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Mungbeans

December 2014

planning and paddock preparation • pre-planting • planting • plant growth and physiology • nutrition and fertiliser • weed control • insect management • nematode control • diseases • plant growth regulators and canopy management • desiccation • harvest • storage • environmental issues • marketing • current research

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SECTION A

Introduction

A.1 Management at a glance

- Prior to planting, assess starting soil water and estimate plant available water (PAW). At least 100 mm of PAW is recommended.
- Harvest losses can be as high as 50% in paddocks that have major variations in soil type or evenness.
- Use high-quality seed. Check the germination percentage, disease status and varietal purity of seed.
- Fertilise according to soil test analyses, arbuscular mycorrhizal (AM) 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/m.
- 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.
- Avoid planting mungbean if there is a risk of herbicide residues from previous cropping.
- 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–black pod stage. Maximise leaf dry-down to avoid dust sticking to seed when harvesting. [1]

More information

Mungbean management guide.

[1] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

Figure 1: Mungbeans have enjoyed recent popularity as a crop for the northern grains region following development of improved varieties and export demand.

A.2 About mungbean

Mungbean (*Vigna radiata* (L.) Wilczek) is a tropical grain legume grown in summer-dominant rainfall areas of northern Australia. Until 2009, annual production of this crop was ~35,000 t, generating >AU$25 million in exports to Japan, India, the USA and the Philippines.

Based on the current and projected demand of this crop, there is potential to increase the size of the mungbean industry to 100,000 t/year. A major problem in achieving this target, however, seems to be that the crop's production fluctuates considerably, which is not conducive to maintaining reliability of supply. Historically, poor perception by farmers of mungbean as a low-yielding high-risk crop after a winter cereal (Lawn and Russell 1978) has limited the expansion of the crop into new areas and planting windows (Robertson *et al.* 2000).

The mungbean cultivar Crystal(Þ has a yield advantage of ~20% compared with the first germplasm introduction of varieties such as Emerald(Þ and White Gold™ in Australia. The cultivation of Crystal(Þ is therefore resulting in higher profitability, boosting growers' confidence and improving the perception of the crop (Figure 1). However, its yield potential remains less than that of other summer legumes. Yields of up to 5 t/ha of newly released peanut and soybean cultivars of comparable maturity are being realised in good rainfall years in Australia. This suggests that high commercial yield from legumes is possible. [2]

[2] YS Chauhan *et al.* (2010) Physiology of mungbean and development of the mungbean crop model. Ist Australian Summer Grains Conference, https://www.grdc.com.au/uploads/documents/2010ASGCEditedPapersPDF/Chauhan_MungbeanCropModel_edited_paper.pdf

A.3 Mungbean in Australia

The first commercial mungbean varieties grown in Australia in the late 1960s and 1970s were introduced from The World Vegetable Center (AVRDC) in Taiwan. The Grains Research and Development Corporation (GRDC) then supported CSIRO to begin breeding for Australian environments. With the release of new adapted varieties such as Emerald⊅, mungbean crop production expanded from ~10,000 t in the late 1980s to 20,000 t in 1996 and ~45,000 t by the mid-2000s. CSIRO divested its investment in mungbean in 2002 and research ceased following the release of the variety White Gold™.

In 2003, the Department of Agriculture, Fisheries and Forestry, Queensland (DAFF) and GRDC initiated the National Mungbean Improvement Program (NMIP) to increase productivity of the Australian industry. NMIP targeted improved yield and reliability through utilisation of mungbean genetic resources, improved regional adaptation and new foliar disease resistances, with widespread testing of advanced lines across the northern grains region.

Since the release of Crystal⊅ and Satin II⊅ in 2008, grower and industry confidence has risen markedly, as evidenced by increased planting area (from 45,000 to 66,000 ha) and production (65,000 t). Further benefits of these investments will be realised as new varieties with improved disease resistance come to market.

About 95% of mungbean produced in Australia are exported. Mungbean are mainly marketed as a vegetable rather than as bulk grain, so appearance is very important. A small proportion of mungbean seed produced is used in Australia for sprouting.

Plant breeding was a high priority for the Australian Mungbean Association (AMA) before this investment commenced. Unreliable dryland production was considered a constraint in marketing, so the AMA has set a target of stable annual production of 50,000 t by 2014. Improved yields and greater disease resistance were favoured strategies for increasing the area planted to mungbean through higher profits and greater reliability and confidence. [3]

More information

International collaboration to develop the Australian mungbean industry.

An economic analysis of GRDC investment in the Mungbean Improvement Program.

[3] Agtrans Research (2011) An economic analysis of GRDC investment in the Mungbean Improvement Program. GRDC, https://www.grdc.com.au/uploads/documents/Mungbean%20Breeding%20final%2030%20June%2020111.pdf

A.4 Certified Agronomist Scheme

In September 2000 the AMA, in conjunction with the (then) Queensland Department of Primary Industries and Fisheries and Pulse Australia, initiated an industry-accredited training courses for agronomists.

The aim of these courses is to provide agronomists with the technical knowledge and practical skills required to assist growers to achieve more reliable and profitable mungbean production.

The need for these courses was based on feedback from growers that many agronomists had an inadequate level of expertise in mungbean management. This resulted in some poor decisions during critical stages of crop development, particularly insect management and desiccation. Most agronomists spend only a small percentage of their time working with mungbean, so this was understandable, and a targeted training program was seen as the most effective solution.

Growers are also encouraged to attend these courses. Agronomists and growers wishing to attend a future course should contact the AMA or Pulse Australia.

A.4.1 Industry accreditation

The accreditation process is based on four key steps:

1. A 2-day technical workshop addresses the 18 key issues identified by the industry as the main prerequisites for more reliable and profitable mungbean production.
2. Detailed in-field monitoring of at least one commercial mungbean crop, where the agronomists must demonstrate that they can apply the technical skills and processes covered in the initial workshop. This is the auditable component of the course and the main prerequisite for accreditation within the industry guidelines.
3. In-crop training sessions. Agronomists are further supported by in-crop training sessions on insect scouting techniques and management, as well as disease diagnosis.
4. Ongoing technical support on current research and reassessment of best management practices within the mungbean industry. The network of certified agronomists is also kept informed of any new and emerging issues within the industry, e.g. new pesticide registrations or permits.

More information

Australian Mungbean Association Certified Agronomist Scheme.

A.5 Keywords

Mungbean, black gram, pulse, legume, breeding, accredited agronomist scheme.

SECTION 1

Planning and paddock preparation

More information

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Summer-crop-options-for-the-central-west-mungbeans-soybeans

http://www.regional.org.au/au/asa/1993/concurrent/summer-crops/p.htm

http://www.queenslandcountrylife.com.au/news/agriculture/cropping/general-news/mung-beans-the-opportunity-crop/2684808.aspx

1.1 Paddock selection

Paddocks selected for mungbean should have relatively uniform soil type and stubble cover and a lack of harvest impediments such as sticks and stones. These are important considerations because of the low height of mungbean pods and the need to reduce the tendency for uneven crop maturity. [1]

Selection of the most appropriate paddock for growing mungbean requires consideration of previous crops, the history of diseases on mungbean, other crops and weeds in the paddock, and the herbicide history. Other legume crops such as cowpeas, navy beans and soybeans are known hosts of the important bacterial pathogens of mungbean, while crops such as sorghum, sunflowers and maize and many weeds are important hosts of charcoal rot.

Sulfonylurea (Group B herbicide), triazine (Group C), or Group I herbicides such as Lontrel™ (active ingredient clopyralid) and Tordon 75-D (picloram + 2,4-D) applied in the last 12 months can either cause direct damage or favour the development of some diseases (particularly charcoal rot) in herbicide-weakened plants. The presence of these herbicide residues in soil may cause crop damage, making in-field disease diagnosis difficult. [2]

1.2 Paddock history and double-cropping

Mungbean are sensitive to several residual herbicides, so caution is needed when selecting paddocks where residual products have been used. [3] Paddock selection should be based on crop history and herbicide history.

Mungbean are best included in the rotation after a cereal crop (either winter or summer). This may be as a double-cropping option immediately following winter cereal harvest, as a short fallow (6 months) following sorghum, or after a long fallow (18 months) from a winter cereal crop. In all situations, mungbean are well suited to no-till situations, and

[1] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[2] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

[3] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

planting directly into standing cereal stubble encourages the crop to grow taller, resulting in additional height to the lowest pods for ease of harvest.

Relay cropping is another option, whereby mungbean are sown into a standing crop such as maize or wheat before that crop is harvested (Figure 1).

Mungbean should not be planted into winter cereal stubbles where Group B herbicides such as Ally® (metsulfuron), Glean® (chlorsulfuron) or Logran® (triasulfuron) have been applied, as these products typically have a 9–15-month plant-back period. Similarly, when planting into sorghum stubble, atrazine residues are most likely to be a concern. The rate used will determine the plant-back safety, with 9 months being adequate at lower rates. [4]

More information

http://grdc.com.au/Media-Centre/GRDC-Podcasts/Northern-Weekly-Update/2014/11/061-north

http://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-104-May-June-2013/Relay-cropping-extends-cropping-window

Figure 2: Relay cropping mungbean into maize. (Photo: GRDC)

1.3 Benefits as a rotation crop

Mungbean are a summer crop alternative to provide diversification for risk management in terms of agronomy, environment and marketing. As a quick-maturing crop, they often slot between other summer crops, allowing for better utilisation of farm labour and machinery.

Summer grains, including mungbean, have cemented their place in northern rotations as valuable break-crops for managing pests, diseases and herbicide resistance.

Crop sequencing with summer grains can also lift farm profits by adding income and potentially reducing fertiliser and other costs.

[4] L Jenkins (2012) Summer crop options for the central west—mungbeans & soybeans. GRDC Update Papers, 10 April 2012, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Summer-crop-options-for-the-central-west-mungbeans-soybeans

Research trial results

Over the 2012–13 summer, two mungbean trials were conducted at Taabinga and Redvale, near Kingaroy, Queensland. Both trials were a factorial combination of the following treatments: 2 row spacings (30 and 90 cm) × 3 plant populations (20, 30 and 40 plants/m^2) × 3 varieties (Crystal(), Satin II(), and Jade-AU()). Each trial had 3 replicates.

Yields were not significantly different for any of the treatments at either trial, but N fixation analyses showed that variety interacted with row spacing for %Ndfa (percentage of N in the plant shoots that is derived from the atmosphere rather than soil nitrate supplies). Both Crystal() and Jade-AU() had much reduced N fixation as row spacing changed from 30 to 90 cm (Crystal , but Satin II() fixed a similar, high proportion of N (48% and 49%) at both row spacings (Figure 2).

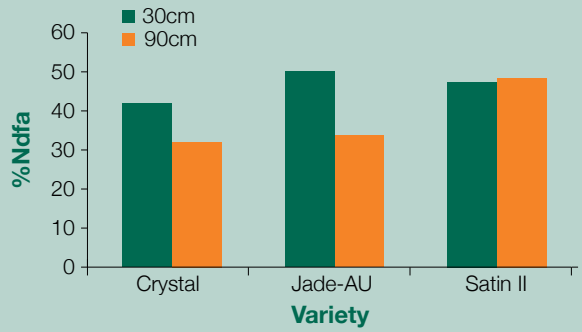

Figure 3: Percentage of N derived from the atmosphere for three mungbean varieties grown at two different row spacings.

More information

http://grdc.com.au/Resources/Factsheets/2011/03/Choosing-Rotation-Crops-North

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Rootlesion-nematodes-Crop-rotations-and-varietal-impacts-on-nematode-populations

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Latest-nematode-summer-and-winter-crop-rotation-results

1.4 Disadvantages of mungbean as a rotation crop with sugarcane

Legumes are proving complementary crops for inclusion in sugarcane rotations; however, some perform better than others. Although the 3-month growing period of mungbean makes them well suited to the sugarcane rotation, the crop is not considered the ideal choice for this situation.

Mungbean and navy bean crops have similar requirements, although mungbean are hardier. Navy beans are currently grown in the Atherton Tableland. Mungbean have been tried in the Burdekin and Mackay sugarcane districts.

A consistent demand exists for mungbean, but freight costs to buying depots in Kingaroy and Biloela can be a limitation. Global supplies and quality determine the price, and small areas in cane fallows are unlikely to give attractive returns.

Insect pests such as bean fly, *Helicoverpa* and green vegetable bugs are potential problems, and nematodes destroyed many of the crops in Mackay. It is essential to engage consultants to scout for bugs. [5]

1.5 Avoiding the risk of herbicide-residue damage

Herbicide residues can be a significant problem in mungbean, because many growers use

[5] DAFF (2011) Complementary crops in the sugarcane industry. Department of Agriculture, Fisheries and Forestry Queensland, https://www.daff.qld.gov.au/plants/field-crops-and-pastures/sugar/complementary-crops

More information

http://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS111/Rotate-to-reduce-nematode-risk

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Management-impacts-on-N-fixation-of-mungbeans-and-chickpeas

the crop opportunistically and will either double-crop after winter cereals or short-fallow through from summer crops such as sorghum or cotton. In both cases, herbicide residues can pose a risk, particularly after dry or cold winter conditions.

When the crop is used opportunistically, it is often difficult to plan an appropriate herbicide strategy with the preceding crop that will avoid residue problems in mungbean. However, if planning to plant mungbean, consider using alternatives to Tordon™ (picloram + 2,4-D), Glean® (chlorsulfuron) and atrazine in the preceding crop.[6]

1.5.1 Sulfonylurea (SU) residues (Group B herbicides)

[Chlorsulfuron (Glean®), triasulfuron (Logran®), metosulam (Eclipse®), metsulfuron (Ally®, Harmony® M)]

Breakdown of SU occurs by hydrolysis, and is favoured by warm, moist conditions in neutral to acid soils. Residues will tend to persist for longer periods under alkaline, dry conditions. Persistence of SU residues is greater for chlorsulfuron and triasulfuron, than for metsulfuron.

Residues are absorbed by roots and translocated to the growing points; therefore, both roots and shots are affected.

At moderate residue levels, seeds will fail to emerge.

At low residue levels, seedlings develop symptoms as the roots hit the SU residue layer in the soil. This may occur in the early seedling stage on heavy clay soils, or slightly later on light sandy soils due to movement of residues down the soil profile.

Symptoms include:

- spear-tipping of lateral roots (root pruning)
- reddening or purpling of uppermost leaves, progressing to older, lower leaves in severe cases
- development of zinc deficiency symptoms (leaf cupping)
- biomass reduction (reduced growth)

Highly susceptible indicator weeds:

- brassicas—turnip and mustard 0.5 ppb (0.5 µg/L) of Glean®
- red pigweed, mintweed
- native jute
- Parthenium weed

High sensitive crops (in order of susceptibility):

- sunflower
- mungbean
- cotton

[6] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

Strategy: Avoid using chlorsulfuron (Glean®) or triasulfuron (Logran®) for winter cereal production in the same year as you intend growing mungbean. Revise strategy if soil pH is above 8.5 or drought conditions are experienced. [7]

1.5.2 Triazine residues (Group C herbicides)

(Atrazine and simazine)

Atrazine breakdown is strongly influenced by soil type and climate. Rates of breakdown slow considerably under dry conditions, and can stop altogether under drought. Atrazine is more persistent under the following conditions:

- alkaline soils (especially pH >8.0)
- increasing clay content (i.e. black earths)
- low soil temperatures
- low soil moisture levels

Atrazine is absorbed by roots and translocated up into the shoots where it accumulates and inhibits photosynthesis.

Symptoms: Plants usually emerge but begin to show symptoms of stunting and chlorosis at 2–6 weeks of age. Atrazine accumulates from the tip down to the base of the leaf, and along the leaf margins of the older leaves, followed by necrosis and death of the leaf or, eventually, the whole plant. Death of leaves proceeds from the oldest lower leaves and gradually extends up the plant to the youngest leaves.

General stunting of whole of plant (leaves and stem) often occurs first. There is usually a uniform chlorosis of the oldest leaves. No speckling or stripes occur in mungbean. Sometimes a whitish, bleached appearance may occur on the leaves. The stem below the affected leaves may bend, and occasionally there may be some chlorosis and or bleaching of this area.

Other Group C herbicides such as diuron and fluometuron cause similar symptoms, mainly on the older, lower leaves. This can occur in a replant situation after failed or hailed-out cotton.

Highly susceptible indicator plants:

- mintweed
- brassicas
- sunflower
- black pigweed

Strategy: Avoid using heavier rates of atrazine (>2.5 L) for sorghum production in the same year as you intend growing mungbean. Revise mungbean planting strategy on highly alkaline black earths if drought conditions are experienced. [8]

[7] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

[8] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

1.5.3 Picloram residues (long-lasting residual Group I herbicides)

[Picloram: (+ 2,4-D; Tordon 75-D™), (+ MCPA; Tordon 242™), (+ triclopyr + aminopyralid; Grazon DS™)]

Picloram residues are relatively stable in the soil, with residues fixed into clay particles and remaining concentrated in the top 10–15 cm of soil. Residues are slowly broken down by microbial action, with decomposition slowing during the colder winter months. Up to 25% of the applied dose can persist for up to 12 months, or longer under dry conditions.

Symptoms of low-level residue damage are not always readily visible in mungbean.

Symptoms include:

- retarded, slow growth
- thickening and callousing of the lower stem, usually just above ground level; can be accompanied by cracking and splitting of the stem
- proliferation of short, lateral roots
- some slight twisting and bending of the main stem
- at heavier rates of residue, effects on leaf shape, with a narrowing and thickening of leaves.
- severe reaction, possible cupping and stunting of leaves

Indicator plants: Sunflowers are highly susceptible, affected by soil residues as low as 5 ppb (5 µg/L).

Strategy: Avoid using Tordon™ products for winter cereal production if you are considering the option of double-cropping back to mungbean.[9]

1.5.4 Relative susceptibility to residues

Different weeds and crops have different levels of susceptibility to herbicide residues (see Table 1).[10]

Table 1: Weed and crop susceptibility to residues (source: Steve Walker, DPI&F)

Bioassay based on dose needed to cause a 30% reduction in seedling growth. Note: 1 ppb in the top 10 cm soil = 1 µg/L; 1 ppm in the top 10 cm soil = 1 mg/L

Atrazine	(ppm)	Glean® (chlorsulfuron)	(ppb)	Ally® (metsulfuron)	(ppb)	Logran® (triasulfuron)	(ppb)
Mintweed	0.03	Sunflowers	0.42	Sunflowers	0.07	Sunflowers	0.24
Sunflowers	0.05	Turnip weed	0.47	Cotton	0.29	Mungbean	0.26
Barnyard grass	0.08	Mungbean	0.84	Mungbean	0.39	Cottom	0.78
Mungbean	0.15	Sorghum	0.86	Sorghum	0.61	Sorghum	0.86
Cotton	0.15	Cotton	0.91				
Sorghum	0.73	Paradoxa grass	0.92				

[9] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

[10] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

1.6 Seedbed requirements

Soil type, paddock topography, and surface condition of the paddock are all important suitability criteria for mungbean planting.

Harvest losses are much higher in rough or uneven paddocks, particularly in dry seasons when crop height is reduced. Sticks or rocks, eroded gullies or gilgais (melon holes) will prevent headers operating at low cutting height. On-farm surveys have shown unharvested losses to be five times greater and total harvest losses 50% higher in rough paddocks than in smooth paddocks (Easdown and Walsh 1988). This is particularly important when headers with wide fronts are to be used. Small variations in paddocks topography can lead to big variations in cutting height across a wide front and a subsequent increase in harvest losses.

Crop maturity can be significantly affected by moisture supply. Changes in soil type and moisture-holding capacity across a paddock can lead to uneven crop maturation, delayed harvesting and increased risk of weather damage or high harvest losses. Paddocks with even soil types are easier to harvest, and are preferred for mungbean. [11]

1.6.1 Avoid major variations in soil types

Crop maturity can be significantly affected by moisture supply during the growing season. Any major changes in soil type and moisture storage capacity across a paddock can lead to uneven crop maturity, delayed harvest, and increased risk of weather damage and/or high harvest losses due to shattering. Uneven crop development also complicates timing of insecticide sprays, and timing of desiccation.

Selecting a paddock with minimal variation in soil type will often help to provide even maturity and ripening of the crop. This will enable harvesting at the earliest possible time, increase quality, and minimise harvest losses. The overall result is usually a more profitable crop. [12]

1.6.2 Avoid gilgai or contoured country

Contours and undulating melon hole country present two problems to the mungbean grower.

First, uneven crop maturity can occur if there is variable soil moisture across the paddock. Melon holes usually store more water than the mounds, and these areas will often continue flowering and podding when the rest of the crop is already drying down. Similarly, contour banks retain more moisture after rain, and prolong crop maturity relative to the rest of the crop.

