledge that the adults will not lay eggs until the start of seed fill.

**Table 10. Nysius spp. thresholds in sunflowers.**

<table>
<thead>
<tr>
<th>Crop type and growth stage</th>
<th>Recommended threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early plant sunflowers</td>
<td></td>
</tr>
<tr>
<td>– Budding</td>
<td>10–15 adults/plant</td>
</tr>
<tr>
<td>– Seed fill</td>
<td>20–25 adults/plant</td>
</tr>
<tr>
<td>Late plant sunflowers</td>
<td></td>
</tr>
<tr>
<td>– Budding</td>
<td>20–25 adults/plant</td>
</tr>
<tr>
<td>– Seed fill</td>
<td>50 adults/plant</td>
</tr>
<tr>
<td>Confectionary sunflowers</td>
<td>5 adults/plant</td>
</tr>
</tbody>
</table>

**Management**

Several synthetic pyrethroids are registered and they are the most effective pesticide for control. Synthetic pyrethroids have very little residual effect and severely disrupt natural predator populations. Best results are achieved when spraying occurs before the heads turn down. However, Rutherglen bug repeatedly infest over several weeks. Multiple treatments may be needed. Ideally sprays should be targeted at adults, timed to prevent them breeding. Time sprays before heads turn down or at the end of flowering when adults begin to lay their eggs.

Maintaining clean fields and fallows is important to prevent alternative hosting on weeds

**Soybean Looper (Thysanoplusia orichaeia)**

The soybean looper is a sporadic pest of sunflower. They can be identified by their distinctive “looping” action and they only have two pairs of hind legs unlike heliothis which have 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 give preference to 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 Beneficial Disruption Index, presented in the Cotton CRC publication, Cotton pest management guide.

**Crop desiccation**

Crop desiccation is not a common practice in sunflowers. However it has been used in seasons to speed up or even out maturity of a crop. Diquat is the only product registered for use as a harvest aid in sunflowers. There is an emergency use permit (Permit 13118, expires 31/3/2015) for the use of glyphosate as a pre-harvest desiccant.

Desiccation of a sunflower crop can only commence once the crop has reached physiological maturity. A sunflower plant has reached physiological maturity when the bracts surrounding the head have turned brown. At this point the seed should be mature and the moisture content below 35%.

**Harvest**

Sunflower harvesting is best carried out as close to 9% seed moisture content as possible. There is a tendency to overestimate moisture content of a sunflower crop, meaning harvest is often delayed until moisture content is on average 7%. This results in a loss of yield and more difficulty in obtaining a clean sample. As sunflowers become drier and more brittle, the bracts, and parts of the head break into small pieces which are difficult to separate from the seeds. As a result admixture levels are usually higher when moisture contents are lower at harvest.

Machinery setup can have a big effect on the quality of the sample harvested and the speed at which a crop may be harvested. Headers with ‘head snatchers’ and sullivan reels are a popular choice. These adaptations allow the sunflower heads and approximately 20 cm of stalk only to be fed through the header. This means a large reduction in the amount of material which needs to be threshed and reduces the likelihood of excessive trash and admixture in the sample. Sunflower trays
are also a useful addition for retaining heads and seeds in the header front. Harvesting sunflowers when they are too moist can cause problems with threshing as the heads retain a significant amount of moisture, particularly in the pith. Slow drum speeds aid in harvest. Speeds of around 450 rpm for conventional headers and 250–350 rpm for rotary headers are suggested. Fan speeds should be fairly fast, but will often depend on the size of the seed.

**Receival standards**

Sunflowers should be delivered at 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.

A copy of the receival standards is included at the back of the guide. Storage of sunflowers is also covered in the grain storage section towards the back of this guide.

**Marketing**

Sunflowers are grown to meet three main markets. The highest demand is for monounsaturated sunflowers. Polysaturated 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 sunflowers include industrial oils and potentially biodiesel.

**Monounsaturated sunflower**

Monounsaturated sunflowers produce 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.

**Polysaturated sunflower**

Polysaturated sunflowers are 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 polysaturated sunflower seeds need to fill seed 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 sunflowers are traditionally the grey striped sunflowers, however a black hybrid with dual purpose characteristics is also available. 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 sunflowers 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 which are not dehulled and are primarily sold into the birdseed market.