Second, gilgais can lead to high harvest losses and increased risk of dirt contamination in the header sample. Many dryland mungbean crops require the header front to be set close to ground level, and even small variations in paddock topography can lead to large variations

[11] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

[12] G Cumming *et al.* (2014) Northern mungbean. Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

in cutting height across the header front, and a significant increase in harvest losses. Contamination of the harvested sample with soil and clods is difficult to avoid in undulating, melon-hole country and can cause significant downgrading of quality and price. [13]

1.6.3 Sticks, stones, clods of soil, ridged surface

The smoother the paddock surface, the easier it is to harvest mungbean.

Stones and sticks are a concern in either poorly or recently cleared country. Harvest losses increase dramatically if the front needs to be raised to avoid serious mechanical damage to the header. Small stones and wood fragments can also contaminate the seed sample and downgrade quality.

Cloddy or badly ridged paddocks are likely to cause contamination of the mungbean sample during harvest. Small clods of black soil are difficult to grade out and can limit market opportunities for the crop. Level the soil surface as much as possible, during ground preparation or at planting. Use of a land-roller after planting can be helpful where you need to level the soil surface, to push clods of soil and small stones back down level with the surface.

1.6.4 Bunching and clumping of stubble

Stubble bunching or clumping can occur in many no-till situations as a result of blockages at planting time. These mounds of stubble are often picked up in the header front, causing mechanical blockages and contamination of the sample if they contain excessive amounts of soil.

Management options for dealing with stubble clumping include:

- using a no-till planter capable of handling heavy stubble
- modifying existing air-seeders (lifting some tines)
- using rotary hoes to spread and level stubble

Standing stubble can be slashed or burnt if planting equipment with good trash flow is not available. [14]

1.6.5 Avoid high risk, marginal soil types

Several soil types are considered marginal for mungbean production because of unreliable performance under all but very favourable climatic conditions:

- high bulk density, compacted soils
- sodic soils
- soils with saline layers in the root-zone

All of these soil conditions can severely restrict root development and limit access to stored soil water. Affected crops display poor growth and early onset of moisture stress.

[13] G Cumming *et al.* (2014) Northern mungbean. Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

[14] G Cumming *et al.* (2014) Northern mungbean. Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

It is often difficult to balance the costs associated with mungbean production (i.e. insect management, desiccation, etc.) against a reasonable profit on these marginal soil types.[15]

1.6.6 Compacted, high bulk-density soils

Quick-maturing, taprooted crops such as mungbean tend to struggle on dense soils (bulk density >1.4 g/cm^3) and often have poor growth, with reduced yield potential and harvest difficulties because of the reduced crop height. These problems can be further compounded by tillage plough-pans and compaction caused by livestock.

Some of these problems can be partially offset by:

- planting only on a full profile of soil moisture
- adopting a no-till system
- maintaining heavy stubble cover
- avoiding grazing fallows prior to cropping
- using wider row spacing to assist harvest operations and cut production costs (e.g. band-spraying)[16]

1.6.7 Sodic soils

Soils high in sodium are structurally unstable, with clay particles dispersing when wet. This blocks soil pores, reduces water infiltration and aeration, and retards root growth. On drying, a sodic soil becomes dense, and forms a hard crust up to 10 mm thick. This can also restrict seedling emergence.

Sodicity is measured as the exchangeable sodium percentage (ESP), ranked as:

- non-sodic soil, ESP <3
- sodic soil, ESP 3–14
- strongly sodic soil, ESP ≥15

Soils that are sodic in the topsoil have the greatest impact on crop performance. Sodic layers deeper in the soil profile are not as great a concern, but can still affect yields by restricting root development and water extraction from depth.

Different crops have varying tolerance to sodicity (see Table 3). Affected crops display poor growth and early onset of moisture stress.

[15] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

[16] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

Table 2: Relative tolerance of crops to sodicity (high exchangeable sodium percentage) (source: Abrol 1973)

Tolerant	Semi-tolerant	Sensitive
Rice	Barley	Maize
	Wheat	Cowpeas
	Cotton	Peanuts
	Sorghum	Mungbean
		Lentils
		Sunflowers
		Guar
		Chickpeas

Soil sodic layers deeper than 60 cm are unlikely to impact significantly on mungbean yields.

Although there is no clear-cut association between topography and vegetation type on the occurrence of sodicity, the problem is more likely to occur in:

- brigalow and brigalow–belah land systems
- duplex red-brown earths
- poplar box on texture-contrast soils
- ironbark/bulloak country

Some indictors of surface sodicity include:

- soils prone to crusting and sealing up
- ongoing problems with poor plant establishment
- presence of scalded areas in adjoining pastures [17]

1.6.8 Saline soils

Mungbean are extremely sensitive to salinity, and are unable to access water and nutrients from saline layers in the soil. This limits root development and, consequently, yield.

As with sodicity, saline soil deeper than 60 cm in the profile is unlikely to affect mungbean yields. The closer salinity to the surface, the greater the detrimental effect.

Electrical conductivity (EC) levels >2 dS/m will cause yield reduction in mungbean, whereas other crops will tolerate up to 6 dS/m with no yield reduction. [18]

1.7 Soil moisture

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

Mungbean are well suited to no-till situations, and planting into standing cereal stubble often encourages taller growth, meaning additional height to the lowest pods for ease of

[17] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

[18] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

harvest. No-till also increases the efficiency of storing moisture in the fallow, reducing the risk of crop failure. [19]

More information

http://www.moreprofitperdrop.com.au/wp-content/uploads/2012/02/200809MungbeanExcellenceAwardbrochure.pdf

1.7.1 Dryland

Growers must assess the amount of stored soil water and potential yield. Paddocks with <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. [20]

Assessing soil water and yield potential to achieve reliable mungbean yields

Growers must have a realistic yield expectation of mungbean, based on stored soil water, when planning for the crop.

Monitoring of commercial crops by Agricultural Production Systems Research Unit (APSRU) has clearly demonstrated that many growers and agronomists overestimate the amount of water stored in the soil, PAW capacity, in some cases by as much as 100 mm on clay soils.

Crops usually struggle when planted in situations of low PAW, and growers are reluctant to make significant management inputs into the crop. Insect control is often neglected, or left unchecked until late in the season, bringing about a further reduction in yield and quality.

This is the most important issue affecting overall levels of mungbean crop reliability and profitability, and needs to be dealt with as a priority by accredited mungbean agronomists.

The best way of dealing with this problem is to establish a realistic yield estimate for each paddock situation, based on an accurate assessment of soil water storage prior to planting.

Paddocks with <75 mm PAW often produce unreliable or unprofitable crops, and are often best left unplanted and fallowed through to another crop later in the season. It is difficult to justify the significant cost inputs associated with mungbean production if yield potential is <0.7 t/ha. [21]

More information

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/175911/East-dryland-mungbeans-12-13.pdf

Plant-available water capacity

Approximate values for PAW capacities for a well-grown mungbean crop are presented in Table 4 for general categories of soil type/vegetation type.

Estimates are based on the water extraction capability of a mungbean crop. Potential PAW extraction levels will be higher for other crops such as sorghum, cotton and wheat. PAW estimates assume no restrictions on rooting depth from salt, compaction or high bulk density.

[19] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[20] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[21] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

Table 3: Plant-available water capacity (mm) for various soil types at three depths (source: M. Robertson, CSIRO)

Values are approximations only and individual soils may vary by as much as ±15 mm from the value quoted for each major soil type

Soil type	Total storage capacity	0–30 cm	30–60 cm	60–90 cm
Heavy alluvial	190	70	60	60
Heavy black earth	170	70	50	50
Medium black earth	170	60	45	45
Heavy grey clay	140	60	40	40
Grey clay	120	50	35	35
Open downs	100	40	30	30
Red earth	100	40	30	30
Red Ferrosol	90	30	30	30
Shallow black earth (30–60 cm deep)	60-80	50	20	10

Mungbean yield potential based on estimates of starting soil water

Mungbean yield is largely determined by the starting PAW but is also significantly affected by in-crop rainfall.

Table 5 shows Agricultural Production Systems Simulator (APSIM)-simulated mungbean yields for three levels of starting PAW at nine locations in the northern grains region. Simulations were conducted with 100 years of daily historical climate data at each location. The simulation set-up involved the variety Emerald sown on 15 December at 25 plants/m^2. Pests, diseases, weeds and nutrition were not limiting to yields.

Table 4: Predicted mungbean yields (kg/ha) with varying starting soil water and predicted seasonal conditions (source: M. Robertson CSIRO

	Starting soil water (mm)	Drier 10% years	Drier 30% years	Average	Wettest 30% years	Wettest 10% years
Dubbo	170	1050	1285	1511	1822	2238
	110	735	860	1170	1542	1983
	55	382	579	740	1110	1678
Gunnedah	170	1227	1492	1769	2075	2456
	110	886	1123	1400	1727	2292
	55	408	657	886	1265	1836
Walgett	170	987	1184	1396	1718	2369
	110	661	846	1014	1351	2044
	55	322	472	615	933	1538
Moree	170	1090	1309	1503	1811	2511
	110	763	915	1184	1467	2213
	55	409	561	726	1038	1713
Dalby	170	1298	1685	2049	2451	2880
	110	927	1248	1774	2254	2752
	55	549	758	1204	1775	2392
Roma	170	1025	1277	1580	1803	2334
	110	807	1028	1326	1594	2230
	55	441	602	898	1287	1913
Kingaroy	170	1648	1959	2288	2736	3297
	110	1163	1493	1998	2494	2881
	55	682	915	1440	1792	2411
Biloela	170	1408	1666	1861	2150	2433
	110	957	1105	1406	1710	2298
	55	552	693	877	1189	1834
Emerald	170	1061	1318	1563	1834	2245
	110	743	927	1147	1498	1844
	55	415	559	678	983	1307

Rooting depth

Mungbeans can access moisture to 90 cm depth if there is no compaction or saline–sodic layer in the soil profile. Dense, impermeable subsoils (high bulk density) can lead to extensive development of lateral roots in the top 30 cm of soil, with only weak development of the taproot at depth. [22]

1.7.2 Irrigation

Mungbean do not tolerate waterlogging, so irrigation management is critical. Waterlogging will reduce the ability of nodules to fix N2, resulting in induced N deficiency as well. Mungbean require a estimated 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 water/week is normally required during flowering and podfill.

[22] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

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

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

More information

http://www.moreprofitperdrop.com.au/wp-content/uploads/2013/10/WATERpak-4_6-Irrigated-Mungbens-best-practice.pdf

The timing of irrigations is suggested as:

- irrigation 1, ~7 days prior to the start of flowering, which is usually ~30–40 days after planting
- irrigation 2, early pod development

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

Irrigating too late into grainfill may cause production of another flush of flowers, resulting in a split maturity in the crop, delayed harvest, and increased risk of downgrading quality.[23]

Water requirement varies from 350 to 550 mm, Mungbean are sensitive to waterlogging, particularly if irrigated when the soil has been allowed to crack open.

Mungbean should be planted into a full profile; pre-irrigate if necessary to achieve this.

Field selection and fast watering practices are needed to minimise the risk of crop death through waterlogging.

Schedule the first irrigation at 7 days prior to budding (R1). A second furrow irrigation is usually needed only on soils of lower PAW capacity.

Maintain soil water >50% PAW capacity during flowering, podding and seed development. Irrigation is not necessary beyond the full seed stage (R4).

Attention to varietal choice, planting date, row spacing, and plant population are critical to achieving a profitable mungbean crop. [24]

1.8 Yield and targets

1.8.1 Seasonal outlook

Queensland Alliance for Agriculture & Food Innovation (QAAFI) produces regular, seasonal outlooks for summer crop producers. These high-value reports are written in an easy-to-read style and are free. For more information, visit Seasonal Crop Outlook (Sorghum).

[23] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[24] G Harris, G Mace. Irrigated mungbeans—best practice guide. More Profit per Drop, Department of Agriculture, Fisheries and Forestry Queensland, http://www.moreprofitperdrop.com.au/wp-content/uploads/2013/10/WATERpak-4_6-Irrigated-Mungbens-best-practice.pdf

More information

El Niño—Southern Oscillation.

Managing Climate Variability Climate Champion program.

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

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

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

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

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

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

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

More information

J Sabburg, G Allen (2013) Seasonal climate outlook improvements changes from historical to real time data. GRDC Update Papers.

Australian CliMate.

As outputs, text and two graphical presentations are used to show the current season in the context of the average and all years. Departures from the average are shown in a fire-risk chart as the departure from the average in units of standard deviation. [25]

The Bureau of Meteorology has moved from a statistics-based to a physics-based (dynamical) model for its seasonal climate outlooks. The new system has better overall skill, is reliable, allows for incremental improvements in skill over time, and provides a framework for new outlook services including multi-week or monthly outlooks and the forecasting of additional climate variables. [26]

[25] Australian CliMate—Climate tools for decision makers, www.australianclimate.net.au

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

1.8.2 Fallow moisture

The basis of a successful dryland summer crop is a weed-free fallow. No-till and minimum-till fallows have become the norm; no-till has enabled crops to be sown at the optimum time and to be sown when it is too dry to sow into a cultivated fallow. In addition, no-till has often reduced operating costs to less than those for cultivated fallows, with significant machinery and tractor-time savings.

More information

http://www.apsim.info/Documentation/Model,CropandSoil/CropModuleDocumentation/MungBean.aspx

Opportunity double-cropping following winter cereals has succeeded where there is sufficient soil moisture. In no-tillage systems, stubble retention is vital for improving soil structure, reducing soil erosion and degradation, storing soil moisture, and having a wetter seedbed. Farmers have moved away from cultivating fallows to minimum and no tillage by substituting knockdown and residual herbicides. [27]

1.8.3 Water-use efficiency

Under dryland situations, mungbean has a water-use efficiency of ~5–6 kg grain/mm.ha. [28]

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Summer-crop-options-for-the-central-west-mungbeans-soybeans

http://www.publish.csiro.au/paper/CP10141.htm

http://www.moreprofitperdrop.com.au/wp-content/uploads/2013/10/WATERpak-4_6-Irrigated-Mungbens-best-practice.pdf

1.8.4 Nitrogen-use efficiency

Changes to agronomy can change N fixation in grain legumes .In general, increasing row spacing may decrease the amount of N fixed by legumes. Mungbean variety Satin II, however, appears to compensate for wider rows in its ability to fix N. Varieties can differ significantly in amount of N fixation and this is related to biomass.

High soil nitrate levels can reduce legume nodulation and N fixation. Addition of N fertiliser does not provice a yield advantage in chickpeas or mungbean and may reduce the amount of N available for the following crop.

The amount of N fixed by a legume increases as legume biomass increases and is reduced by high levels of soil nitrate. In general, legume reliance on N fixation is high when soil nitrate levels are <50 kg N/ha in the top 1 m of soil. At soil nitrate levels >200 kg N/ha, N fixation is generally close to zero.

Fixed N is used for the growth of the legume itself (saving fertiliser application of the legume crop), as well as potentially leaving residual N for the following cereal or oilseed crop and providing a break from cereal stubble- and soil-borne diseases. [29]

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[27] J Fleming *et al.* (2012) Weed control in winter crops 2012–13. NSW DPI Management Guide. NSW Department of Primary Industries. http://www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/publications/summer

[28] L Jenkins (2012) Summer crop options for the central west—mungbeans & soybeans. GRDC Update Papers, 10 April 2012, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Summer-crop-options-for-the-central-west-mungbeans-soybeans?highlight=water+use+efficiency

[29] N Seymour *et al.* (2013) Management impacts on N fixation of mungbeans and chickpeas. GRDC Update Papers, http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Management-impacts-on-N-fixation-of-mungbeans-and-chickpeas

More information

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Management-impacts-on-N-fixation-of-mungbeans-and-chickpeas

1.9 Nematode status

Paddocks should be diagnosed for plant parasitic nematodes so that optimal management strategies can be implemented. Testing your farm will tell you:

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

It is important to know which species are present because some crop-management options are species-specific. If a particular species is present in high numbers, immediate decisions must be made to avoid losses in the next crop to be grown. With low numbers, it is important to take decisions to safeguard future crops. Learning that a paddock is free of these nematodes is valuable information because steps may be taken to avoid future contamination of that field. [30]

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

More information

http://www.crownanalytical.com.au

PreDicta B. SARDI Diagnostic Services.

Root-lesion nematodes—management of root-lesion nematodes in the northern grain region. QPIF.

1.10 Insect status

Bean fly and thrips can be damaging to emerging mungbean crops, with thrips a potential risk in spring-sown crops planted near infested winter cereals. [31]

Mungbean are most susceptible to pest attack from budding onwards. In summer in Central Queensland, budding can occur as early as 28–35 days after planting. In spring plantings, budding usually occurs 50–55 days after planting.

Crops should be monitored at least once per week during vegetative growth, preferably

[30] Queensland Primary Industries and Fisheries (2009) Root-lesion nematodes—management of root-lesion nematodes in the northern grain region. Queensland Government, http://www.daff.qld.gov.au/__data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf

[31] NIPI. Mungbeans. IPM Guidelines. National Invertebrate Pest Initiative, http://ipmguidelinesforgrains.com.au/crops/summer-pulses/mungbean/

More information

http://ipmguidelinesforgrains.com.au/crops/summer-pulses/mungbean/

http://ipmworkshops.com.au/wp-content/uploads/BestBet_EstablishmentNorth2014.pdf

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/09/Insect-thresholds-for-key-insects-in-sorghum-sunflower-mungbeans-What-are-they-based-on-and-when-and-how-can-they-be-modified

twice weekly, to determine exactly when the crop is entering its first susceptible stage, i.e. budding. Because the first buds are borne below the top of the canopy, the start of this stage can be determined only by assessing plants within the crop, not by looking at a crop from the road.[32]

[32] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

SECTION 2

Pre-planting

More information

http://grdc.com.au/Media-Centre/Over-the-Fence/Over-The-Fence-Videos/Over-the-Fence/NwdDCFFUQLU

http://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-106-Sept-Oct-2013/Research-delivers-advanced-new-mungbean

Final Report DAQ00060 - National Mungbean Improvement Program.

2.1 Variety characteristics

Mungbean varieties should be clearly separated at planting. Varietal mixtures are unacceptable in the market, and they will usually incur 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. New varieties have been released including Crystal(Þ and Satin II(Þ in 2008, Jade-AU(Þ in 2013 and Celera II-AU(Þ in 2014 (Figure 1).[1]

[1] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

Figure 1: Recently released varieties include Jade-AU(D (pictured) and Crystal(D.

2.1.1 Current varieties of *Vigna radiata*

Jade-AU(D (released 2013): A large-seeded, bright-green mungbean that is broadly adapted to the northern region (Figure 2).

It is suitable for both spring planting (September–October) and conventional summer planting (December–January). It has a demonstrated consistent yield increase of 12% compared with Crystal(D across all regions of central and southern Queensland and northern New South Wales (NSW). It has grain quality equivalent to Crystal(D and is highly acceptable in the market place.

Jade-AU(D has the best available combined suite of resistance to powdery mildew (moderately susceptible (MS), greater than Crystal(D), tan spot and halo blight (MS, equivalent to Crystal(D). Jade-AU(D is of an equivalent plant type and has similar production agronomy to Crystal(D and other current varieties. [2]

[2] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

Figure 2: Jade-AU(D has high grain quality characteristics, equivalent to Crystal(D, and is suitable for the No. 1, Processing and manufacturing markets.

More information

http://www.mungbean.org.au/pdf/Jade%20AU%20VMP.pdf

To hear Department of Agriculture, Fisheries and Forestry, Queensland pulse breeder Col Douglas discuss the benefits of Jade-AU, visit: www.grdc.com.au/MR-MungbeanJade.

Crystal(D (released in 2008): 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, increasing its attractiveness to the cooking and processing markets. Crystal(D is a relatively tall, erect variety with lodging resistance similar to Emerald. [3]

Crystal(D is a large-seeded, bright-green mungbean. It was released by the National Mungbean Improvement Program, under PBR, to the Australian Mungbean Association (AMA) in 2008. It is a cross between White Gold™, Emerald(D and CPI 109897.

Crystal(D is a consistent performer in all regions. Across 5 years of regional testing, it achieved an average of 20% higher yields than Emerald(D and 4% higher than White Gold™. It has the best available combined suite of resistance to powdery mildew, tan spot and halo blight.

More information

http://www.mungbean.org.au/pdf/Crystal%20VMP.pdf

Crystal(D has a widespread adaptation to planting times and is suitable for spring plantings (September–early October), due to its weathering ability, and conventional summer plantings (December–January), due to its level of powdery mildew resistance. [4]

[3] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[4] DAFF (2012) Mungbean varieties. Department of Agriculture, fisheries and Forestry Queensland, https://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/mungbeans/varieties

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 (tan spot, powdery mildew, halo blight) and can be prone to lodging, weather damage and cracking. These factors increase the difficulty of achieving a premium for sprouting-grade quality. [5]

Berkin has medium–large, evenly sized, bright-green seeds and is relatively easy to market because it produces the large sprouts preferred by buyers. Its popularity is enhanced by ready availability of seed and premium achievable over other varieties when seed quality is high.

Berken is very prone to powdery mildew and tan spot. Heavy crops may lodge and grain is susceptible to weather damage and cracking. Without the implementation of best management practices, it is difficult to achieve a premium for sprouting grade beans. [6]

More information

http://www.mungbean.org.au/pdf/Satin%20II%20VMP.pdf

Satin IIФ (released 2008 as a replacement for Satin): A dull-seeded mungbean grown for a niche market. Satin IIФ has improved seed quality, including increased seed size, and offers both significant yield increases (20%) and disease advantages (powdery mildew and tan spot) over Satin. Satin IIФ also offers improved lodging resistance and equal plant maturity compared with Satin. Note, however, that Satin IIФ is a niche variety with a limited market. [7]

Celera II-AUФ (released in 2014 as a replacement for CeleraФ and Green DiamondФ): A small-seeded variety with low levels of hard seed, grown for a niche market in many European and Asian countries. Splitters and millers also like small green mungbean. Note, however, that Celera II-AUФ is a niche variety with a limited market; growers are advised to consult their marketer before planting.

Celera II-AUФ is the first mungbean variety released with an improved resistance to halo blight (moderately resistant, MR). Under moderate–high halo blight pressure, it is higher yielding than all other commercial varieties, reducing production risk. It is broadly adapted to northern NSW and southern Queensland and is suitable for both spring and summer plantings. In Central Queensland, yields have been consistently lower than Jade-AUФ and CrystalФ. [8] [9]

Green DiamondФ (released 1997): A small-seeded variety with very high levels of hard seed (70%). It is a relatively quick-maturing variety, and as such, it often performs better under drier conditions and may be more suited to double-crop situations and the drier

[5] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[6] DAFF (2012) Mungbean varieties. Department of Agriculture, fisheries and Forestry Queensland, https://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/mungbeans/varieties

[7] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[8] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[9] DAFF (2012) Mungbean varieties. Department of Agriculture, fisheries and Forestry Queensland, https://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/mungbeans/varieties

western areas. It is moderately susceptible to all three key diseases. Growers are advised to consult their marketer before planting. [10]

This variety was released by the CSIRO through the AMA in 1997 and is subject to PBR. It has a similar grain quality to Celera(). Hard seed levels can be as high as 70%.

Green Diamond() is a relatively quick-maturing variety that has an even podset and is quick to dry down. It has performed very well in spring-planting situations.

Green Diamond() has an erect growth habit with the pods carried high in the canopy. It often performs better than other varieties under drier conditions, and may be more suited to double-crop situations and the drier western Queensland cropping areas. [11]

Reselected Emerald() (released 1993 by CSIRO through the AMA; subject to PBR): Reselected and increased from original breeders' seed to minimise problems with variability in seed quality in lines of Emerald() that had been in circulation for up to 10 years. In comparative trials, Reselected Emerald() established higher plant populations than regular Emerald() seed. Growers are advised to source Reselected Emerald().

It has medium-large, bright-green seed, and is almost identical in appearance to Berken. Levels of hard seed may be quite high (50%), which currently limits its acceptance into sprouting markets. Demand for this variety is mainly from cooking and processing markets in Asia.

Yields are similar to Berken under tough conditions, but may be up to 20% higher than Berken under favourable growing conditions or if crops are likely to be affected by powdery mildew (late plantings).

Emerald() has been a mainstay of the Australian mungbean industry for many years and is particularly favoured in Central Queensland. It grows taller than most other varieties and is less likely to lodge than Berken. It now has only a low level of resistance to powdery mildew. Crystal(), Satin II(), White Gold™, Emerald() and Delta are still the preferred varieties for late plantings. Emerald() is resistant to Cercospora leaf spot. Maturity can be delayed and uneven where soil moisture levels remain high during the grain-filling period.

High levels of hard seed can cause problems with volunteer plants in subsequent rotational crops (especially cotton). [12]

Tables 1 and 2 present descriptions of available mungbean varieties and comparative grain yields across sites and years.

[10] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[11] DAFF (2012) Mungbean varieties. Department of Agriculture, fisheries and Forestry Queensland, https://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/mungbeans/varieties

[12] DAFF (2012) Mungbean varieties. Department of Agriculture, fisheries and Forestry Queensland, https://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/mungbeans/varieties

Table 1: Characteristics of mungbean varieties available in 2014–15 [13]

Variety	Seed colour	Weathering resistance	Height	Powdery mildew resistance	Lodging resistance	Approximate no. of seeds/kg
Berken	Green	Poor	Short	Very susceptible	Fair	15–20 000
CeleraII-AU(Þ	Green	Fair	Medium	Susceptible	Fair	27–30 000
Crystal(Þ	Green	Fair	Tall	Susceptible	Good	14–17 000
Green Diamond(Þ	Green	Fair	Medium	Moderately susceptible	Good	27–30 000
Jade-AU(Þ	Green	Fair	Tall	Moderately susceptible	Good	13–17 000
Satin II(Þ	Green (dull)	Fair	Tall	Susceptible	Good	14–17 000

Table 2: Grain yields for commercial mungbean varieties expressed as a percentage of Crystal(Þ, and as t/ha (Jade-AU(Þ only) [14]

	Central Queensland	Southern Queensland	Northern NSW	2008	2009	2010	2011	2012	Average
Jade-AU(Þ	1.19	1.14	1.18	1.16	1.10	1.30	1.13	0.95	1.13
Jade-AU(Þ	112	114	108	119	115	111	108	105	112
Berken	86	83	55	80	95	67	84	59	77
Crystal(Þ	100	100	100	100	100	100	100	100	100
Satin II(Þ	106	111	93	116	114	98	104	106	107
No of sites	14	15	9	3	8	14	9	4	38

More information

https://www.grdc.com.au/uploads/documents/Mungbean%20Breeding%20final%2030%20June%2020111.pdf

http://www.mungbean.org.au/pdf/Mungbean%20Management%20Guide.pdf

2.1.2 Black gram (*Vigna mungo*)

The black gram species is closely related to mungbean. It has dull grey-black seeds and pods borne throughout the bush. It is more difficult to harvest because pods are set lower on the plant and maturity is often uneven.

Regur: Has a dark grey seed with good resistance to cracking and weather damage at maturity. Under wet conditions, Regur is more likely to produce seed of reasonable quality. It is more tolerant to waterlogging than the mungbean varieties. It is usually shorter growing than mungbeans and tends to flower over a prolonged period, ripening unevenly. Regur can make excessive vegetative growth under favourable growing conditions and is prone to lodging.

Flowers can abort if prolonged periods of overcast, wet weather are experienced at flowering.

Nodulation is often a problem with Regur, and the crop can be responsive to nitrogen fertiliser. Some growers opt to grow Regur in a back-to-back rotation after mungbeans to improve nodulation.

There is strong demand for high-quality Regur beans for export to Japan. Several grading sheds and grain traders specialise in the marketing of Regur. Processing-grade beans are

[13] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[14] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

sold into other markets for dhal and flour. Growers contemplating planting Regur must ensure effective segregation of black- and green-seeded mungbeans in the paddock, the header and in storage; mixed seed lots cannot be sorted and will be very difficult to market.

Regur is not recommended in Central Queensland, where plants only grow very short, and delayed maturity limits yield. [15]

2.2 Yield assessment

An estimate of yield can be obtained, based on a count of:

- plants per m^2
- pods per plant

Count only mature, black or yellow pods if the crop is ready to harvest. Disregard green pods, or pods stunted by insect damage. The calculation assumes an average of 10 seeds per pod (which is consistent, at 10 or 11 seeds per pod) and an average seed weight of 15,500 seeds/kg (Table 3).

This estimate can be adjusted up or down by 20% based on actual seed size; for small seed reduce the estimate by 20%, and for large seed increase the yield by 20%. Variety has a major effect on seed size (Table 4).

Table 3: Estimated mungbean yield (kg/ha) based on plant population and number of pods per plant

Population (plants/m^2)	No. of pods per plant			
	5	10	15	20
10	250	500	750	1000
15	375	750	1125	1500
20	500	1000	1500	2000
25	625	1250	1875	2500
30	750	1500	2250	3000

[15] DAFF (2012) Mungbean varieties. Department of Agriculture, fisheries and Forestry Queensland, https://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/mungbeans/varieties

Table 4: Effect of variety on seed size of mungbean varieties and Regur black gram

Varieties	Release	Seed colour	No. of seeds/kg
Berken	1975	Bright green	16,000
Black Pearl	1994	Bright green	17,000
Celera(b)	1969	Bright green	29,000
Crystal(b)	2008	Bright green	16,000
Delta	1997	Bright green	15,000
Emerald(b)	1993	Bright green	16,000
Green Diamond(b)	1997	Bright green	26,000
Satin II(b)	2008	Dull green	15,000
White Gold™	2002	Bright-green	13,000
Jade-AU(b)	2013	Shiny green	15,500
Celera II-AU(b)	2014	Shiny green	15,500
Regur (black gram)	1975	Dull grey-black	19,000

Each variety can vary ±15–20% around the values in Table 4 based on environmental conditions experienced during podding and grainfill. For example, Crystal(b) can range from 14,000 to 17,000 seeds/kg.

infocus

2.2.1 APSIM Mungbean Model

Yield formation in mungbean can be described by the daily capture and utilisation of environmental resources such as solar radiation, soil water and nutrients for biomass production (Figure 3).

To accomplish this, leaf canopy is produced, incident radiation is intercepted, and the absorbed energy is converted into assimilates, which are partitioned between plant components, including seed. The soil supplies water and nutrients needed by plants; various plant processes can be limited if the demand exceeds the soil supply. These processes occur as the plant goes through a series of phenological events in response to environmental stimuli, which set the potential biomass production and its partitioning into different components, including yield.

Different components of this framework offer opportunities for genetic and agronomic manipulation to improve yield, but the potential to manipulate seems greater for some components than others (Figure 3). This basic framework, as for other legume crops, forms the basis of the current Agricultural Production Systems Simulator (APSIM) mungbean model (Robertson *et al.* 2002). [16]

[16] YS Chauhan *et al.* (2010) Physiology of mungbean and development of the mungbean crop model. Ist Australian Summer Grains Conference, https://www.grdc.com.au/uploads/documents/2010ASGCEditedPapersPDF/Chauhan_MungbeanCropModel_edited_paper.pdf

More information

https://www.grdc.com.au/uploads/documents/2010ASGCEditedPapersPDF/Chauhan_MungbeanCropModel_edited_paper.pdf

http://www.apsim.info/Documentation/Model,CropandSoil/CropModuleDocumentation/MungBean.aspx

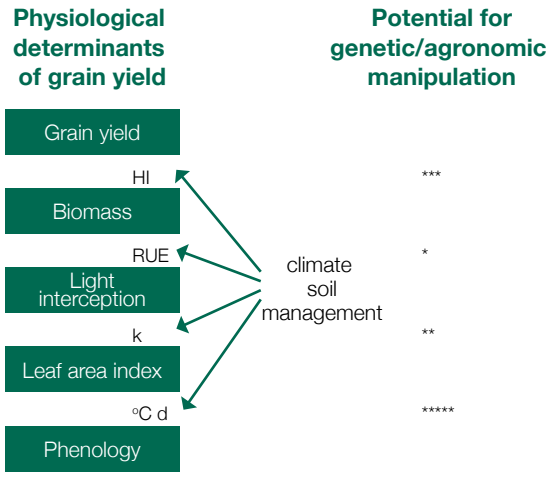


Figure 3: A physiological framework of yield formation in mungbean; the potential for genetic and agronomic manipulation at a particular level is indicated by the number of asterisks (with increasing number of asterisks indicating greater potential for manipulation).

2.3 Seed quality

2.3.1 Seed quality and varietal purity

Varietal purity is essential, because mixtures are unacceptable in the market. Mixed seed lines will often attract heavy discounts purely on their appearance. This particularly applies to contamination with varieties such as Satin II(D), with its dull seed coat giving the appearance of weather damage in the sample. Mixtures can also create problems by germinating unevenly (a consideration for sprouting beans).

The quality of grower-retained seed can deteriorate over 2–3 years of grow-outs due to genetic drift. These seed samples often look uneven and may have a large proportion of dull blue-green seeds mixed with shiny seeds.

Replace planting seed every 2–3 years. Grower-kept and older seed stocks have poorer emergence than seed from the AMA Approved Seed Scheme.

The AMA is the current commercial partner of the National Mungbean Improvement Program, and as such, it is responsible for the production of all commercially available seed. Purchase only seed that is clearly labeled as AMA-approved seed.

Seed is available directly from your AMA members or your local seed merchant. [17]

2.3.2 Germination

All seed offered for sale must clearly state the germination percentage and purity of that seed line. If planting grower-retained seed, the seed should be laboratory-tested, because germination can deteriorate over time.

Crystal(D) and Jade-AU(D) both have low levels of hard seed; however, many of the older varieties such as Emerald(D) and Green Diamond(D) can contain high levels of hard seed.

[17] J Gentry (2010) Mungbean management guide. 2nd edn. Pulse Australia, Australian Mungbean Association, Queensland Government, http://www.mungbean.org.au/pdf/Mungbean%20Management%20Guide.pdf

High levels of hard seed can result in uneven germination and establishment. This will complicate decisions about insect and harvest management and can dramatically reduce the financial return. Hard seeds planted into marginal moisture may not germinate until the next in-crop rainfall event after planting.

For the same reason, hard-seeded lines should also be avoided on lighter soils in western areas. The seed zone can dry out rapidly at planting time, with hard seed failing to germinate until there is follow-up rain.

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

Seed retained on-farm for planting purposes should be heavily graded to remove small seeds and any cracked or broken grain. Seed from the AMA Approved Seed Scheme generates higher plant populations than ungraded, grower-kept seed. [18]

2.4 Safe rates of fertiliser sown with seed

Fertiliser recommendations for mungbean tend to be very generic, with a reliance on relatively low rates of mono-ammonium phosphate (MAP)-based starter fertilisers for meeting the crop's full nutritional requirements. This often based on convenience and availability. Although planter configuration (row spacing and opener type) needs to be considered in relation to the risk of seed burn, in practice this is not a problem because of the low rates used.

[18] J Gentry (2010) Mungbean management guide. 2nd edn. Pulse Australia, Australian Mungbean Association, Queensland Government, http://www.mungbean.org.au/pdf/Mungbean%20Management%20Guide.pdf

SECTION 3

Planting

Mungbean varieties should be clearly separated at planting. Varietal mixtures are unacceptable in the market. Unless harvest equipment and storage facilities can be thoroughly cleaned, restrict planting to one variety.

Achieving an even strike and even maturity is vital for mungbean. Extra care at planting can produce more uniform flowering, making both insect management and harvesting more straightforward.

To achieve a better quality sample and higher returns growers should:

- Avoid paddocks with major changes in soil types, which can result in uneven maturity.
- Avoid sowing wheel tracks, which could result in staggered germination.
- Avoid paddocks with a rough seedbed or stones.
- Employ rolling or 'prickle chaining' on non-crusting soils, which helps to level the surface and promotes more even emergence and maturity.
- Ensure an even planting depth right across the machine; this is particularly important with airseeders.
- Avoid sowing mungbean if moisture levels are marginal and likely to result in a patchy strike or staggered germination.
- Avoid seed lines with high levels of hard seed (dormant seed), which can result in an uneven, staggered germination.

Herbicide residues can be a significant problem in mungbean, because many growers plant the crop opportunistically and will double-crop after winter cereals, or short-fallow through from summer crops such as sorghum or cotton. In both cases, herbicide residues can pose a risk, particularly after dry or cold winter conditions. Plan an appropriate herbicide strategy within the preceding crop that will avoid the threat of residue problems in mungbean. [1]

3.1 Inoculants

Mungbean is an introduced species requiring the correct strain of bacteria to fix atmospheric nitrogen (N_2) effectively. All seed should be inoculated with Group I mungbean inoculant (*Rhizobium* strain CB 1015). A sticker is essential to retain the inoculum on the seed and increase survival percentages when sowing into hot soil conditions. Always refer to the product's instructions.

Mungbean seed should be sown as soon as possible after inoculation into moist soil to

[1] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

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 significant yield reduction.

Inoculation may be carried out in several ways: by coating the seed with peat slurry, by using granular products, or via water injection behind the sowing tines or discs. [2]

Inoculation is essential for successful nodulation. Poor nodulation is a common problem in mungbean and can result in a significant yield reduction (up to 50%) in situations where residual nitrogen (N) levels in the soil profile are already low (i.e. double-crop situations). Growers are urged to pay greater attention to inoculation practices if these problems are to be avoided.

A survey in 2004–05 of commercial mungbean crops, conducted by the (then) Department of Employment, Economic Development and Innovation, Queensland (DEEDI), indicated that only 50% of crops were nodulated with the correct strain. Mungbean will nodulate with a range of native soil bacteria but their N-fixation is very erratic. The most effective method of ensuring nodulation with the applied strain of inoculum is to deliver the highest possible concentration of live cultures onto the seed and sow as quickly as possible.

Field trials by DEEDI have found water injection to be the most effective means of delivering inoculum, producing higher levels of nodule occupancy than slurry methods and uninoculated controls. However, water injection will likely require modification to planting equipment and water volumes may be unsuitable for larger areas.

More information

http://www.grdc.com.au/GRDC-Booklet-InoculatingLegumes

The most common means of inoculating mungbean is to coat the seed with a slurry of peat-based inoculum immediately before planting. New developments in inoculum delivery have led to products that offer easier handling and more convenient application methods.

Avoid exposing recently inoculated seed to hot, drying winds or direct sunlight. This rapidly kills the bacteria. [3]

3.1.1 Methods of inoculation

There are two main methods of inoculation: using a slurry and water injection. Dry inoculation is not recommended. It is preferable not to mix fertilisers and insecticides with inoculum or inoculated seed because many pesticides are toxic to rhizobia. Check compatibility before use. Where fertilisers or insecticides are mixed with inoculum, use immediately.

Slurry inoculation with water

This is the most common form of inoculation. The inoculant is mixed with cool water then mechanically mixed (with a cement mixer, feed mixer, auger, or recirculating grain dryer) to evenly coat the seed. Be careful to avoid crushing or cracking the seed coat. The auger system is the most common and is effective provided you have an accurate and constant

[2] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[3] J Gentry (2010) Mungbean management guide. 2nd edn. Pulse Australia, Australian Mungbean Association, Queensland Government, http://www.mungbean.org.au/pdf/Mungbean%20Management%20Guide.pdf

metering system for the slurry mix. Meter the slurry in according to the flow rate of the auger (~1 L slurry is needed per 100 kg seeds) and adjust accordingly. Too much water means sticky seed and blockages in the planter. Make sure the auger is running as slowly as possible. Reduce the height of the auger to minimise seed damage as the seed falls from the auger.

Water injection

This method places a band of inoculum, suspended in water, in the seed furrow. The roots of the germinating seed grow through the band of inoculated soil. Results are generally good, except under very dry conditions. Water rates vary depending on row spacing. Conventional water injection equipment can be used if it is free from pesticide or fertiliser residues.

If water-injecting both inoculant and fertiliser, ensure that there is no zinc in the fertiliser formulation. Zinc is highly toxic to inoculum.

Dry inoculation

This method is not recommended because survival of inoculum is low, and most of the inoculum is lost from the seed before and during planting. It involves mixing packets of peat inoculum with the seed, or dusting it in the seed box. [4]

3.1.2 Inoculation checklist

When purchasing inoculant:

- Check the expiry date on packet.
- Check how it has been stored—packets should be stored at ~4°C.
- Do not freeze (<0°C) or exceed 15°C.
- Select Group I mungbean inoculum.

When applying inoculum:

- Prepare slurry and apply in the shade, avoid high temperatures (<30°C), direct sunlight, and hot winds.
- Accurately meter adhesive slurry onto the seed, too much water means sticky seeds and blockages in the planter.
- Avoid high speed mixing in augers.
- Sow inoculated seed immediately. Never delay beyond 12 h.
- Check air-seeders for excessively high temperatures in the airstream; temperatures >50°C can kill the bacteria. [5]

[4] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

[5] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

3.2 Nodulation—meeting the crop nitrogen requirement

Nodulation and yield responses to inoculation are inconsistent in mungbean. Reasons for this variable response include:

- Paddocks often contain a reasonable level of residual nitrate-N in the soil profile (especially in fallow situations due to mineralisation). Mungbean has a moderate N requirement, which can often be met by soil nitrate supply provided it is in the top 0–60 cm. A crop of 1 t/ha requires only 70 kg N/ha in total.
- Residual soil N levels >20 kg/ha can suppress and/or delay nodule formulation.
- Mungbean freely nodulates with naturalised rhizobia in the soil, and responses to inoculation are not normally obtained if the paddock has recently been cropped to mungbean or if it contains leguminous weeds such as *Sesbania*.