**Further information**

- The Big Yellow Sunflower Pack 2010
- Sunflower – Agfact P5.2.3, 2nd edition 1997
- Weed control in summer crops 2012–13
- Insect and mite control in field crops 2013
- Sunflower Production Guidelines for the Northern Grains Region, 2008
- Raising the bar with better sunflower agronomy, 2009, Australian Oilseeds Federation and GRDC.

**References**


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Grain storage

Joanne Holloway and Loretta Serafin

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, scalable storage systems that include both aeration 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 and changes in grain colour. Fortunately, the implementation of good storage practices, as outlined here, will simultaneously reduce the likelihood of all four causes of grain quality loss. Pre-harvest, harvest and post-harvest 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 climate within the storage facility.

Pre-harvest

Remove grain residues

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. Any grain residues can harbour insects and thus need to be removed, even from difficult to reach spaces. Residues should be buried or burned to prevent them being a source of infestation.

Old planting seed remaining in a shed on site poses a major infestation threat. Avoid carrying over planting seed as it is difficult to protect from insect attack. Isolation to another part of the farm may not be effective as many of the insect pests of stored grain can fly several kilometres to relocate.

Apply protectant insecticides

Following cleaning, the harvester and empty silos should be treated with a protectant insecticide or diatomaceous earth (a non-chemical alternative) registered for structural treatment. A summary of registered products is presented in Table 2. Depending on the grain to be stored and its marketing requirements, there may be a number of options available.

Removal of grain residues prior to 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 carry-over grain should be disinfested prior to the addition of the new grain. Currently the only form of treatment for disinfestation of insects is fumigation. Therefore, any grain requiring this treatment will need to be in a gas-tight 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 are 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:

\[
\frac{\text{Silo capacity of the known grain type (tonnes)}}{\text{Volumetric weight of the known grain type (kg/hL)}} \times \frac{\text{Volumetric weight of the new grain type (kg/hL)}}{\text{Silo capacity of the known grain type (tonnes)}}
\]

Example scenario:

A silo is known to hold 200 tonnes of wheat. How many tonnes of sunflowers will it hold?

\[
\frac{200 \text{ (tonnes of wheat)}}{75 \text{ (wheat kg/hL)}} \times 40 \text{ (sunflowers kg/hL)}
\]

Answer: The silo will hold ~107 tonnes of sunflowers

Repair structural faults

Grain stores must be maintained in a serviceable and watertight condition. Repair any structural fault that could let water penetrate.

At harvest

Monitor moisture content

Use a moisture meter to monitor the moisture content of the grain as it dries down. In summer grain dry down can occur very rapidly. Overdrying grain affects profitability as it is a straight loss of revenue, not changing the cost of the harvest operation. For example 2% overdrying 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 additional penalties incurred due to increased grain damage that is likely in overdry grain. In autumn when dry down is progressing slowly, the costs of desiccation and/or grain drying 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 4.

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. Damaged grains are also more likely to be the source of disease. Additionally, the presence of admixture will reduce the evenness of air flows through the stack, limiting the effectiveness of aeration cooling for both insect and disease.
Post-harvest

Cool grain is far less prone to quality loss and changing grain storage temperature is a relatively quick process compared to changing grain moisture.

At any particular temperature moisture will move between the grain and the air in a storage until an equilibrium is reached. Aeration is used to set the temperature that grain will be stored at and keep the amount of moisture present in the air consistent throughout the grain stack. Where aeration is not used, subtle differences in things such as grain moisture and admixture throughout the stack can lead to the formation of ‘hot spots’ where excess moisture and/or heat is trapped. Hot spots are frequently the source of insect pest and disease outbreaks. Spontaneous combustion is also a problem if excess moisture remains in sunflowers. Hot spots can be an ignition source.

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. The availability of artificial drying can make harvesting decisions much easier and the maintenance of grain quality during storage more likely. However damage to some grain types, particularly mungbeans and maize, can occur during the drying process.

When calculating flow rates, remember that the fans will need to work against the back pressure of the stored commodity. Grain weight and type will influence the rate at which the air can flow through the storage.