Many growers have become complacent in their inoculation practices, possibly because it is a time-consuming, labour-intensive procedure representing a major bottleneck at planting. However, the net effect is ineffectual inoculation, and N deficiency in a significant number of crops that completely depend on supplied rhizobia. CSIRO monitoring of commercial crops has repeatedly shown that ~50% of all crops are poorly nodulated or fail to nodulate.

If poor nodulation and N deficiency are to be eliminated as a major constraint to mungbean production, we will need to either:

- pay much greater attention to inoculation practices and our treatment and handling of inoculant materials; or
- consider the alternative of using sufficient rates of N fertiliser to meet the crops full N requirements.

Presently, neither is done properly, and the result is inadequate inoculation practices combined with relatively low rates of N contained in starter fertiliser.[6]

3.2.1 Nodule development in mungbeans

Nodules develop rapidly, and N fixation commences as early as 14–25 days after planting (depending on environmental conditions).

Half of the total nodule mass should form prior to flowering (by 40 days post-planting), with the remainder developing over the next 10 days (coinciding with early podding). Maximum N fixation is at mid–late podding, and activity subsequently declines rapidly as the nodules begin to senesce.

Rapid formation of crown nodules is essential in short-season crops such as mungbean, and any delays can have a significant impact on fixation and yield potential. Inoculation promotes rapid formation of crown nodules.[7]

[6] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

[7] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

3.2.2 Rating level of nodulation

The amount of N fixed is strongly correlated with nodule rating as detailed in Table 1 and the photo-standards in Figure 1. When using this rating system, plants should be gently dug from the soil and the root system rinsed under water before scoring the level of nodulation. Obvious signs of nodulation should be visible by 6 weeks after planting (even in high soil-nitrate situations).

3.2.3 How to rate the level of nodulation

5. Rate the level of nodulation using the photo-standards (Figure 1). This is based on nodule number and their position on the root system.
6. Observe the pattern of nodules on the root system. Nodules on the main taproot clustered near the seed are a clear indication that nodulation occurred as a result of the inoculation process. These are referred to as 'crown nodules'.
7. If there are no crown nodules, but nodules on the lateral roots, it is likely that they have formed from native soil bacteria. These are usually ineffective in fixing N in mungbean. Nodules on both the crown and lateral branches indicate that inoculation was successful, and that bacteria have spread in the soil.
8. Inspect nodules for N-fixation activity. The best method is to slice a few nodules open with a razor blade or sharp knife and look at their colour.

Young nodules are usually white and still need to develop. White nodules can also indicate the wrong bacteria in the nodule, and these will not fix N. Effective nodules are a rusty red or pink colour inside and these are usually actively fixing N (Figure 2). Effective red nodules can sometimes turn green when a plant is under water stress, disease or other stress, or is suffering from nutrient deficiencies. Green nodules do not fix N, but they can revert to red and start to work again if the stress if relieved before too much damage is done. Black nodules are usually dead or dying. These are often seen as the crop matures, or after a crop has suffered waterlogging.[8]

Table 1: Nodulation score chart

No. of nodules		Average score	Interpretation
Depth from topmost lateral root:			
0–5 cm	5 cm		
Nil	Nil	0	No nodulation, no N fixation
<5	Nil	1	Poor nodulation, little N fixation
5-10	Nil	2	Fair nodulation, not sufficient for crop's demands
>10	Nil	3	Average nodulation, may provide crop's demands
>10	<10	4	Good nodulation, good N fixation
>10	>10	5	Excellent nodulation, excellent N fixation

[8] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

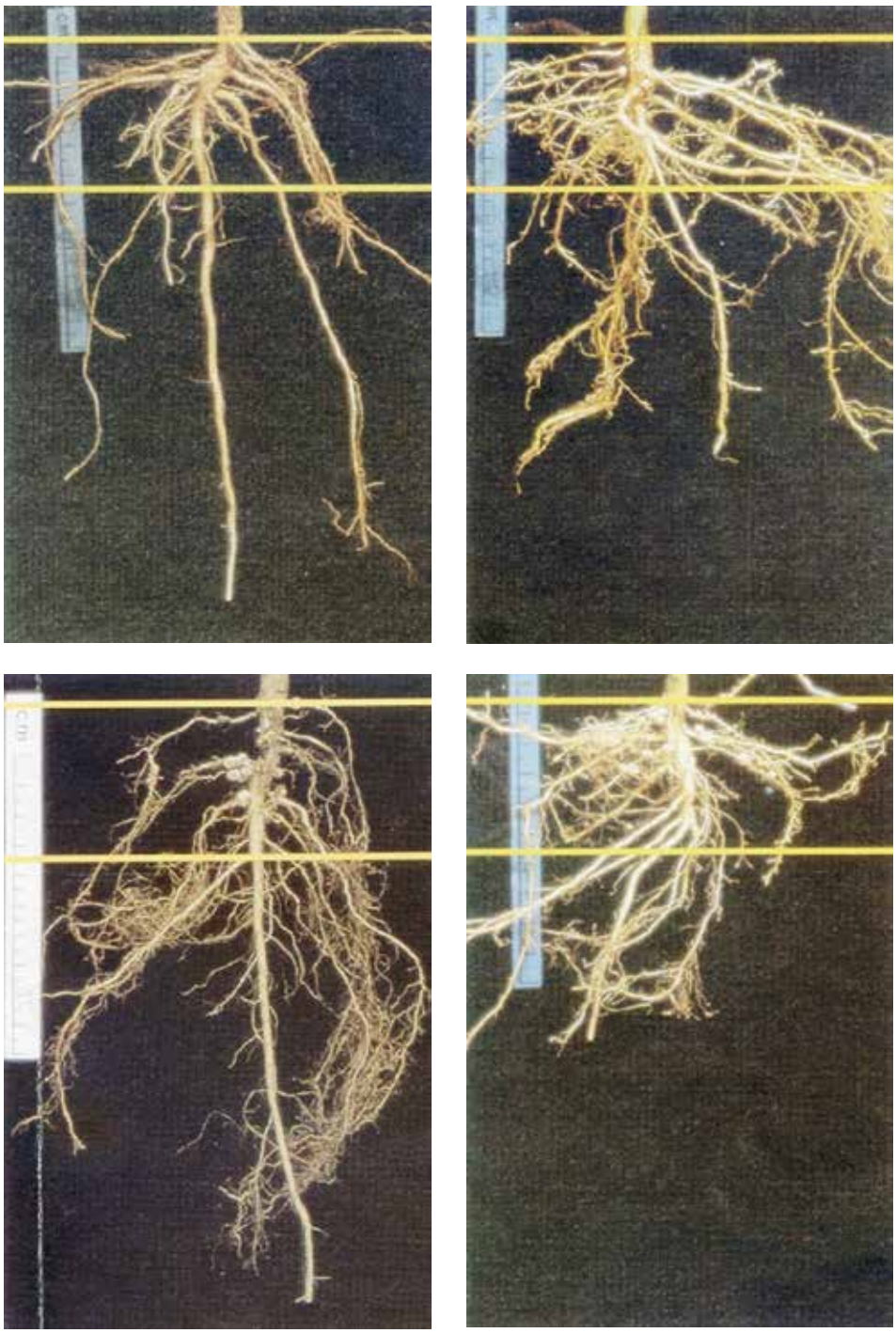


Figure 1: Nodulation photo-standards. (Source: NSW Agriculture)

Note:

- Where plant-available soil N is low, the crop depends heavily on good nodulation for its N supply. A score of 4–5 is desirable (Figure 3).
- Where plant-available soil N is high, nodulation may be partly inhibited and the crop will depend mainly on the soil to provide N.
- Yield may be affected if the score is ≤2–3.
- A high score indicates that the crop will yield well and conserve soil N for use by a following crop.
- A low score suggests that the crop will yield poorly and deplete soil N. [9]

Figure 2: Active nodules have a pink centre. (Photo: G. Cumming, Pulse Australia)

[9] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

Figure 3: Roots of mungbean plants at flowering with poor nodulation on the left (rating 1) and good nodulation on the right (rating 5).

3.3 Time of sowing

There are two main planting windows for mungbean: spring, and the more conventional summer planting. Planting within the preferred window is critical to maximise yield and grain quality. If planting outside these windows, be sure to select an appropriate variety.

3.3.1 Spring planting

Spring planted mungbean can produce reasonable yields provided that specific attention is paid to:

- stored soil moisture levels at planting (at least 90 mm of plant-available water, PAW)
- management of thrips on seedling plants
- control of mirids at flowering
- desiccation prior to harvest
- increased weed pressure

The most consistent results with spring plantings have been achieved with late September–early October plantings in situations with ≥90 mm of PAW.

Late October–November plantings are considered riskier in western areas because of the increased chance of experiencing dry, heatwave conditions on the emerging seedlings and on plants at flowering.

Crystal(D) is suited to early plantings in spring because it is less susceptible to weather damage at harvest, and matures more evenly than the other varieties.

3.3.2 Late planting

Jade-AU(D), Crystal(D) and Satin II(D) are preferred for late plantings because they have some resistance to powdery mildew.

Late planting can result in lower yields, as the crop often flowers ~35 days after planting, and the small plants fail to achieve canopy closure. If planting on narrower rows, increase the seeding rate by 5 kg/ha for plantings made after mid-January. This helps to compensate for smaller plant size. [10]

The black gram variety Regur is not recommended in Central Queensland, where plants grow very short, and delayed maturity limits yield.

3.3.3 Planting dates

The suggested sowing times for mungbean in northern NSW, southern and Central Queensland are outlined in Table 2.

Spring-plant mungbean are less exposed to heatwave conditions during flowering and seedfill. However, plants tend to have more vegetative material.

Spring plantings are predisposed to higher pressure from mirids and thrips, so timely insect control is critical. In addition, weed pressure is often higher because 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 powdery mildew infections during podfill. Very late plantings also risk slow dry-down to harvest.

Planting time also has an effect on the number of days to flowering, with later plantings reaching flowering quicker. [11]

[10] J Gentry (2010) Mungbean management guide. 2nd edn. Pulse Australia, Australian Mungbean Association, Queensland Government, http://www.mungbean.org.au/pdf/Mungbean%20Management%20Guide.pdf

[11] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

Table 2: Planting windows for mungbean in Queensland and northern New South Wales [12]

>, Earlier than ideal, but acceptable; ◊, optimum sowing time; <, later than ideal, but acceptable

	Early plant								Late plant																	
Region	Sept.				Oct.				Nov.				Dec.				Jan.				Feb.				Mar.	
Week	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
Central Queensland	>	>	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	<	<	>	>	◊	◊	◊	◊	◊	◊	◊	◊	<	<
Darling Downs, Qld		>	>	◊	◊	◊	◊	◊	◊	◊	<	<	>	>	◊	◊	◊	◊	◊	<	<					
Western Downs, Qld			>	>	◊	◊	◊	◊	◊	◊	<	<	<	>	>	>	◊	◊	◊	◊	<	<				
Goondiwindi, Qld, Moree and Narrabri, NSW			>	>	◊	◊	◊	◊	◊	◊	<	<	>	>	◊	◊	◊	◊	<	<						
Gunnedah and Tamworth, NSW			>	>	◊	◊	◊	◊	◊	◊	<	<	>	◊	◊	◊	◊	◊	<							
Warren and Narromine, NSW	>	◊	◊	◊	<									>	◊	◊	◊	◊	◊	<						

3.4 Row spacing

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

Narrow rows (<50 cm) have been shown to have higher yield potentials where yields are likely to be >1 t/ha (Figures 4 and 5). Data suggest the yield increase may be as much as 10–15% as yields approach 2 t/ha.

More information

http://grdc.com.au/Media-Centre/Hot-Topics/Row-spacing/Details

3.4.1 Wide rows (50–100 cm)

Advantages:

- ease of checking for insect pressure
- ability to plant into heavy stubble residue in no-till situations
- row-crop planters providing more accurate seed placement, resulting in better establishment and more even plant stands
- improved harvestability because plants tend to grow taller with higher podset; in low-yield situations, plants feeding in better over the knife section due to the concentration of growth within the row
- input costs 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

[12] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

3.4.2 Narrow rows (18–50 cm)

Advantages:

- 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 as alternative options—but mungbean has limited lateral root growth and thus yield potential is limited in these situations [13]

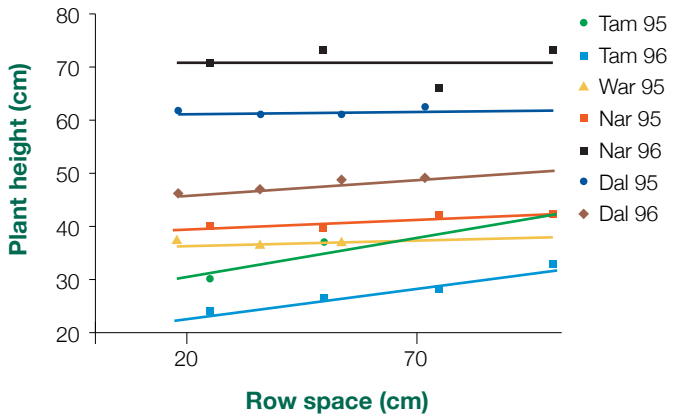


Figure 4: Mungbean plant height response to row spacing. [14]

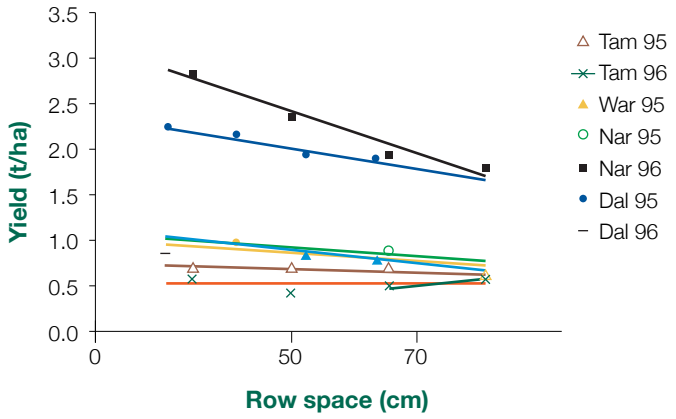


Figure 5: Mungbean seed yield response to row spacing. [15]

[13] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[14] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

[15] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

3.5 Row spacing and planter configuration

Mungbean has been successfully grown using a wide range of planting equipment and row spacings ranging from 18 cm to 1 m. Available planting equipment and farm layout will largely influence the final decision on row spacing and planting configuration.

The recent trend is toward an increasingly higher percentage of the mungbean crop being grown in wider rows of 50–100 cm, often planted up and back. This is mainly due to the greater number of row-crop planters now available, controlled traffic, and the adoption of shielded and band spraying. Wide row spacings also allow for greater use of ground rigs for pesticide application and give the grower more control when insecticides are being applied to the crop. High-temperature application (>28°C) is now widely recognised as a major cause of insecticide spray failures in summer crops.

Before growers make the final decision, they need to consider the relative advantages of wide and narrow production systems.[16]

More information

http://grdc.com.au/Media-Centre/Hot-Topics/Row-spacing/Details

3.5.1 Seed placement depth

Plant into moist soil at a depth of 30–50 mm. Do not use press-wheels that exert heavy pressure directly over the row. Ideally, use wide, no-pressure wheels.

Rolling can be useful because it helps level the entire surface, and can significantly help the harvesting operation.[17]

3.6 Plant population and sowing depth

Aim to establish 20–30 plants/m^2 in dryland crops and 30–40 plants/m^2 in irrigated situations. Consider re-sowing if <10 plants/m^2 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 that the planting depth across the width of sowing machinery is even to aid the timing and consistency of crop emergence.

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

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.[18]

16 J Gentry (2010) Mungbean management guide. 2nd edn. Pulse Australia, Australian Mungbean Association, Queensland Government, http://www.mungbean.org.au/pdf/Mungbean%20Management%20Guide.pdf

17 J Gentry (2010) Mungbean management guide. 2nd edn. Pulse Australia, Australian Mungbean Association, Queensland Government, http://www.mungbean.org.au/pdf/Mungbean%20Management%20Guide.pdf

18 G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

Lodging can be a problem when plant populations are >40 plants/m^2 especially on wider row spacings. Jade-AU(), Crystal() and Satin II() are more resistant to lodging at these higher populations than the other varieties.

Target populations on 1-m wide rows are ideally 20–25 plants/m^2. Higher populations than this will increase the risk of lodging, especially under irrigation. [19]

3.6.1 Calculating planting rates

Planting rates (kg/ha) must be calculated each year because they can vary greatly depending upon variety, germination and planting conditions. Planting rate can be calculated using target plant density, germination percentage, number of seeds/kg and establishment percentage (Table 3):

1. *Target plant density*. This will vary depending on yield potential, whether planting under irrigation or dryland, row spacing, starting moisture and planting time (i.e. increase plant population when later than preferred).
2. *Number of seeds/kg*. There is considerable variation in seed weight between different varieties as well as potential differences between differing seed lines of the same variety. Thus, it is important to determine the actual seed weight of the seed being planted. This can be done by referring to the Australian Mungbean Association-approved seed-bag label or by performing your own seed count by counting a set number of seeds (at least 200) and weighing them. The more seeds counted the more accurate the answer.
3. *Germination percentage.* Germination percentage needs to be determined as close to sowing date as practical. If planting last year's seed, it is recommended to have the seed laboratory-tested, because germination can deteriorate over time.
4. *Establishment percentage.* This will vary depending on planting equipment, soil moisture, temperature, soil type and sowing depth. A realistic estimate of establishment is 85%. [20]

Table 3: Example of calculation of planting rate

Planting rate	=	Target plant density per ha No. of seeds/kg × (germination%/100) × (expected establishment%/100)
For example:		
Target plant density	=	250,000/ha (i.e. 25 plants/m^2)
Seeds/kg	=	13,500
Germination rate	=	95%
Establishment rate	=	85%
Planting rate	=	250,000/(13 500 × (95/100) × (85/100))
	=	24kg/ha

[19] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

[20] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

3.7 Irrigation

Mungbean are sensitive to excessive waterlogging, and good layout and drainage are crucial. Waterlogging events of >5 days duration can cause root nodules to die back, with subsequent N-deficiency problems in the crop.

3.7.1 Flood irrigation

The following irrigation strategies have been developed to minimise the impact of waterlogging in navy beans; they are also directly applicable to mungbean grown under flood irrigation:

- Select fields with reasonably steep grades.
- Fields should not have any low spots; ideally, they should be laser-levelled.
- Form-up high-volume hills or beds, which drain quickly after rain.
- Select fields with short runs—preferably 200–400 m.
- An efficient tail-water system that will rapidly drain water away from the paddock is essential.
- Irrigate down every second, or alternate, furrow.
- Apply water quickly, preferably in 4–8 h; adjust the number of siphons per furrow to suit.
- Irrigating after light rain can help speed up irrigation time.
- The first irrigation should be applied before soil cracks open up.

Nitrogen fertiliser can be used to offset the effects of waterlogging. This can be applied as a foliar urea spray prior to irrigation, or as 15–25 kg urea/ha in the irrigation water (water run).

Being relatively quick maturing, one of the major advantages of mungbean is their low water use and relatively high financial returns per megalitre of water.

Other points to consider are:

- Jade-AU(b) and Crystal(b) offer a greater yield potential than other varieties.
- Narrow rows will maximise yields under favourable conditions.
- Achieving a plant population of ≥30 plants/m^2 is critical to maximising yield.
- Higher yields will be recovered from 2-m beds than from 1-m hills under high lodging pressure (up to 300 kg/ha in trials).
- Irrigating too early can delay or inhibit nodulation.
- The short duration of current varieties places a ceiling on achievable grain yield.
- In Department of Agriculture, Fisheries and Forestry trials at Emerald in Central Queensland, the most effective strategy was flood-irrigating to planting and a single in-crop event to fill the profile at flowering–podding.
- Coordinate irrigation with insect-control strategies.

Irrigating too early in the growth of a crop will encourage excessive vegetative growth. The preferred strategy is to pre-water and then plant on a profile of soil water. The first in-crop

irrigation is usually best applied ~7 days before the start of flowering, i.e. 30–40 days after planting.

On heavy black earths (Darling Downs), one in-crop irrigation applied around flowering is usually sufficient to achieve reasonable yields. In the hotter western or northern areas, two irrigations may be required with flood-irrigation systems.

Water management is very important in mungbean. Particular care is required with varieties such as Emerald(), which, although suited to irrigation because of its yield potential and lodging resistance, can pose problems in terms of uneven maturity or hard-seed levels. In particular, hard seeds can cause volunteer problems in cotton-farming systems.

Moisture stress during grain-filling can reduce yields and increase hard-seed levels; on the other hand, excessive late irrigation can cause considerable delays in maturity. [21]

3.7.2 Row configuration on 2-m beds

In flood-irrigation systems, yield potentials can be maximised by the use of multiple rows planted onto 2-m beds as opposed to the traditional 1 row on 1-m beds (see Figure 6). [22]

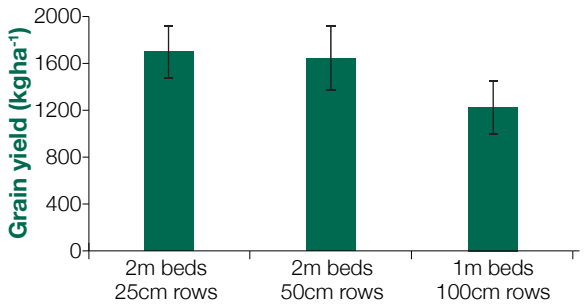


Figure 6: Impact of row spacing on yield under irrigation.

3.7.3 Spray irrigation

This is an option in some areas, and has the advantage of allowing smaller amounts of water to be applied more frequently. This helps reduce waterlogging and can lift yields. Avoid heavy spray irrigation of young plants because the caked-on dirt from mud-splash can reduce growth and thin the plant stand (especially in crusting soils). Approximately 50 mm water/week will normally be required during flowering and podfill. [23]

[21] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

[22] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

[23] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course, Module 2. Pulse Australia Ltd.

SECTION 4

Plant growth and physiology

More information

https://www.grdc.com.au/uploads/documents/2010ASGCEditedPapersPDF/Chauhan_MungbeanCropModel_edited_paper.pdf

http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3656181/

Mungbean or green gram (*Vigna radiata* (L.) R. Wilczek) is a short-season, indeterminate, small-seeded tropical pulse crop originating from the north-east India–Burma region of Asia (Figure 1).

Mungbean is a leguminous species, or pulse crop, grown principally for its protein-rich, edible seeds as a human food crop. Seed appearance and quality are of paramount importance. Mungbean and other pulse crops are also referred to as grain legumes.

Because of its rapid growth and early maturity, mungbean is adapted to multiple cropping systems in the drier and warmer climates of the lowland tropics and subtropics. Optimum seed germination and plant growth occurs at temperatures of 28–33°C.

Flowering in mungbean is photoperiod- and temperature-sensitive, being delayed by long photoperiods and hastened by high temperatures.

Mungbean grows in a wide range of soil types, but thrives best on deep loam or sandy loam soils. Its early maturity enables it to mature on limited soil moisture.

It is favoured by dry weather during pod ripening to facilitate harvest and prevent seed damage. [1]

Figure 1: Typical leaf, flower and pod structure of mungbean (Vigna radiata). (Photo: Gordon Cumming, Pulse Australia)

[1] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

4.1 Growth habit

Mungbean is an annual, semi-erect to erect, deep-rooted herb, 40–125 cm tall (Figure 2; see also Figure 3: black gram, *Vigna mungo* (L.) Hepper). The stems branch from the base and are covered with short fine brownish hairs. The leaves are alternate and trifoliate; leaflets are medium to dark green, broadly ovate, sometime lobed, rounded at the base and pointed at the apex, 5–12 cm long and 2–10 cm wide. Vegetative growth tends to be determinate and stops once flowering has commenced.

Between 10 and 25 flowers are borne in auxiliary clusters or racemes. The flowers are greenish to bright yellow, with a gray-tinged keel, 1–1.75 cm in diameter. Flowers are self-fertile and highly self-pollinated. Flowering is indeterminate and may continue over several weeks if the plant remains healthy.

Pods mature about 20 days after flowering. Rapid senescence does not occur.

The seed pods are cylindrical, straight to slightly curved, pointed at the tip and radiate horizontally in whorls. When mature the pods are glabrous or have short hairs, tawny brown to black, 5–14 cm long and 4–6 cm wide and may burst open when dry, scattering the seeds.

Seeds are borne 8–20 per pod, are globese, glossy or dull, with green, yellow, tawny brown, black or mottled seed coat (testa). Dull seeds are coated with a layer of the pod inner membrane, which may be translucid or pigmented and which covers a shiny testa.

The testa is reticulated with numerous fine wavy ridges and cross-walls. Seeds vary in weight from 15 to 85 mg, generally averaging 25,000–30,000 seeds/kg. The hilum is round, flat (non-concave) and white.

Seed germination is epigeal, the same as in lupins, whereas chickpeas and faba beans are hypogeal.

The Australian mungbean industry and breeding program has focused on the higher value, shiny bright green mungbean with a smooth testa (or outer layer of the seed coat). [2]

Figure 2: Branch, flower, pod and grain of mungbean (Vigna radiata). (Images: Gordon Cumming, Pulse Australia)

[2] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

4.2 Description of black gram (Vigna mungo)

The black gram is an annua, semi-erect to spreading herb 25 to 80cm tall. Stems are diffused, branching and covered with long, dense, brown hairs. Leaves are trifoliate, hairy, with large ovate to Lanceolate, entire leaflets. Black gram is indeterminate in its vegetative growth, and will continue to develop new leaves once flowering commences. Up to 30% of total vegetative growth can occur after flowering.

Flowers are pale yellow, with a yellow spirally coiled keel. The flowers are borne in clusters of five to six on a short hairy penduncle in auxiliary racemes. Flowers are self-fertile and self-pollinated. Flowering is indeterminate.

Pods are short, erect to sub erect, green to brown, hairy, with 6 to 10 seeds. Seeds are small, averaging about 40 milligrams, oblong, dark brown to black.

The seed coat (testa) is smooth and the hilum white and concave.

Germination is epigeal. Pods do not shatter readily.

Figure 3: Branch, flower, pod and grain of black gram (Vigna mungo). (Images: Gordon Cumming, Pulse Australia)

infocus

4.3 Phenology

The mungbean plant develops through nine distinct phenological phases of growth. These phases are: (i) sowing to germination; (ii) germination to emergence; (iii) a period of vegetative growth after emergence called the basic vegetative phase, during which the plant is unresponsive to photoperiod, also called the juvenile phase; (iv) a photoperiod-induced phase, which ends at floral initiation; (v) a flower development phase, which ends at 50% flowering; (vi) a lag phase prior to commencement of grain filling; (vii) a linear phase of grain filling; (viii) a period between the end of grain filling and physiological maturity; and (ix) a harvest-ripe period prior to grain harvest.

The development of mungbean plants during stages (i)–(ix) is mainly related to temperature. This temperature requirement for different development stages is known as thermal time or heat units, called degree-days or growing degree-days. In photoperiod-sensitive cultivars, the thermal time requirement is increased by long photoperiods during phase iv. The mungbean cultivars grown in Australia generally do not respond to photoperiod during this phase (Ellis *et al.* 1994). The Agricultural Production Systems Simulator (APSIM) mungbean model uses thermal time to drive phenological development and canopy expansion.

The cardinal temperatures used in thermal time calculations in the APSIM mungbean model are 7.5°C base, 30°C optimum and 40°C maximum. A typical mungbean cultivar such as Emerald(Ɒ requires in total 1200 degree-days in the time from sowing to maturity. [3]

4.4 Leaf area development

The formation of the leaf canopy to intercept solar radiation depends upon the rate at which leaves form and senesce. The rate of node appearance on the main stem in mungbean is 100 degree-days per node, the potential number of leaves per main stem node is two, and the rate of death on main stem node is 60 degree-days per node (Robertson *et al.* 2002). Thus, higher temperatures (within the cardinal range) early in the life of a plant will result in quicker canopy development, but higher temperature after the canopy development will result in quicker senescence.

Mungbean cultivars currently available to growers in Australia are morphologically determinate, in that the apex of the main stem or a branch always differentiates (develops) into a flower bud (Lawn 1978). This essentially stops the further growth of the main shoot or branches.

The potential number of leaves per main-stem node in mungbean is much less than the 17 in peanuts and 10 in pigeon peas, and may be related to morphological determinacy of mungbean cultivars. In most situations, this constrains closed canopy development in mungbean when grown in wider (~1 m) rows. This limits the ability of determinate cultivars to accumulate more biomass under favourable growing conditions (with regard to soil

[3] YS Chauhan *et al.* (2010) Physiology of mungbean and development of the mungbean crop model. Ist Australian Summer Grains Conference, https://www.grdc.com.au/uploads/documents/2010ASGCEditedPapersPDF/Chauhan_MungbeanCropModel_edited_paper.pdf

moisture and temperature) compared with an indeterminate black gram (*Vigna mungo*) species or its wild relatives (Rebetzke and Lawn 2006) (Figure 4). [4]

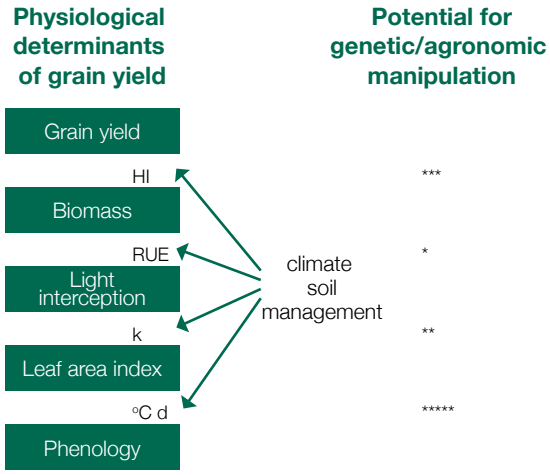


Figure 4: A physiological framework of yield formation in mungbean; the potential for genetic or agronomic manipulation at a particular level is indicated by the number of asterisks (with increasing number of asterisks indicating greater potential for manipulation).

More information

https://www.grdc.com.au/uploads/documents/2010ASGCEditedPapersPDF/Chauhan_MungbeanCropModel_edited_paper.pdf

4.5 Key growth stages of mungbean

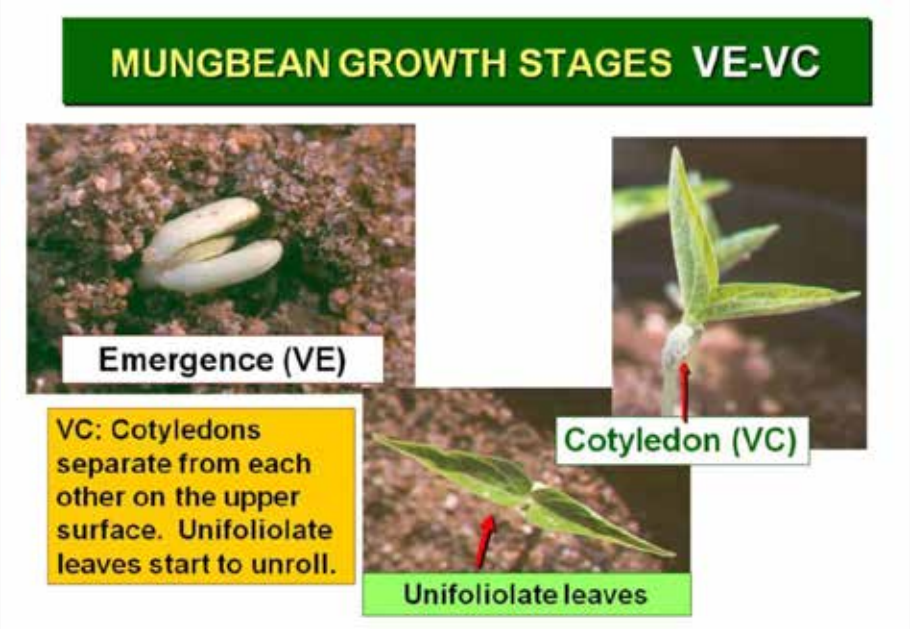
The base soil temperature for emergence is 10.5°C, and plant growth is maximised at ambient temperatures of 28–30°C. As such, spring-planted mungbean are slower to reach all growth stages.

Because mungbean is sensitive to daylength, flowering is delayed moving further south. Variations in temperature can significantly affect flowering times. Generally, warmer temperatures speed the plant's development.

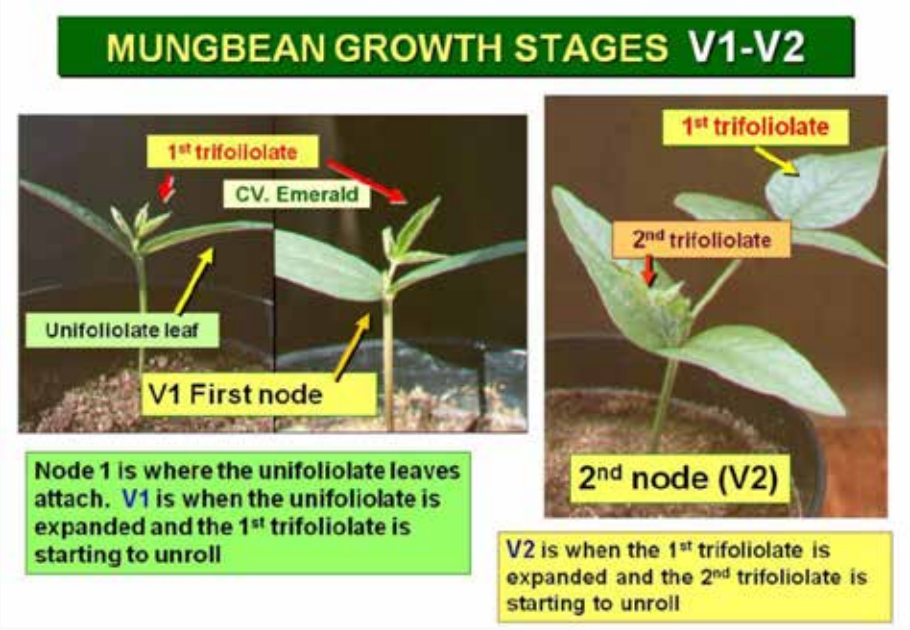
[4] YS Chauhan *et al.* (2010) Physiology of mungbean and development of the mungbean crop model. Ist Australian Summer Grains Conference, https://www.grdc.com.au/uploads/documents/2010ASGCEditedPapersPDF/Chauhan_MungbeanCropModel_edited_paper.pdf

Table 1: Growth stages of mungbean (images: Hugh Brier, DAFF Qld)

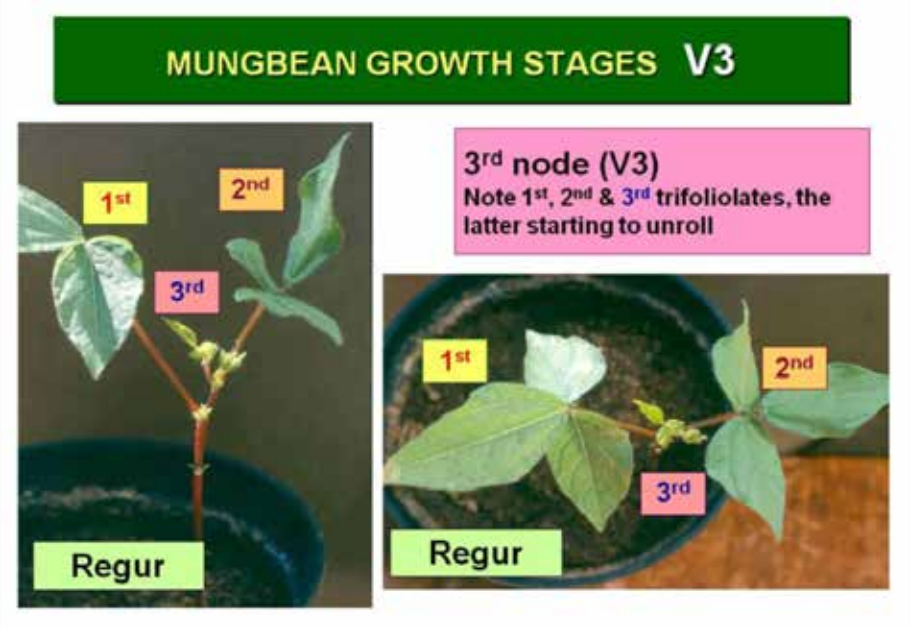
Designation		Description
Vegetative growth stage (V-stage) in mungbeans		
VE	Emergence	Cotyledons near the soil surface, with the seeding showing some part of the plant above the soil surface
VC	Cotyledon	Cotyledons separate from each other on the upper surface. Unifoliolate leaves start to unroll so that the edge of the leaves are not touching each other



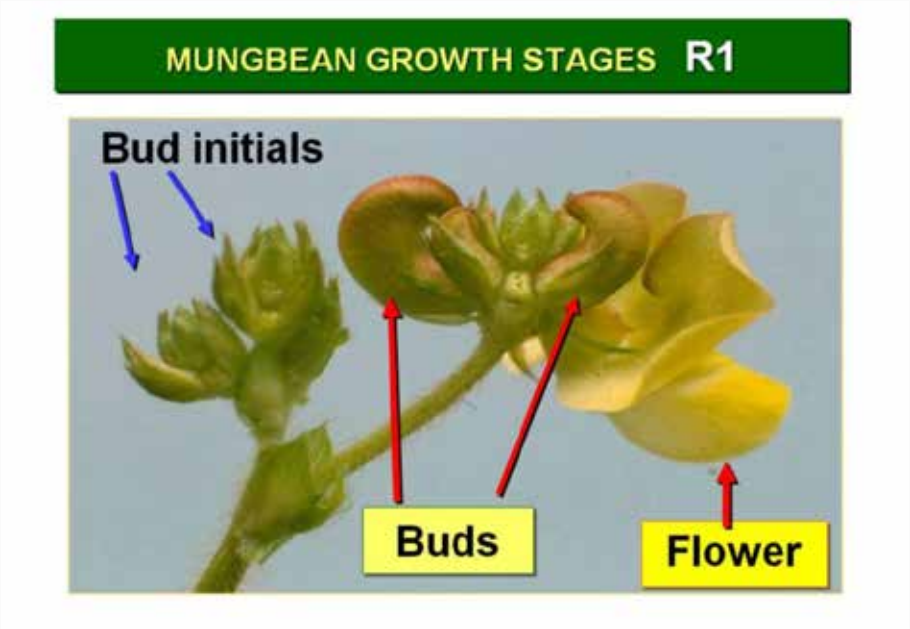
V1	First node	Unifoliolate leaves attached to the first node are fully expanding and flat while the 1st trifoliolate leaf attached to the upper node starts to unroll
V2	Second node	1st trifoliolate leaf attached to the second node is fully expanding and flat while the 2nd trifoliolate leaf on the upper node starts to unroll



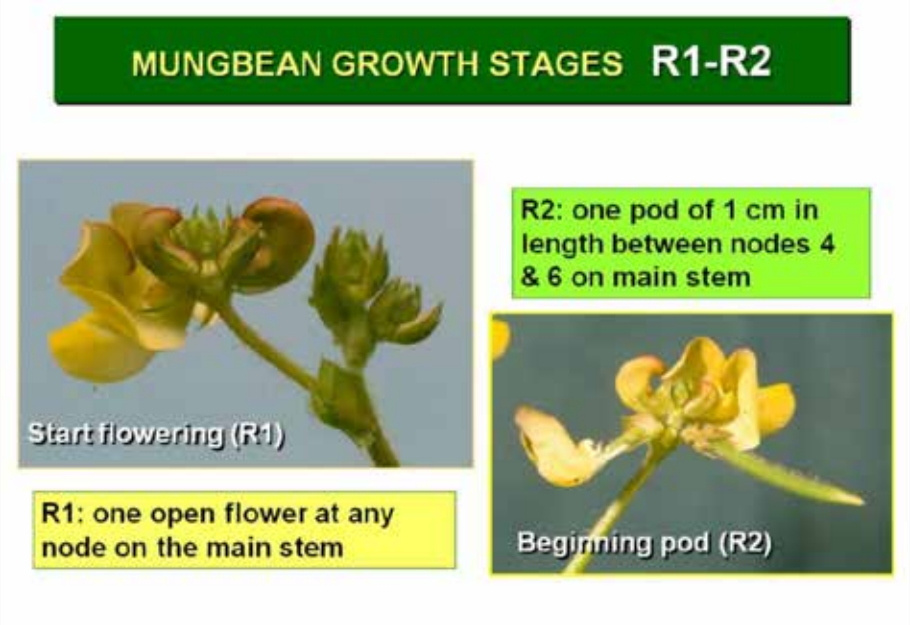
V3	Third node	2nd trifoliolate leaf attached to the third node is fully expanding and flat while the 3rd trifoliolate leaf on the upper node starts to unroll