Low airflow aeration

Low airflow aeration is used when grain is harvested at, or has been dried to, its ideal moisture content for storage. A fan capacity of ~2 L/s/t is usually adequate to aerate and maintain stored grain quality for many months. Fans should be turned on regularly to move fresh, cool air through the grain stack. Poor timing of aeration can lead to rewetting or reheating of the grain. For this reason, temperature monitoring and automated fan control systems are recommended for longer term storage (longer than 6 months). Exhaust air must be able to escape freely from the top of the storage. An opening of 0.1 m² (30 cm × 30 cm) is recommended for each 500 L/s/t of air being delivered. An efficiently run low airflow aeration system can maintain grain storage temperatures between 15°C and 20°C.

Medium airflow aeration

Medium airflow aeration is used when grain is being stored for short periods of time at higher than ideal moisture contents. Airflow rates of 4–10 L/s/t will preserve grain quality for short periods prior to drying. By using aeration prior to drying a consistent feedstock can be provided to the dryer reducing the need to change the dryer speed and heat settings. To hold grain in a safe condition, aim for an equalised air temperature of 20°C and a maximum grain moisture content of 15%.

High airflow aeration drying

High airflow aeration drying can take weeks to achieve what hot air drying can achieve in a day or two. But there is much lower risk of damage to the grain. Airflow rates of ~20 L/s/t are generally required to move moisture through the stack and prevent condensation on the top. The success of this drying strategy relies on the availability of air with low relative humidity. 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. This increases the air temperature by up to 10°C.

Hot air drying

Hot air dryers use heated air to increase the rate of evaporation out of the grain. Dryers may 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 may be a fixed part of the storage complex or they may be portable for use in the field alongside the header and delivery trucks. Where the seed germination percentage is important, grain temperatures should not exceed 43°C during drying. To minimise problems with sweating and caking, grain must be cooled to within 10°C of ambient after drying. Continuous flow systems have a cooling section built in. Storage with aeration capacity of 5–10 L/s/t is sufficient to cool batch dried grain.

Reducing the risk of fire during drying

Sunflowers are able to be dried easily, however their high oil contents predispose them to higher risks of fire and spontaneous combustion. Debris which becomes overdry and combusts is one of the main reasons for fires while drying sunflowers. Fibres from the seed and other trash contained in the harvest sample are often drawn through the drying fans. When these ignited particles come into contact with the sunflower seed a fire often occurs. Adjust harvester setup to minimise admixture in the sample or clean the sample before drying to reduce this risk.

Selecting air for aeration

Manually turning fans on and off can be an efficient means of selecting air in certain circumstances. For aeration drying of summer harvested crops in inland regions, there may be only a few instances of high humidity where fans would need to be turned off. However when aeration is aiming to maintain temperature and moisture parameters during longer term storage, automated controllers are recommended. Automated controllers continuously monitor the air and select ‘set points’ to operate at the times when air is of the best quality.

Monitoring stored grain

Monitoring of any storage system is essential. Inspect stored grains regularly for the presence of:

- odours
- condensation
- visible insects and moulds on the top of the stack
- holes or damage to the grain hot spots (areas where temperature is elevated) in the grain

The presence of insects and moulds are usually greatest near outlet hatches and the top surface. Spend ~5 minutes at each storage taking a few litres sample from each access point. Use a grain
Table 1. Characteristics of key insect pests of stored summer grains.

<table>
<thead>
<tr>
<th>Insect pest</th>
<th>Max. pop’n growth rate/month</th>
<th>Larvae concealed in grain?</th>
<th>Adults walk up glass surfaces?</th>
<th>Means of spread</th>
<th>Resistance status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Protectant Disinfestant</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>OP Methoprene Phosphine</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Weak Strong</td>
<td></td>
</tr>
<tr>
<td>Weevils Sitophilus spp.</td>
<td>25X</td>
<td>YES</td>
<td>YES</td>
<td>adults fly or walk long distances, infest maize prior to harvest</td>
<td>rare</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>common</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>rare</td>
</tr>
<tr>
<td>Lesser grain borer <em>Rhyzopertha dominica</em></td>
<td>20X</td>
<td>YES</td>
<td>NO</td>
<td>adults fly long distances</td>
<td>common</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Very common and increasing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>widespread (5%)</td>
</tr>
<tr>
<td>Rust red flour beetle Tribolium castaneum</td>
<td>70X</td>
<td>NO</td>
<td>NO</td>
<td>adults fly long distances</td>
<td>rare</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>uncommon</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>common</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>uncommon</td>
</tr>
<tr>
<td>Sawtooth grain beetle <em>Oryzaephilus surinamensis</em></td>
<td>50X</td>
<td>NO</td>
<td>YES</td>
<td>adults fly or walk long distances</td>
<td>common</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>rare</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>common</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>uncommon</td>
</tr>
<tr>
<td>Flat grain beetle <em>Cryptolestes</em> spp.</td>
<td>55X</td>
<td>NO</td>
<td>NO</td>
<td>adults long lived and fly long distances</td>
<td>rare</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>rare</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>common</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>widespread (30%)</td>
</tr>
<tr>
<td>Psocids Liposcelis spp.</td>
<td>25X</td>
<td>NO</td>
<td>NO</td>
<td>on infested grain, machinery</td>
<td>no known cases</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>rare</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>rare</td>
</tr>
<tr>
<td>Angoumois grain moth <em>Sitotroga cerealella</em></td>
<td>50X</td>
<td>YES</td>
<td>NO</td>
<td>strong fliers, infest maize prior to harvest</td>
<td>no known cases</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NI</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NI</td>
</tr>
<tr>
<td>Cowpea brucid <em>Callosobruchus</em> spp.</td>
<td>NI</td>
<td>YES</td>
<td>NO</td>
<td>adults short lived but strong fliers, infest mungbeans prior to harvest</td>
<td>NR</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NR</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>no known cases</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>no known cases</td>
</tr>
</tbody>
</table>

NI = No Information NS = Not Susceptible NR = Not Registered OP = organophosphate

Table 2. Insecticides registered for disinfesting empty grain storages and grain handling equipment.

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Insecticide</th>
<th>Mixing rate /L</th>
<th>Summary notes: read the label before using</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disinfecting empty silos, storage areas and equipment such as headers, augers, mobile bins.</td>
<td>Carbaryl 500</td>
<td>10 mL</td>
<td>Carbaryl is registered for control of lesser grain borer only, while Reldan®, Actellic® and Fenitrothion do NOT control lesser grain borer. Therefore, mixtures of carbaryl with any of the other components listed here may be used for control of all species. Follow label precautions about mixing. Do not pre-mix concentrates. Agitate thoroughly and clean equipment after use. Vat mixtures may lose compatibility if left overnight. Refer to label for spraying rates. Do not use Reldan® 500 on stored maize destined for export. Do not use in storages where canola and other oilseeds are to be stored.</td>
</tr>
<tr>
<td></td>
<td>Actellic® 900</td>
<td>11–22 mL</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reldan® 500</td>
<td>20 mL</td>
<td>A pre-mixed formulation of Reldan® and methoprene may be used for control of all stored grain insect pests. Do not use Reldan® 500 on stored maize destined for export. Do not use in storages where canola and other oilseeds are to be stored.</td>
</tr>
<tr>
<td></td>
<td>Fenitrothion 1000</td>
<td>10 mL</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reldan® plus IGR</td>
<td>20 mL</td>
<td></td>
</tr>
<tr>
<td>Desiccant dust treatments (amorphous silica)</td>
<td>Abrade™</td>
<td>240 mL (1 L/20 m²)</td>
<td>For small storages apply with a standard back pack or mechanical sprayer through fan-jet nozzles at 300–400 kPa. For large storages use high pressure equipment at pressures of 3000–4000 kPa. Spray to just before the point of run-off. Reticulation/irrigation of spray mix is important to maintain good dispersion in the spray mix. Do not treat directly onto grain to be delivered to grain handling authorities.</td>
</tr>
<tr>
<td></td>
<td>Absorba-cide®</td>
<td>120 g (1 L/20 m²)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cut ‘N Dry® Dryacide®</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Absorba-cide®</td>
<td>2 g/m² (dry)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cut ‘N Dry®</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dryacide®</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3. Protectant and fumigant insecticides registered for treating grain in storage.