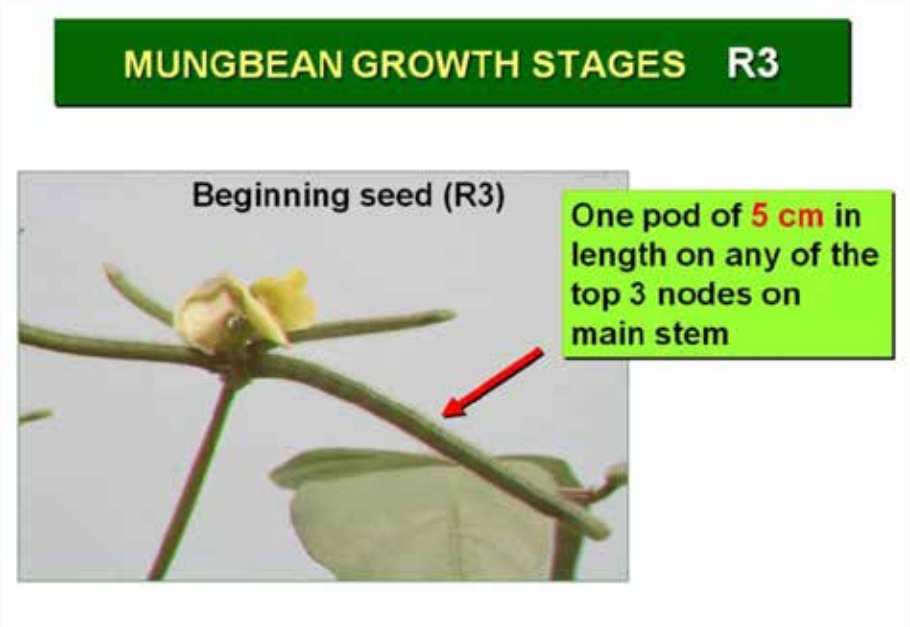
V4	Fourth node	3rd trifoliolate lead attached to the third node is fully expanding and flat while the 4th trifoliolate leaf on the upper node starts to unroll
V(n)	N-node	A node is counted when its trifoliolate leaf is unfolded and its leaflets are flat
Reproductive growth stage (R-stage) in mungbean		
R1	Start flowering	One open flower at any node on the main stem



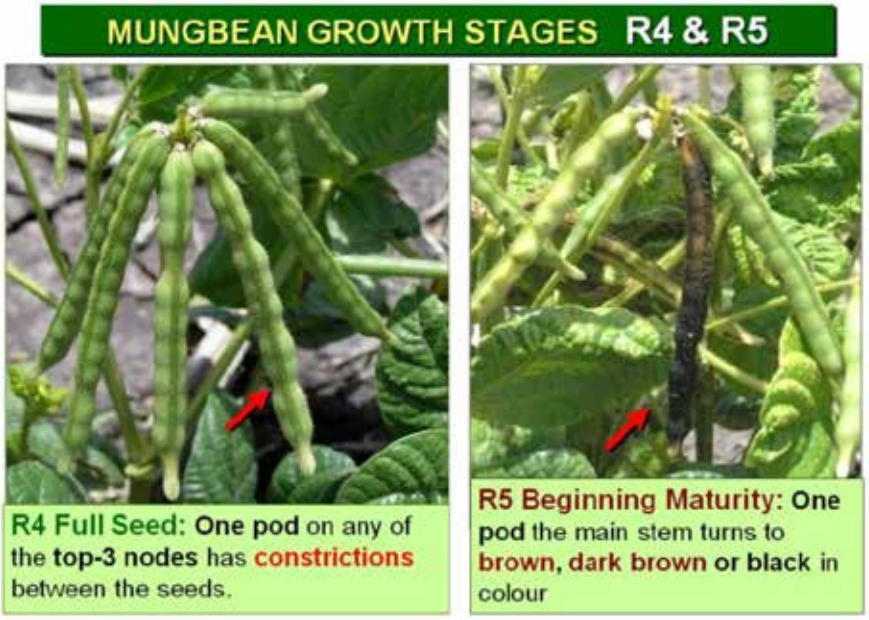
R2	Beginning pod	One pod of 1 cm length is found between nodes 4 and 6 on main stem



R3	Beginning seed	One pod of 5 cm length is found on any of the top 3 nodes on main stem



R4	Full seed	One pod on any of the top 3 nodes has constriction between seed
R5	Beginning maturity	On pod, the main stem turns to brown, dark brown or black in colour



R6	50% black pod	50% of pods on the plant mature

R7	90% black pod	90% of pods physiologically mature (yellow through to black) [5]

The key is based on counting the number of nodes on the main stream.

Germination is epigeal, with the cotyledons emerging above the soil surface.

The node at which the cotyledons are attached (the cotyledonary node) is counted as node 0, and the node at which the two unifoliate leaves are attached to the main stem is counted as node 1:

- In mungbean, alternate trifoliate leaves are attached at all nodes above the unifoliate node (usually 5 trifoliate leaves on the main stem, although it can sometimes increase to 6 or 7).
- A node is counted as developed when its trifoliate leaf has developed to the stage that the leaflets are unfolded and flattened out.
- Mungbeans are considered determinate in their growth habit, with vegetative growth ceasing at the commencement of flowering.
- Flower terminals normally develop from auxiliary buds in nodes 4–6.
- The auxiliary buds in nodes 0–3, if not dormant, will develop into a branch.

Mungbean flowers are yellow or greenish yellow, and borne on terminal inflorescences that arise from both the main stem and upper branches.

There are normally 5–15 flowers clustered at the top of each terminal raceme.

Inflorescences remain meristematic, and if flowers abscise or abort, up to 30 new flowers may develop successively if moisture conditions allow. Flowers are primarily self-fertilised. [6]

[5] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[6] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

4.6 Growth and development

Mungbean is a short-duration crop, usually flowering within 30–60 days of planting, depending on photoperiod and temperature.

4.6.1 Photoperiod

Flowering is sensitive to day length, and flowering tends to be progressively delayed with increasing latitude (at more southern growing locations). Mean days to first flower for a December-planted mungbean crop are approximately 41 days for Central Queensland, 42 days for southern Queensland, and 46 days for central New South Wales.

4.6.2 Temperature

Germination, emergence, vegetative growth, and rate of pod development are all temperature-sensitive. At any location, seasonal variations in temperature can cause a significant shift in flowering times (i.e. ±5 days from the values quoted above). In general, warmer temperatures hasten development.

The threshold temperature (base) for emergence is 10.5°C, although mungbean is regarded as chilling-sensitive. Below 15°C the growth rate is significantly retarded. Below this temperature, cell structure and function are impaired. Plants grown at mean temperatures <18°C are often stunted from a shortening of the internode length (see Figure 5).

Both internode length and number of internodes on each plant will increase with increasing mean temperatures up to 28–30ºC.This helps explain the slow growth rate and delays in time of flowering in spring-planted crops in southern Queensland and in New South Wales. Optimum mean temperatures for growth and development are in the range 28–30°C (Table 2).

Yields drop away sharply where mean temperatures are >33°C. High air temperatures induce flower shedding, particularly if soil moisture is limited and humidity low.

The effects of large diurnal temperature fluctuations (cool night temperatures) in spring crops have not been quantified but work is ongoing.[7]

Figure 6 summarises the key growth stages in development and the environmental drivers at each growth stage, for mungbean cultivar Emerald(Ⅰ).

[7] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

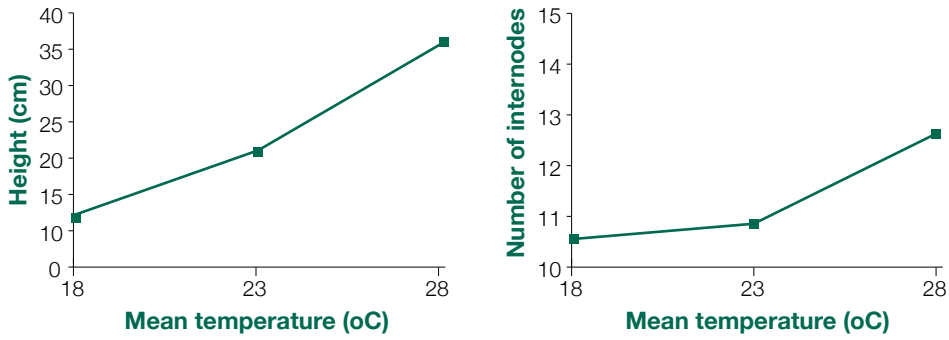
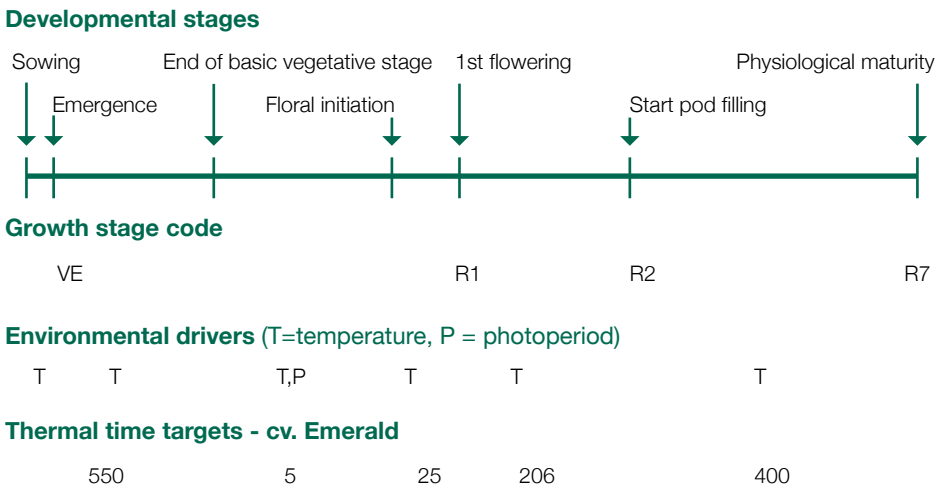


Figure 5: Left: effect of temperature on mean height of seven mungbean accessions growing in a 12-h photoperiod. Right: effect of temperature on mean number of internodes of seven mungbean accessions growing in a 12-h photoperiod (Aggarwal 1976).

Table 2: Predicted time of flowering in mungbean (assuming photoperiod-insensitive variety) based on climate data from 1960 to 2002

DAS, Days after sowing. Note: 1 August sowing at Dalby failed due to frosting

Sowing date		Days to first flower					
		Emerald		Mackay		Dalby	
		DAS	Date	DAS	Date	DAS	Date
01 Aug.	Earliest	52	22 Sept.	48	18 Sept.	–	–
	Average	58	27 Sept.	54	23 Sept.	–	–
	Latest	66	06 Oct.	59	29 Sept.	–	–
01 Oct.	Earliest	40	10 Nov.	37	7 Nov.	45	15 Nov.
	Average	42	12 Nov.	40	09 Nov.	50	19 Nov.
	Latest	45	15 Nov.	43	13 Nov.	56	26 Nov.
01 Dec.	Earliest	38	08 Jan.	34	04 Jan.	40	10 Jan.
	Average	41	10 Jan.	36	05 Jan.	42	11 Jan.
	Latest	45	15 Jan.	37	07 Jan.	45	15 Jan.



Thermal time (degree-days) = ∑ (Tmean – 8°C)

Figure 6: Key developmental stages of mungbean, their growth stage code, environmental drivers and their thermal-time (degree-day) targets.

The duration of different reproductive structures or stages (from buds to mature pods) has been measured for Berken mungbeans under controlled temperature conditions (constant 25°C) (Figure 7) and for a summer-planted crop of Emerald(Ɒ mungbeans (Figures 8 and 9).

4.7 Flowering

The flowers of mungbean are borne in clusters of 10–20 on terminal racemes. Pollination occurs at night, beginning around 22:00 (10pm), and it is usually completed by midnight while the flower is still in the unopened bud stage. Early the next morning, the flower opens and remains in full bloom until around midday. It then begins to close, and is fully closed by mid–late afternoon.

Most flowers are self-pollinated, and outcrossing percentage is generally ~2–3% depending on genetic factors and environmental conditions (temperature, humidity, wind speed, and distance pollen grains must travel).

Flower shedding is common in mungbean, and is increased by high temperatures (>33°), rainfall, desiccating winds, and sucking insects. It is often ~40–70%. [8]

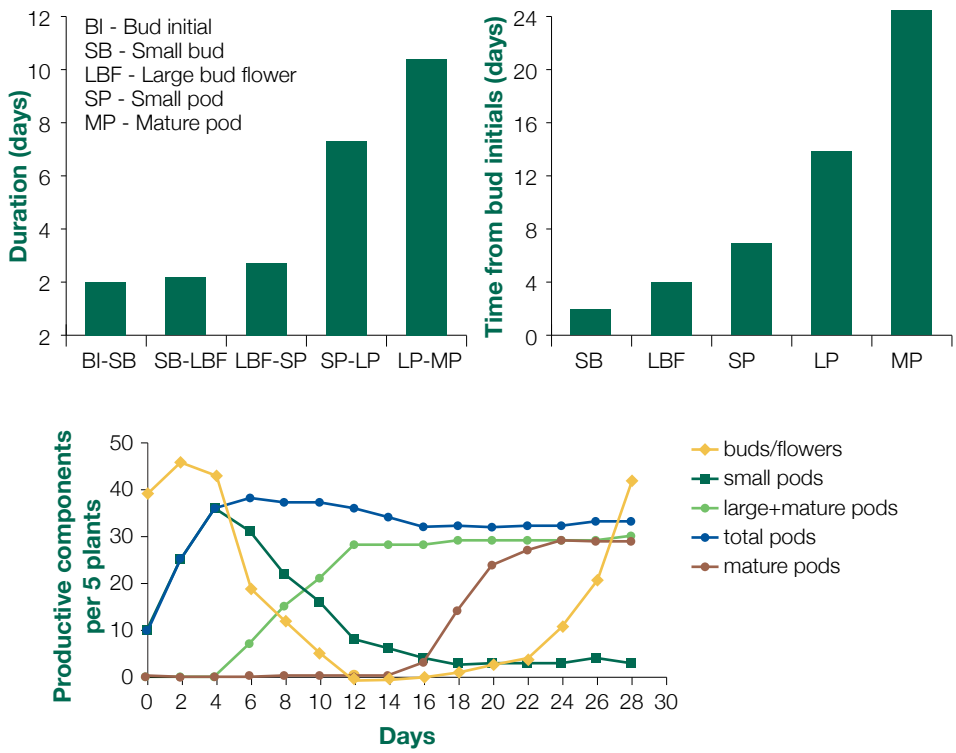


Figure 7: Duration of different reproductive structures (from buds to mature pods) of Berken mungbeans at a constant 25°C.

[8] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

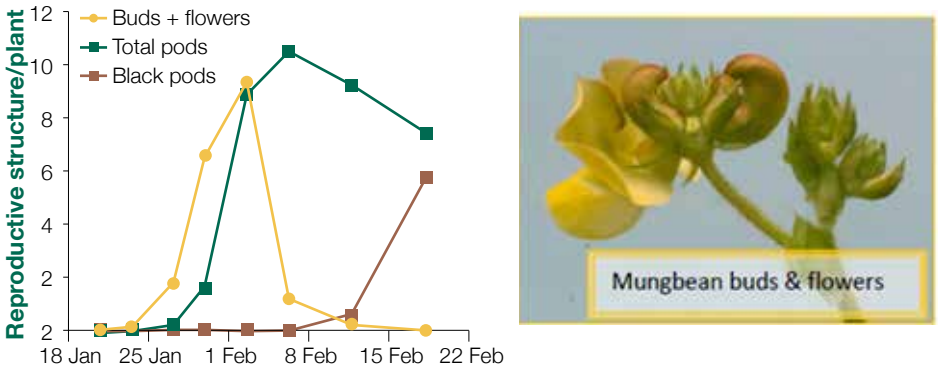


Figure 8: Development of summer-planted crop of Emerald(ɒ mungbeans. Note how (under high peak summer temperatures) flowering was virtually over within 2 weeks of the 1st budding, and that pods were maturing quickly (45% black pod) by 4 weeks after 1st budding. (Images: Hugh Brier, DAFF Qld)

Figure 9: From top left: crop of Emerald(ɒ mungbeans at 1st bud (24 Jan), full flower (31 Jan.), peak green podding (8 Feb.) and 45% black pod (15 Feb.). Note how at the 1st bud, no buds can be seen from above the canopy, and how rapidly the crop develops with 45% black pods within 4 weeks of 1st budding. (Images: Hugh Brier, DAFF Qld)

4.8 Appendix: mungbean crop growth stages (in pictures)

(Images: Hugh Brier, DAFF Qld)

4.8.1 24 Jan 2005 - G3 JBPRS - start of budding (not visible)

Look for bracts covering the 1st bud initials and buds

4.8.2 28 Jan 2005 - G3 JBPRS - budding (buds now visible)

4.8.3 31 Jan 2005 - G3 JBPRS - peak flowering

4.8.4 8 Feb 2005 - G3 JBPRS - podding

4.8.5 15 Feb 2005 - G3 JBPRS - late podding

Harvested 11 March

SECTION 5

Nutrition and fertiliser

More information

http://grdc.com.au/Media-Centre/Ground-Cover/GC111/Know-your-legumes-nitrogen-value

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Management-impacts-on-N-fixation-of-mungbeans-and-chickpeas

Fertiliser recommendations need to be based on soil test results, fallow length, yield potential and paddock history.

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(e) (or AM) (previously known as VAM). 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. [1]

Mungbean is a legume, and when properly inoculated and planted into situations with low background soil nitrogen (N) levels, mungbean plants should fix sufficient atmospheric N2 to support their own growth, and may often leave some residual N for the following crop. As a guide, a 1.5 t/ha crop of mungbean requires a total of 100 kg N/ha.

Application of starter fertilisers containing low rates of N as well as P, sulfur (S) and Zn are often recommended. [2]

5.1 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 salinity is 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 >2 dS/m are sufficient to cause a yield reduction in mungbean.

More information

http://www.terragis.bees.unsw.edu.au/terraGIS_soil/sp_exchangeable_sodium_percentage.html

In situations where there is subsoil sodicity, the amount of plant-available water will be limited, and as a result, yield potential will be limited. Sodicity is measured as exchangeable sodium percentage (ESP) and levels >6% ESP are considered sodic however there can still be constraints at lower sodium levels, particularly when magnesium is also high.

[1] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[2] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

Subsoil acidity can also be a problem if the pH is <5.5 (measured in 1:5 soil–water), and this can induce nutrient imbalances. [3]

5.2 Customising fertiliser recommendations to meet specific crop requirements

Fertiliser recommendations for mungbean tend to be very generic, with an over-reliance on relatively low rates of mono-ammonium phosphate (MAP)-based starter fertiliser for meeting the crop's full nutritional requirements.

Fertiliser recommendations should take into account:

- soil type
- rotations (fallow length and impact on AM levels)
- yield potential of the crop
- plant configuration (row spacing, type of opener and risk of 'seed burn')
- soil analysis
- effectiveness of inoculation techniques [4]

5.2.1 Nutrient removal and crop requirement

Table 1 present the quantities of nutrients required to produce 1 t of grain, and the amounts of N, P, K, and S removed in the grain.

Table 1: Mungbean nutrient removal for a crop yield of 1 t/ha [5]

Nutrient	Removed in grain (kg/ha)	Total crop requirement (kg/ha)
Nitrogen	35–40	60–70
Phosphorus	3–5	6–9
Potassium	12–14	45–50
Sulfur	2–2.5	3–7
Calcium		18–30
Magnesium		8–13

5.3 Nitrogen (N)

Mungbeans should not usually need N fertiliser if plants have effectively nodulated (see *GrowNotes Mungbean Section 3. Planting* for further details). See Table 2 for the N balance for mungbean crops for a range of dry matter yields.