<table>
<thead>
<tr>
<th>Grain situation</th>
<th>Insecticide rate /100 L</th>
<th>Summary notes: read the label before treating for limitations and full instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protect cereal grain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GROUP A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actellic®</td>
<td>0.45 L</td>
<td>Make up ONE Group A insecticide to strength before adding the required amount of ONE Group B insecticide to the spray mix. Mixtures are needed to control the whole range of grain insects. Apply 1 L of diluted spray per tonne of grain entering storage. Treat only non-infested grain with protectants. Ensure treatment is acceptable to buyer. Full rate treatment is intended for 3–9 months storage; half rates on some labels are up to 3 months storage. Grain treated with full rates of Group A insecticides should be held for 3 months before use. Read the label instructions carefully to ensure the correct rates are used for the desired storage period. Group B insecticides are based on methoprene or 5-methoprene. IGR grain protectant is available in various strengths. Refer to label for mixing rate.</td>
</tr>
<tr>
<td>Reldan®</td>
<td>2.0 L</td>
<td></td>
</tr>
<tr>
<td>Fenitrothion</td>
<td>1.2 L</td>
<td></td>
</tr>
<tr>
<td>GROUP B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rizacon-S®</td>
<td>0.2 L various rates/100 L</td>
<td></td>
</tr>
<tr>
<td>IGR grain protectant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TWIN PACK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two-component packs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRE-MIXED</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reldan® + IGR</td>
<td>2.0 L</td>
<td></td>
</tr>
<tr>
<td>K-Obiol Combi (Deltamethrin)</td>
<td>2.0 L</td>
<td>May be used against all major stored grain insect pests. Restricted to one application per parcel of grain. Only available through a stewardship program with Bayer.</td>
</tr>
<tr>
<td>Conserve On Farm Grain Protector</td>
<td>2.8 L</td>
<td>May be used against all major stored grain insect pests. Restricted to one application per parcel of grain. Only available through a stewardship program with Dow Agrosciences. Not to be used on rice, maize or malting barley.</td>
</tr>
<tr>
<td>Protect cereal grain for use on-farm only, and organic cereal grain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dryacide®</td>
<td>100 kg/100 t</td>
<td>Apply dust to grain as it passes through the auger to give uniform distribution through the grain. A dust applicator should be used.</td>
</tr>
<tr>
<td>Absorba-cide®</td>
<td>150–200 kg/100 t 3.3 L as a 23% slurry (3.3 L of water/ kg product)</td>
<td>Spray the slurry over a moving grain stream. See label recommendations. Use the higher rates on heavily infested grain. Do not exceed the rate of 100 kg/ 100 t on grain for human consumption. Do not treat grain to be delivered to grain handling authorities.</td>
</tr>
<tr>
<td>Cut 'N Dry®</td>
<td>5 litres/100 sq mt</td>
<td>Spray as a 11% slurry (120 g Dryacide/litre water) at 40–60 psi (300–400 kPa) using a centrifugal pump or venturi-type sandblaster and flat, fan spray nozzle of at least 5 L/min capacity. Use tank mixer or recirculate through slurry tank throughout operation to maintain good slurry dispersion. Rinse nozzle, lines and equipment with clean water directly after use. Do not allow the mixed slurry to stand without agitation.</td>
</tr>
<tr>
<td>Absorba-cide®</td>
<td>100 kg/100 t 100 kg/100 t</td>
<td>Dusted grain may retain protection for more than 12 months if grain moisture is low. Higher rates may be used for dirty or infested grain, but not where grain is for human consumption. Apply dusts evenly and reduce auger rate to prevent choking. A dust applicator should be used.</td>
</tr>
<tr>
<td>Cut 'N Dry®</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disinfect cereals and oilseeds by fumigation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminium phosphide (producing phosphine gas)</td>
<td>150 tablets/100 m³</td>
<td>Ensure silo is gas-tight. Calculate fumigant as if the silo is full. Phosphine tablets: fumigate for 7–10 days, 20 days for silos larger than 375 m³. Withholding period 2 days after ventilation. Other phosphine formulations are available, including pellets, sachets, belts, blankets and cylinder gas. Refer to labels for rates and methods of use. ProFume requires fumigator trained under the Dow AgroSciences Precision training program and a gas-tight silo.</td>
</tr>
<tr>
<td>ProFume® (sulphuryl fluoride)</td>
<td>As per Fumiguide</td>
<td></td>
</tr>
</tbody>
</table>

Registered insecticides as at July 2014. The product names are supplied on the understanding that no preference between equivalent products is intended, and that inclusion of a product does not imply endorsement by Industry & Investment NSW over any other equivalent product from another manufacturer. Aluminium phosphide products include; Alphos®, Celphide®, Fumiphos®, Fumitoxin®, Gastion®, Pestex®, Quickphos® and similar preparations.

Some registered products are not available for general use.

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 in, or omitted from, this publication.

Cereal grains include wheat, barley, oats, maize, sorghum, triticale, paddy rice and millet. Canola and other oilseeds may only be treated with phosphine. Withholding periods listed on some labels ensure that residues decay to acceptable levels before grain is sold. Seek further information from the Grain Storage Unit at Wagga Wagga.
probe or spear to sample from the top surface. Sieve the grain. The regularity with which grain should be monitored is dependent on the type of grain and season. Industry recommendations for monitoring intervals are provided in Table 4.

Grain moisture content should continue to be monitored post-harvest. Changes in grain moisture can identify a problem with automated fan controls that can occur, particularly during change of season.

**Insect pests**

Grain insects are sensitive to temperature. Most reproduce fastest when the temperature is about 30°C. The potential for population growth of key storage pests, along with other characteristics are outlined in Table 1. Cooling the temperature to below 20°C slows their growth and development sufficiently that little damage may occur. Once temperatures are below 15°C, reproduction is halted in most species until temperatures rise again. However continue to monitor for signs of insects as some species may adapt to cooler grain temperatures.

Some storage pest infestations commence in the field prior to harvest. Maize weevil lay eggs in the cobs of maturing maize crops 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. While such pests are common in the field at harvest, control at this time is neither economically feasible or likely to provide the 100% control that would be required to prevent storage infestation.

**Protectants**

Where there is acceptance of chemical residues on grain in the market place, protectant chemicals can be used to provide 6–9 months protection. However, when applied in hot weather the chemicals tend to degenerate more quickly resulting in a shorter period of protection. They can be applied to grain while it is entering storage, though are not designed to control infestations that are already visible in the grain. A summary of the insecticide registrations for protecting stored grain is presented in Table 3.

Disinfestation

When insect infestations do occur, there are limited options for disinfestation, particularly for some storage and marketing situations. A summary of the insecticide registrations for treating grain is presented in Table 3.

**Fumigation**

The primary option for fumigation is aluminium phosphide. This is available only where grain is being stored in a sealed gastight silo. Prior to 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 5 minutes in a full silo.

Phosphine fumigation is highly effective when used correctly. However populations of lesser grain borer, weevils and flat grain beetles with resistance to phosphine are common throughout NSW. Under-dosing by fumigating in leaky bins selects for stronger resistance.

Preferably fumigate by hanging bags, chains or sachets of aluminium phosphide in the headspace of the sealed silo. If using tablets, spread them out in a tray. Avoid the tablets contacting 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 convection currents.

Fumigations need to be long enough to allow time for the gas to evolve, diffuse through the grain and kill the insects. At lower temperatures phosphine kills more slowly. The times taken for a fumigation using tablets in a small silo (< 300 m³) to be successful are shown in Table 5. Larger silos and bags, chains or sachets require longer periods. Always refer to the label for dose and duration information.

**Table 4. Parameters for storing and drying summer grains.**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Maximum moisture content at harvest</th>
<th>Ideal moisture content for grain storage</th>
<th>Maximum air temperature for grain drying</th>
<th>Maximum grain temperature for grain drying</th>
<th>Volumetric grain weight</th>
<th>Storage monitoring schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Short term</td>
<td>Longer term</td>
<td></td>
<td>kg/hl</td>
<td>Summer</td>
</tr>
<tr>
<td>Maize</td>
<td>24%</td>
<td>12–13.5%</td>
<td>12%</td>
<td>49°C</td>
<td>38°C</td>
<td>72</td>
</tr>
<tr>
<td>Mungbean</td>
<td>14%</td>
<td>12–14%</td>
<td>12%</td>
<td>Ambient</td>
<td>Ambient</td>
<td>75</td>
</tr>
<tr>
<td>Sorghum</td>
<td>25%</td>
<td>13–14%</td>
<td>12%</td>
<td>93°C</td>
<td>80°C</td>
<td>72</td>
</tr>
<tr>
<td>Soybean</td>
<td>18%</td>
<td>13%</td>
<td>10–11%</td>
<td>55°CΨ</td>
<td>40°CΨ</td>
<td>75</td>
</tr>
<tr>
<td>Sunflower</td>
<td>15%</td>
<td>&lt; 9%*</td>
<td>8%*</td>
<td>45–50°C</td>
<td>43°C</td>
<td>40</td>
</tr>
</tbody>
</table>

* To avoid stress cracking for milling markets.