[3] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[4] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[5] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

More information

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Management-impacts-on-N-fixation-of-mungbeans-and-chickpeas

Some situations where N fertiliser may warrant consideration include:

- The grower is unwilling to adopt recommended inoculation procedures.
- Planting into double-crop situations with high levels of freshly decomposing wheat or barley stubble. Low rates of N can help with early vigour and growth of the crop until nodulation comes into effect.
- Late plant situations where the crop can flower in as early as 35 days, and rapid early growth is critical in achieving adequate height and canopy closure. [6]

Table 2: Nitrogen balance for a mungbean crop [7]

HI, Grain harvest index is the grain yield as a percentage of total shoot dry matter production (average 40%); NHI, the amount of N removed in the grain as a percentage of total crop nitrogen requirement (averages 70%)

Total shoot dry matter yield (t/ha)	Grain yield (40% HI) (t/ha)	Total crop N requirement (2%N) (kg/ha)	N removal in grain (NHI 70%) (kg/ha)
1.25	0.5	35	18
2.50	1.0	70	35
3.75	1.5	105	53
5.00	2.0	140	70
6.25	2.5	175	88

5.4 Phosphorus

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

Mungbean is highly dependent on AM, so the crop's position in the rotation is important. Planting following a long fallow may increase the risk of P deficiency.

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

A starter fertiliser containing P is recommended. [8]

Although mungbean has a moderately high requirement for P, fertiliser responses will be strongly influenced by the level of AM spore survival in the soil. Mungbean is dependent on AM to extract P from the soil, and any P recommendation should be based on the current AM level in the soil.

5.4.1 Arbuscular mycorrhizae

Soils naturally contain beneficial fungi that help a crop to access nutrients such as P and Zn. The AM are the combination of the fungus and crop root. Many different species of fungi can have this association with the roots of crops. Many that are associated with crops also form structures called vesicles in the roots.

[6] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Module 2. Pulse Australia Ltd.

[7] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Module 2. Pulse Australia Ltd.

[8] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

The AM cannot manufacture P or Zn; they can access the nutrients in the soil better than the roots alone. Phosphorus and Zn fertilisers are used more efficiently with AM present. In soil with a lower P background, P fertiliser may need to be added, even with good AM levels.

Severe reduction or lack of AM shows up as long-fallow disorder—the failure of crops to thrive despite adequate moisture. Ongoing drought in the 1990s and beyond has highlighted long-fallow disorder where AM have died out through lack of host plant roots during periods of long fallow (see Tables 3 and 4). As cropping programs restart after dry years, an unexpected yield drop is likely due to reduced AM levels, making it difficult for the crop to access nutrients.

Table 3: Effect of fallow length on AM spore survival, Trial 1

Fallow duration (months)	AM spores (no./g soil)	Maize yield	
		–(P + Zn)	+(P + Zn)
21	14	2865	4937
11	26	3625	3632
6	44	5162	4704

Table 4: Effect of fallow length on AM spore survival, Trial 2

Fallow duration (months)	AM spores (no./g soil)
18	16
6	46
2	54

Table 5: Effect of fallow length on chickpea yields

Fallow length	Dry weight (g/plant) of chickpea at 12 weeks			
	Nil fertiliser	P (50 kg/ha)	Zn (10 kg/ha)	P + Zn
Long (14 months)	1.0	1.2	0.4	1.9
Short (6 months after wheat)	3.1	2.8	2.7	3.3

Results of a Queensland Wheat Research Institute (QWRI) trial at Macalister show that yields of chickpeas grown on short-fallow land (6 months after wheat) were much better than yields after long fallow on the same property (Table 5). The addition of P and Zn fertilisers could not entirely compensate for the lack of AM in chickpeas on the long fallow.

Long-fallow disorder is usually typified by poor crop growth. Plants seem to remain in their seedling stages for weeks and development is very slow. Mungbean plants remain very short and there is often an upward cupping of the youngest leaves. Additionally, because mungbean is such a quick-maturing crop, it is less likely to recover from long-fallow disorder (see Figure 1).

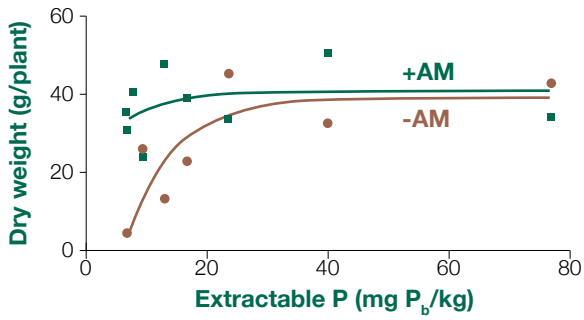


Figure 1: Mungbean dry weight with and without AM over a range of P levels.

5.5 Sulfur

Problems with S deficiency are most likely in double-cropped situations. Symptoms will first appear as yellowing of the upper leaves and petioles. Sulfur levels should be monitored through regular soil testing. Checking S levels before sowing will indicate the potential for deficiency, which can then be addressed through the use of a starter fertiliser containing S, or with gypsum or sulfate of ammonia. [9]

On soils with marginal levels of S, deficiency is most likely in double-crop situations where levels of available S have become very depleted (after high-yielding wheat or barley crops).

Soil sampling to a depth of 60 cm is recommended in the case of S.

Application of 5–10 kg S/ha will usually correct deficiency of S.

5.6 Zinc

Mungbean is responsive to Zn, and deficiency symptoms will appear as stunted plants and dead tissue between the veins. Foliar sprays can assist to overcome mild deficiencies in-crop, or regular applications of fertilisers containing Zn are a longer term solution. [10]

5.6.1 Pre-plant treatments

Severe deficiencies can be corrected for 5–8 years with a soil application of 15–20 kg/ha of zinc sulfate monohydrate worked into the soil 3–4 months before planting.

In the first year after application, the soil-applied Zn may not be fully effective, and a foliar Zn spray may also be required.

5.6.2 Seed treatments

Zinc seed treatments may be a cost-effective option where soil P levels are adequate but Zn levels are likely to be deficient.

[9] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[10] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

Zinc is highly toxic to rhizobia; therefore, label directions must be checked and followed. To minimise any damaging effect on the rhizobia, the Zn treatment needs to be applied first and then allowed to dry before applying the inoculum. Inoculated seed must be sown immediately into moist soil.

5.6.3 Fertiliser applied at planting and in-crop

Several phosphate-based fertilisers either contain, or they can be blended with, a Zn additive.

Foliar zinc sprays

Various liquid forms of Zn are available—check with your supplier.

5.7 Potassium

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

5.8 Foliar symptoms of nutrient disorders

5.8.1 Nitrogen deficiency

Leaves, petioles and stems of N-deficient plants turn lighter green in colour. This light green colouration is uniform throughout the plants, affecting both younger and older leaves.

Pink pigmentations extend up the major veins of leaflets and smaller specks of purple-brown anthocyanin are formed along the surface of petioles directly exposed to light. This pigmentation is more intense towards the distal end of the petioles and at petiole–petiolule joints. A fine strip of dark purple pigmentation then forms along some of the secondary veins and leaflets. It may also occur on the distal end of the midrib but rarely on the proximal end. This symptom, which starts with the older leaves and progresses up the plant as deficiency persists, is more apparent on the lower surface of the leaves (see Figure 2 for visual symptoms of N deficiency).

With severe N deficiency, a light brown pigmentation also develops in interveinal areas on the upper surface of leaves. Upper leaflets may also become cupped or crimped rather than flat. This symptom may be accompanied by purple pigmentation developing in the veins around the leaflet margin.

Figure 2: Symptoms of nitrogen deficiency in mungbean.

Because mungbean is a leguminous species, factors that affect either nodulation or N fixation can result in symptoms of N deficiency. Among such factors are the absence of an effective strain of *Rhizobium*, low soil pH, and deficiencies of nutrients such as molybdenum, cobalt, S or boron, which may be required in higher concentrations for N fixation than for plant growth. [11]

5.8.2 Phosphorous deficiency

Phosphorus-deficient plants remain dark green initially and leaflets are smaller than on plants receiving adequate P.

A band of anthocyanin pigmentation, 1–3 mm wide, is laid down at each node. Small purple specks are also formed along the ridges of the stems and petioles. These are more numerous near the base of the plant, where they coalesce to give the appearance of vertical purple stripes along the stem. There is an increase in the amount of anthocyanin formed towards the end of the petiole/petiolule joints. This colouration may also extend up the major veins of some leaflets but is less intense than on petioles.

Lower leaves lose colour later and exhibit a blotchy green appearance. Brown colouration may develop adjacent to the small veins on these leaves. This colouration is particularly apparent from the underside of the leaflets (Figure 3). [12]

Figure 3: Symptoms of phosphorus deficiency in mungbean.

[11] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Module 2. Pulse Australia Ltd.

[12] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Module 2. Pulse Australia Ltd.

5.8.3 Calcium deficiency

Calcium deficiency affects the young leaves at the top of the plant; older leaves near the base are normal and remain dark green. Young expanded leaves first turn light green, then brown necrotic areas develop on their leaflets, primarily between the veins. These begin as grey-brown spots and later expand to form a central light brown area, ~1 mm in diameter, surrounded by a darker brown area 3–7 mm in diameter. A light-brown necrotic area develops on the margin of the stipules of these leaves. The petiolules of these leaflets then turn dark brown and collapse, and the petiole itself may begin to die back along its length (Figure 4).

Expanding leaves fail to develop and leaflets abscise readily. Internode length towards the top of the plant is reduced and the terminal bud withers and dies, resulting in a stunted plant. Roots are shot and thick with black tips. [13]

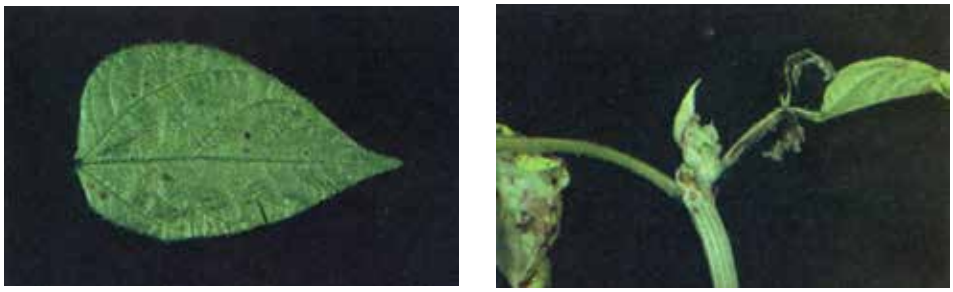


Figure 4: Symptoms of calcium deficiency in mungbean.

5.8.4 Potassium deficiency

The first symptom noted on K-deficient plants is the malformation of leaves midway down the stem. The leaflets of these leaves are severely crimped and crinkled and tend to curl down and roll inward at their tips (Figure 5). They remain dark green initially and are somewhat shinier on their upper surface than are normal leaves. The major leaf veins on the lower surface of the leaflets become brown in colour. This symptom, however, does not appear on the upper leaflet surface. Small dark brown specks, <0.5 mm in diameter, form between the veins on the upper surface of leaflets of secondary leaves. These specks are particularly numerous where leaf surfaces are exposed to sunlight and they tend to coalesce to form large brown areas adjacent to the major veins. However, they do not extend over the veins.

As K deficiency becomes more acute, the lower leaves turn lighter green. Yellowing tends to begin on the leaflet margins and progresses inward toward major veins and midrib. Light brown necrotic patches may develop between the veins on the lower surfaces of leaflets of lower leaves and on the tips and margins of the stipules. [14]

[13] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Module 2. Pulse Australia Ltd.

[14] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Module 2. Pulse Australia Ltd.

Figure 5: Symptoms of potassium deficiency in mungbean.

5.8.5 Sulfur deficiency

The first symptom that appears on S-deficient plants is yellowing of the upper leaves and petioles (Figure 6).

Red-purple anthocyanin accumulates on the petioles, particularly on the end adjacent to the petiolules. It may also be seen as a pink colouration on the upper surface of the midrib and main veins of young expanded leaflets (Figure 6). Bands of anthocyanin, 1–3 mm wide, accumulate on the stem at the nodes of upper leaves. Ridges on the lower stem also become reddened with anthocyanin.

As S deficiency becomes more severe, lower leaves also become lighter green in colour. At this stage, symptoms of S deficiency are undistinguishable from those of N deficiency. [15]

Figure 6: Symptoms of sulfur deficiency in mungbean.

5.8.6 Iron deficiency

Iron deficiency symptoms appear on the young expanding leaves at the top of the plant. These leaves, together with their petioles, are yellow-green in colour (Figure 7).

Areas immediately adjacent to the midrib and major leaf veins remain darker green than the remainder of the leaflet surfaces (Figure 7), but often, there is not a strong pattern on interveinal chlorosis as occurs on many other species. Apart from a very narrow, purple band at the base of each petiolule, very little anthocyanin accumulates on iron-deficient plants. [16]

[15] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Module 2. Pulse Australia Ltd.

[16] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Module 2. Pulse Australia Ltd.

Figure 7: Symptoms of iron deficiency in mungbean.

5.8.7 Zinc deficiency

Young expanding leaflets of Zn-deficient plants curl inwards at the margins (Figure 8). This symptom is very striking and quite specific to Zn deficiency in mungbean.

Internodes are shortened and the plant stunted. Older expanded leaflets turn lighter green but areas immediately adjacent to the major veins usually retain their dark green colour. These leaves have a crisp, brittle feel and their tips curl downward. A light brown colouration may also form on both their upper and lower surfaces between the veins. Numerous small dark brown specks <0.5 mm in diameter also form on the upper surface of the leaflets (Figure 8).

On the lower surface, many of the secondary veins turn brown. Light-brown necrotic areas with a narrow, darker brown margin then develop between the veins. These expand to form irregularly necrotic patches, up to 15 mm long.[17]

Figure 8: Symptoms of zinc deficiency in mungbean.

5.8.8 Magnesium deficiency

Leaves of magnesium (Mg)-deficient plants tend to 'droop' and curl downward. They are lighter green in colour than those of normal plants. Grey-green 'scalded' areas develop between the major veins on the leaflets of fully expanded leaves (Figure 9). Tissues in these areas die, to form light-brown or straw-coloured necrotic patches with darker brown margins. These areas increase in size and may cover most of the leaflet surface.

The midrib area and some of the major veins on these leaflets remain green, however, resulting in the characteristic Mg-deficiency symptom shown in Figure 9. Yellowing

[17] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Module 2. Pulse Australia Ltd.

intensifies between the veins on lower leaves, resulting in a blotchy appearance of these leaves. [18]

Figure 9: Symptoms of magnesium deficiency in mungbean.

5.8.9 Copper deficiency

Copper deficiency symptoms first appear on expanded leaves midway down the stem. Leaflets of these leaves 'droop' and appear wilted, particularly during the early afternoon. They become a little lighter green in colour, and grey-green 'scalded' areas form on the surfaces of the leaflets between the veins (Figure 10). These increase in size until most of the leaflet withers and it falls from the plant.

The petioles of the lower leaves also collapse. Tissue breakdown begins near the distal end of the petiole as brown necrotic streaks in the four grooves that occur around the petiole. The lower side of the petiole is usually more severely affected than the upper side (Figure 10). This causes the end of the petiole to fall downward in a 'hooked' manner. [19]

Figure 10: Symptoms of copper deficiency in mungbean.

5.8.10 Manganese deficiency

Manganese (Mn) deficiency affects the young expanding leaves on the top of the plant. These leaves become distorted as they expand (Figure 11). Leaflet tips roll under and the remainder of the surface is crinkled. Small dark-brown spots, <0.5 mm in diameter, form between the veins of these leaflets. These may be so numerous as to almost completely cover the interveinal areas of some expanding leaves. In others, they may coalesce to form larger, irregularly shaped, dark-brown areas. Necrosis then develops in these larger areas. When this occurs, the central area loses most of its colour and becomes transparent. This is often surrounded by a very dark brown margin ~0.5 mm wide.

[18] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Module 2. Pulse Australia Ltd.

[19] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Module 2. Pulse Australia Ltd.

Very little chlorophyll is formed in interveinal cells of young Mn-deficient leaflets; tissue immediately adjacent to the veins is green, but in other areas the leaflets are translucent. With severe deficiency, the terminal buds turn black and die. Auxiliary buds may then begin to develop, but if deficiency persists, these also die, resulting in a stunted plant.[20]

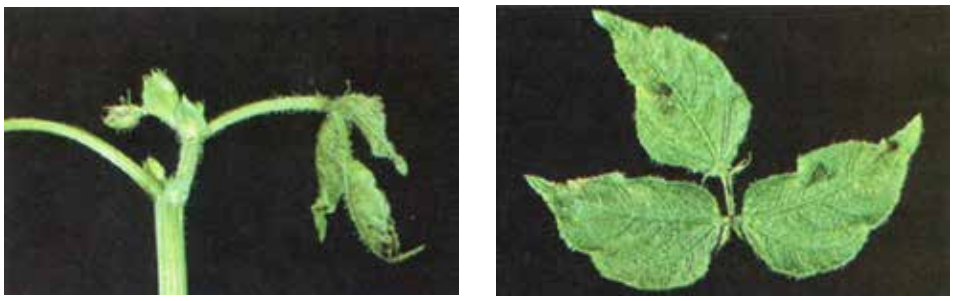


Figure 11: Symptoms of manganese deficiency in mungbean.

5.8.11 Boron deficiency

Boron-deficient plants remain dark green. Leaflets are thicker than on normal plants, tend to 'droop' downward and abscise readily.

The characteristic symptom is death of the terminal growing point (Figure 12). This turns black, withers and dies, resulting in a stunted plant. Auxiliary bud development is enhanced because of this, but if deficiency persists, these also turn black and die. Young leaves roll inward at the margins. Where lower secondary leaves do not absciss, they may develop interveinal chlorosis (Figure 12).

No anthocyanin accumulation occurs on the plant shoots. Root growth is severely reduced. Roots tend to be short and thick with dark brown tips.[21]

Figure 12: Symptoms of boron deficiency in mungbean.

5.8.12 Manganese toxicity

Mungbean is more sensitive to excess Mn than many other species. The first symptom seen on plants is on the primary unifoliate leaves. Dark-purple pigmentation is formed on many of the major veins of these leaves (Figure 13). This pigmentation is particularly prominent on the lower surface of these leaves. Dark brown flecking is particularly prominent on the lower trifoliate leaves, on the petiolules and on stipules. Although these

[20] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Module 2. Pulse Australia Ltd.

[21] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Module 2. Pulse Australia Ltd.

flecks can form anywhere on the leaflet surfaces, initially there is a tendency for them to concentrate adjacent to the major veins on the upper surface.

As toxicity becomes more severe, the upper leaves become yellow and develop a chlorosis similar to that due to iron deficiency. A pattern of brown colouration then forms around the veins on the upper surface of leaflets of young expanded leaves. This pattern is composed of numerous dark brown spots, <0.2 mm in diameter, on a lighter brown background in interveinal areas close to the major veins (Figure 14). With severe Mn toxicity, young expanding leaves are yellow with large brown necrotic patches occurring between the veins.

Red-brown necrosis may develop on the ridge of petioles of the lower leaves. The necrosis may also extend down the ridges on the stem immediately below the node. Tissue on the lower side of the petiole collapses, and the leaf 'droops' down.[22]

Figure 13: Early symptoms of manganese toxicity in mungbean,

Figure 14: Later symptoms of manganese toxicity in mungbean.

[22] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Module 2. Pulse Australia Ltd.

5.8.13 Boron toxicity

Dark-brown necrotic spots 0.5–2 mm in diameter develop on the primary unifoliate and the lower trifoliate leaves. These spots form in interveinal areas towards the margins and between the major veins of these leaves; they rarely form close to the midrib or major leaflet veins (Figure 15). They are visible on both the upper and lower surfaces of the leaflets, but on the lower surface are frequently surrounded by a light-brown stained area.

As toxicity persists, these spots become more numerous and coalesce to form larger necrotic area. The interveinal tissue may break down completely leaving dead, light-brown patches, 3–5 mm in diameter on the leaf surface. Leaves with severe symptoms may then yellow and abscise (Figure 15). These symptoms progress up successive leaves on the plant and on younger leaves may be accompanied by some interveinal chlorosis particularly around the leaflet margins. [23]

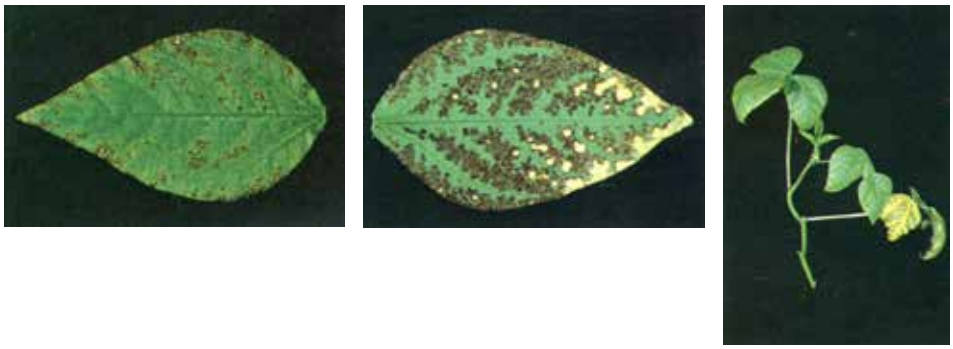


Figure 15: Symptoms of boron toxicity in mungbean.