** To reduce the risk of mycotoxin contamination, temperature and humidity should be checked daily.

Ψ Higher temperatures can be tolerated when grain is harvested at 14–16% mc 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%.

* Dependent on oil content. Seed with oil contents higher than 40% require lower moisture content for safe storage.
Table 5. Phosphine fumigation in a sealed silo.

<table>
<thead>
<tr>
<th>Air temperature in the silo</th>
<th>Recommended time for fumigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 25°C</td>
<td>7 days</td>
</tr>
<tr>
<td>20–24°C</td>
<td>at least 10 days</td>
</tr>
</tbody>
</table>

Source: Pat Collins, GRDC.

An alternative fumigant, ProFume® (sulfuryl fluoride) is now on the market. It also requires a sealed gas-tight silo and is available to those who have successfully completed the Dow AgroSciences Precision Fumigation training program.

Dichlorvos spray application

Following a review by APVMA, for health and safety concerns, dichlorvos (aka Divap) is no longer supported as a postharvest treatment for stored grain or storages. Any remaining dichlorvos chemical product should be disposed of according to instructions found on the label or MSDS.

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. These are more susceptible to both disease infection and insect attack. The peaks and edges of the grain pile 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 the Maize section of this guide.

Further information

Stored Grain Management CD, GRDC and QPI&F.

Websites:

Industry & Investment NSW Grain Storage Unit at Wagga Wagga
Phone: (02) 6938 1605 or Mobile: 0410 410 736
Email: joanne.holloway@dpi.nsw.gov.au

References

Collins, Pat (2007) Insect management and resistance challenges in on-farm storage, GRDC Update Narrabri

Contributing authors

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Loretta Serafin, Leader, Northern Dryland Cropping Systems, NSW DPI, Tamworth.

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Receival standards

Grain 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 impact on grain performance against receival standards.

Receival standards are set by Grain Trade Australia (GTA), formerly known as NACMA. In conjunction with various industry organisations, GTA develops and publishes grain standards to ensure objectivity in grain specifications. These standards are updated yearly and are accepted as the industry’s standard reference.

For the latest receival standards and information about the role of GTA, refer to their website; www.graintrade.org.au
Also refer to the websites of industry organisations; Australian Mungbean Association: www.mungbean.org.au
Australian Oilseeds Federation: www.australianoilseeds.com
Pulse Australia: www.pulseaus.com.au
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 GTA and the 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 for the first time.
### Example seed treatment trade name and manufacturer

<table>
<thead>
<tr>
<th>Insecticide seed dressings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example seed treatment trade name and manufacturer</td>
</tr>
<tr>
<td><strong>Cosmos</strong> – Cropcare</td>
</tr>
<tr>
<td><strong>Senator</strong> 600 Red – Cropcare</td>
</tr>
<tr>
<td><strong>Gaucho</strong> 600 – Bayer CropScience</td>
</tr>
<tr>
<td><strong>Cruiser 350 FS</strong> – Syngenta</td>
</tr>
<tr>
<td><strong>Cruiser 600 FS</strong> – Syngenta**</td>
</tr>
</tbody>
</table>

* Check water rates on the label as they may vary.
** Only available to accredited applicators. Price is included in seed costs.
* Major products readily available in NSW. Other trade names may also be available.
** Prices quoted are GST inclusive at January 2011 and approximate only. Prices will vary depending on product, pack size purchased, seed treatment services i.e. imidacloprid + fluquinconazole, and special marketing arrangements.
Caution: Observe stock withholding periods on crops produced from treated seed.
The NSW Department of Primary Industries offers a variety of PROfarm short courses for individuals or groups including – safe quad bike handling, chainsaws, off-road four wheel driving, tractors, chemicals, grazing management, grass recognition and identification, weed recognition and identification, livestock handling, faecal egg counting for worms. If you have a group of people who require training, we will arrange the course you want at a location near you, provided we have the numbers to fill the course.

**ENQUIRIES AND REGISTRATION**
Tamworth/Northern NSW 6763 1276/85
Camden/Sydney Basin 4640 6333
Paterson/Hunter Valley 1800 025 520
Yanco/Southern NSW 1800 628 422
or go to www.profarm.com.au for an up-to-date list of courses.