[23] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Module 2. Pulse Australia Ltd.

SECTION 6

Weed control

More information

J Fleming *et al.* (2012) Weed control in summer crops 2012–13. NSW DPI Management Guide.

Australian Pesticides and Veterinary Medicines Authority.

Mungbean are poor competitors with weeds, and this can compromise water-use efficiency, interfere with harvesting, and contaminate the seed sample.

Limited broadleaf herbicide options exist for use in mungbean either pre- or post-emergence. Growers should select paddocks clean of broadleaf weeds. A range of post-emergent options is available for grass weed control.

Mungbean are generally desiccated for harvest, and some desiccants can provide a degree of late-season control of weed escapes.

The problem of herbicide resistance should be considered, 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 in alkaline soils and dry conditions.

Some residual herbicides in winter cereals have a minimum 12-month plant-back to mungbean. The shorter minimum for some herbicides may need to be extended in high pH soil or dry conditions.

More information

Managing the weed seedbank. Section 3. GRDC Integrated Weed Management Hub.

Clean seed. WeedSmart.

Growers need to consider the previous herbicide usage on a paddock prior to planting mungbean. In a set rotation where mungbean are planned, weed control in the previous crop and fallow will likely require knockdown herbicides so that residual carryover is not a plant-back concern in the mungbean crop. Knowledge of the likely weed seedbank in a paddock will guide the decision on its suitability for mungbean in a rotation.

Weed-seed contamination in harvested mungbean makes marketing more difficult and can result in a lower price. Although some weed seeds can be removed by grading, sorghum and thornapple seeds are particularly difficult to remove. Desiccation is recommended for removing green weed material, which can cause harvesting difficulties and higher moisture in the sample, as well as for removing the potential for weed-seed contamination (see *GrowNotes Mungbean* Section 11: Crop desiccation, *and* Section 12: Harvest). [1]

[1] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

6.1 Getting best results from herbicides

Successful results from herbicide application depend on many interacting factors including biological (weed health, growth stage of crop and weed, density), environmental (conditions prior to, during and post spraying), and management (droplet size, volume, product etc.).

Annual weeds mainly compete with cereals and broadleaf crops when the crops are in their earlier stages of growth. Weeds should be removed no later than 6 weeks after sowing to minimise losses. Early post-emergence control nearly always results in higher yields than treatments applied after branching in broadleaf crops.

Points to remember for the successful use of herbicides:

- Follow the recommendations on the label.
- Read the label. Check that the chemical is appropriate. Note any mixing instructions, especially when tank mixing.
- Carefully check crop and weed growth stages before deciding upon a specific post-emergent herbicide.
- Conditions inhibiting plant cell growth, such as stress from drought, waterlogging, poor nutrition, high or low temperatures, low light intensity, disease or insect attack, or a previous herbicide application, are not conducive to maximum herbicide uptake and translocation.
- Plan the operation; check the paddock sizes, tank capacities, and water availability and supply.
- Do not spray outside the recommended crop growth stages because crop damage may result.
- Use good quality water. Incorrect pH, hardness and muddy water can reduce the effectiveness of some herbicides.
- Use good equipment checked frequently for performance and output.
- Use sufficient water to ensure a thorough, uniform coverage regardless of the method of application.
- Check boom height with spray pattern operation for full coverage of the target.
- Check the accuracy of boom width marking equipment.
- Check wind speed and direction. A light breeze helps herbicide penetration into crops. However, do not spray when wind is strong (>10–15 km/h). Do not spray if rain is imminent or when heavy dew or frost is present.
- Select the appropriate nozzle type for the application. Avoid compromising nozzle-types when tank-mixing herbicides with fungicides or insecticides.
- Be aware of spray conditions to avoid potential spray drift onto sensitive crops and pastures, roadways, dams, trees, watercourses or public places.
- Check that thorough decontamination was carried out after the previous spray application. Details of the decontamination required can be found on the herbicide label.
- Seek advice before spraying recently released pulse varieties. They may differ in their tolerance to herbicides.
- Keep appropriate spray records for each spray operation.

More information

Australian Pesticides and Veterinary Medicines Authority.

J Fleming *et al.* (2012) Weed control in summer crops 2012–13. NSW DPI Management Guide.

6.2 Broadleaf weed control

Control options for broadleaf weeds are very limited in mungbean, and a weed management strategy should be developed prior to planting.

Only one active ingredient, acifluorfen (224 g/L in Blazer®), is registered for post-emergent control in mungbean. Pre-emergent options are also limited to trifluralin (480 g/L, Treflan™), pendimethalin (455 g/L, Stomp® XTRA) and imazethapyr (700 g/kg, Spinnaker®).

Spring plantings, in particular, often encounter significant weed problems because of high populations of both grass and broadleaf weeds after the first 'summer' rains.[2]

6.2.1 Trifluralin (Treflan™) and pendimethalin (Stomp®)

For best results, both products require incorporation after applications and as such are not suitable for no-tillage farming systems. However, some producers are looking to use these products as part of their Group A herbicide resistance management.

Trifluralin can reduce establishment and early seedling vigour in mungbean. Ideally, it should be applied 2–3 weeks prior to planting to minimise the risk of crop damage. This particularly applies where the higher rates are used.[3]

6.2.2 Imazethapyr (Spinnaker®)

More information

APVMA PubCRIS database.

Re-cropping intervals

Although this product controls a wide range of broadleaf and grass weeds, its use is restricted by residual activity and limitations on re-cropping. Spinnaker® is only registered as a pre-emergent in mungbean.[4]

6.2.3 Acifluorfen (Blazer®)

Acifluorfen (Herbicide Group G) is a contact herbicide causing desiccation die-back of the weeds.

Weeds should be treated when small (see Blazer® product label); larger weeds often have the ability to recover from application (e.g. bladder ketmia) (Table 1).

Weeds should be actively growing and not subject to heat or moisture stress. In summer, there is only a 3–10-day window after rain for optimum control.

Coverage is critical. Nozzle selection and operating pressure are just as important as high water volumes.

[2] Cumming, G (2014) et al, Pulse Australia Ltd, Northern Mungbean – Best Management Practices Training Course

[3] Cumming, G (2014) et al, Pulse Australia Ltd, Northern Mungbean – Best Management Practices Training Course

[4] Cumming, G (2014) et al, Pulse Australia Ltd, Northern Mungbean – Best Management Practices Training Course

Avoid application during the heat of the day to minimise the extent of leaf burn in the mungbean.

Very late afternoon or night-time has been shown to be the safest time to apply Blazer® in mungbean.

The addition of ethylated vegetable oil adjuvant (i.e. Hasten™) dramatically increases efficacy on weeds, but has possible phytotoxic effects on the crop. Never exceed 1 L Blazer®/ha when using Hasten™ at 1%. [5]

Table 1: Registered weeds for mungbean on Blazer® label

Common name	Scientific name	Maximum weed size	Label rate
Annual ground cherry	*Physalis* spp.	200 mm high	2.0 L
Apple of Peru	*Nicandra physalodes*	6-leaf	1.5 L
Bellvine*	*Ipomoea plebia*	6-leaf	2.0 L
Blackberry nightshade	*Solanum nigrum*	4-leaf	2.0 L
Bladder ketmia*	*Hibiscus trionum*	4-leaf	2.0 L
Capeweed	*Arctotheca calendula*	4-leaf	2.0 L
Fumitory	*Fumaria* spp.	4-leaf	2.0 L
Giant pigweed	*Trianthema* spp.	2-leaf	2.0 L
Jute	*Corchorus* spp.	6-leaf	2.0 L
Noogoora burr*	*Xanthium occidentale*	4-leaf	2.0 L
Pigweed	*Portulaca oleracea*	100 mm diameter	1.5 L
Prince of Wales feather	*Amaranthus* spp.	6-leaf	2.0 L
Redshank	*Amaranthus hybridus*	6-leaf	2.0 L
Sesbania pea*	*Sesbania* spp.	200 mm high	2.0 L
Thornapple	*Datura* spp.	6-leaf	2.0 L
Turnip weed	*Rapistrum rugosum*	6-leaf	1.5 L
Wild gooseberry	*Physalis minima*	200 mm high	2.0 L
Wild radish	*Raphanus raphanistrum*	6-leaf	1.5 L

6.3 Post-emergent grass weed control

Effective control of grass weeds with post-emergent herbicide relies on product choice, timeliness, good application practice and robust rates.

Specifically, good knowledge of the grass species present in the paddock based on scouting and previous weed loads will allow rates to be matched to the weed that is hardest to control. Spraying weeds when they are small (3–5-leaf stage) will also provide more consistent control.

The Group A herbicides provide better control when weeds are actively growing and free from heat and nutritional and water stress, both prior to application and for a short period after. Seedling grass weeds such as *Urochloa* or barnyard grass enter into moisture stress quickly, especially if secondary roots have not established. The leaves can also become water-repellent under hot, dusty conditions.

[5] Cumming, G (2014) et al, Pulse Australia Ltd, Northern Mungbean – Best Management Practices Training Course

Grass seedlings are a small target and good application techniques and boom-spray set-up are critical to achieving coverage. High water rates will increase reliability of control.[6]

6.3.1 Mode of action of Group A herbicides

The Group A grass herbicides are systemic and rely on absorption through the leaves and then translocation to the growing points (meristematic tissue) of the plant in order to achieve control. This is why weeds need to be actively growing to achieve effective control.

Treated grasses usually stop growing within 1–2 days of spraying.

Symptoms first appear 7–10 days after treatment, usually as a yellowing of the youngest leaves and a browning of the growing points at the base of the youngest leaves. Unfurled leaves are easily pulled out, revealing brown, rotting buds at the leaf base.

The young leaves turn pale and chlorotic, then they brown off. The older leaves eventually collapse, with complete plant death occurring 4–6 weeks after spraying. Some weed species may also exhibit reddening of lower leaves and leaf sheaths.[7]

6.3.2 Avoidance of stress conditions

All grass herbicide labels emphasise the importance of only spraying when the weeds are actively growing under mild, favourable conditions. Any of the following stress conditions can significantly impair both uptake and translocation of the herbicide within the plant. This may result in incomplete kill or suppression only of weeds:

- moisture stress (and drought)
- waterlogging
- high temperature–low humidity conditions
- nutrient deficiency
- use of pre-emergent herbicides that effect growth and root development, i.e. Spinnaker®, Treflan™, and Stomp® (ensure that grass weeds have fully recovered before applying grass herbicides)
- excessively heavy dews, resulting in poor spray retentions on grass leaves.

Volunteer winter cereals are notoriously difficult to control in double-crop mungbean. This is mainly due to a combination of high temperature and nitrogen-deficiency stresses reducing translocation of the grass herbicides to the main sites of action within the plant.[8]

6.3.3 Adjuvants

Adjuvants can give dramatic improvement in grass weed control when using Group A herbicides. This is primarily through improved leaf coverage and absorption through the leaf cuticle.

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6 Cumming, G (2014) et al, Pulse Australia Ltd, Northern Mungbean – Best Management Practices Training Course

7 Cumming, G (2014) et al, Pulse Australia Ltd, Northern Mungbean – Best Management Practices Training Course

8 Cumming, G (2014) et al, Pulse Australia Ltd, Northern Mungbean – Best Management Practices Training Course

Trials by Dow in 1999 (eight trials) demonstrate that efficacy of marginal rates of use of Group A herbicide on grass weeds can be doubled with the addition of spray oils (Tables 2 and 3).

Table 2: Mean percentage control of four grasses over seven sites with Verdict 104 (a.i. haloxyfop 520 g/L) applied at a marginal use rate with and without spray oil (source: Chris Love 1999)

Spray oil	Rate (% v/v)	% Control
No oil	–	43
D-C-Tron®	1.0	77
Ulvapron®	1.0	79
Uptake™	0.5	90

Table 3: Effect of adjuvants on absorption of Targa (a.i. quizalofop 200 g/L) (source: Beckett et al. 1992)

	% Applied dose inside plant	% Control volunteer corn
Petroleum oil concentrate (mineral oil) 1.5%	80%	97%
Non-ionic surfactant (0.25%)	18%	50%
None	8%	3%

More information

Australian Pesticides and Veterinary Medicines Authority.

Choice of adjuvant will depend on the product(s) being used, the weeds targeted and the environmental conditions. Always consult your agronomist and read the label to follow the recommendations for adjuvant use. [9]

6.3.4 Grass herbicide damage in mungbean

Group A herbicides can occasionally cause leaf spotting in mungbean. This is usually associated with high temperatures soon after spray application. [10]

6.3.5 Sulfonylurea residues in boom-spray

- Traces of SU herbicides in boom-sprays have the potential to cause significant damage to mungbean crops.
- The risk of residue damage is greater in the presence of grass selective herbicides.
- Decontaminate the boom if you have previously used SU herbicides, in accordance with the instructions on the label. [11]

6.4 Water quality for herbicide application

Good quality water is important when mixing and spraying herbicides. It should be clean and of good irrigation quality. Poor quality water can reduce the effectiveness of some

[9] Cumming, G (2014) et al, Pulse Australia Ltd, Northern Mungbean – Best Management Practices Training Course

[10] Cumming, G (2014) et al, Pulse Australia Ltd, Northern Mungbean – Best Management Practices Training Course

[11] Cumming, G (2014) et al, Pulse Australia Ltd, Northern Mungbean – Best Management Practices Training Course

herbicides and damage spray equipment. Some poor results with herbicides may be due to water quality problems. [12]

6.4.1 Effects of water quality

Water quality depends on the source of the water (rainfed tank, dam, river, bore or aquifer) and the season (e.g. heavy rain, drought). Several characteristics of water quality affect chemical performance:

- **Dirt**. Dirty water has very small soil particles (clay and silt) suspended in it. These soil particles can absorb and bind the chemical's active ingredient and reduce its effectiveness. This applies especially to glyphosate, paraquat and diquat. Dirt can also block nozzles, lines and filters and reduce the sprayer's overall performance and life. As a guide, water is considered dirty when it is difficult to see a 10 cent coin in the bottom of a household bucket of water.
- **Water hardness**. Water is termed hard when it has a high percentage of calcium and magnesium. Hard water will not lather with soap and can cause some chemicals to precipitate. Susceptible chemicals often have agents added to overcome this problem. Formulations of 2,4-DB are particularly sensitive to hard water (>400 µg/g of CaCO3 equivalent). Other herbicides such as glyphosate, 2,4-D amine and MCPA amine, clopyralid (Lontrel™) and diflufenican + MCPA (Tigrex®) can also be affected. Hard water can also affect the balance of the surfactant system and affect properties such as wetting, emulsification and dispersion. Very hard water can reduce the efficiency of agents used to clear dirty water.
- **Water pH**. pH is a measure of acidity and alkalinity scaled on a range of 1–14. A pH of 7 is neutral, <7 acid and >7 alkaline. Most natural waters have a pH of 6.5–8. In highly alkaline water (pH >8) many chemicals undergo a process called alkaline hydrolysis. This process causes the breakdown of the active ingredient into other compounds, which can reduce the effectiveness of the pesticide over time. This is one reason why spray mixes should not be left in spray tanks overnight. Very acid water can also affect the stability and physical properties of some chemical formulations.
- **Dissolved salts**. The total amount of mineral salts dissolved in water is usually measured by the electrical conductivity (EC) of the water. The EC of bores and dams depends largely on the salt levels in the rock and soil that surrounds them. During a drought, the salinity of water increases. Very salty water can cause blockages in equipment and is more resistant to changes in pH.
- **Organic matter**. Water containing a lot of organic matter such as leaves or algae can block nozzles, lines and filters. Algae can also react with some chemicals, reducing their effectiveness.
- **Temperature**. Very hot or cold water can affect the performance of some chemicals and the mixing. [13]

[12] G Brooke, C McMaster (2014) Weed control in winter crops 2014. NSW DPI Management Guide. NSW Department of Primary Industries. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/123157/Weed-control-in-winter-crops-2014.pdf

[13] G Brooke, C McMaster (2014) Weed control in winter crops 2014. NSW DPI Management Guide. NSW Department of Primary Industries. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/123157/Weed-control-in-winter-crops-2014.pdf

6.4.2 Improving water quality

Water needs to be tested to determine whether it will affect chemical performance. Commercial products are available to reduce pH (e.g. Primabuf® BB5 and LI700 and Hot-Up®), soften hard water and clear dirty water.

To reduce the effects of very salty water, you may need to mix water from several sources.

Table 4 summarises the effect of water quality on some herbicides. [14]

Table 4: Herbicide tolerances to water qualities (source: Weed control in winter crops 2012, NSW DPI)

✓, Satisfactory; ✗, do not use; NR, not recommended but use quickly if there is no alternative; Test, mix herbicides and water in proportion and observe any instability; Marginal, not ideal, but acceptable

Herbicide	Water quality				
	Muddy	Saline	Hard	Alkaline (>8)	Acidic (<5)
2,4-DB			✗	NR	
2,4-D or MCPA amine	✓	✓	✗	NR	
2,4-D or MCPA ester	✓	Test	Test	✓	✓
Affinity® (carfentrazone-ethyl)	✓	✓	✓	✗	NR
Ally® (metsulfuron-methyl)	✓	✓	✓	Marginal	✗
Brodal® (diflufenican)		✓	✓	✗	
Dicamba	✓	✓	NR	NR	
Diuron	✓	test	✓	✓	
Diuron + 2,4 amine	✓	Test	✗	NR	
Diuron + MCPA amine	✓	Test	✗	NR	
Fusilade Forte™ (fluazifop-p-butyl)	✓	✓	✓	NR	✗
Glean® (chlorsulfuron)	✓	✓	✓	Marginal	✗
Glyphosate	✗	✓	✗		✓
Gramoxone® (paraquat)	✗	✓	✓	✓	✓
Hoegrass® (diclofop-methyl)	✓	✓	✓	NR	✓
Logran® (butafenacil + triasulfuron)	✓	✓	✓	Marginal	✗
Lontrel™ (clopyralid)	✓	✓	✗	✗	
Sertin® (sethoxydim)	✓	✓	✓	✓	✓
Simazine	✓	✗	✓	NR	
Spray.Seed® (paraquat + diquat)	✗	✓	✓	✓	✓
Targa® (quizalofop)	✓	✓	✓	✓	✓
Tigrex® (diflufenican + MCPA)	✓	✗	✗	NR	
Trifluralin		✓	✓	✓	✓
Verdict™ (haloxyfop)	✓	✓	✓	NR	✓

6.5 Tips for tank-mixing herbicides

Tank-mixing of herbicides is a common practice to improve weed control and broaden the weed spectrum.

There may also be some advantages in helping to avoid herbicide resistance. Many tank mixes are included on registered herbicide labels. Generally, provided herbicides are

[14] G Brooke, C McMaster (2014) Weed control in winter crops 2014. NSW DPI Management Guide. NSW Department of Primary Industries. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/123157/Weed-control-in-winter-crops-2014.pdf

registered for a particular use, they may be tank-mixed provided they are compatible and label mixing instructions are followed. Note that some herbicides, although being physically compatible, can be antagonistic to weed control. This information is usually outlined on herbicide label, under 'compatibility'.

The order that herbicides are mixed is also important and the following mixing sequence is usually followed:

1. Water-conditioning agents (if required e.g. LI700, Liase® or Primabuff®)
2. Water-dispersible granules (WG) and dry flowable products (including those in water-soluble bags)
3. Wettable powders (WP)
4. Flowables or suspension concentrates (e.g. atrazine, simazine liquids)
5. Emulsifiable concentrates (EC) (e.g. trifluralin, Verdict®)
6. Water-soluble concentrates (e.g. glyphosate, Surpass®, Spray.Seed®)
7. Surfactants and oils (e.g. BS1000®, Hasten®, DC Trate®)
8. Soluble fertilisers [15]

6.6 Adjuvants

Adjuvants can result in a dramatic improvement in grass weed control when using Group A herbicides. This is primarily by improved leaf coverage and absorption through the leaf cuticle. Choice of adjuvant will depend on the product(s) being used, the weeds targeted and the environmental conditions. Always consult your agronomist and read the label to follow the recommendations for adjuvant use.

6.6.1 Using adjuvants, surfactants and oils with herbicides

An adjuvant is any additive to a herbicide that is intended to improve the effectiveness of the herbicide. Many products have been developed to assist herbicides first to contact the weed target, then to remain and penetrate the weed leaf.

Adjuvants can be classified as follows.

Surfactants

Surfactants are products that increase the spread of droplets, or the wetting of waxy or hairy leaf surfaces.

Surfactants consist of three types:

- Anionic surfactants have a negative charge and are not often used with herbicides.
- Cationic surfactants have a positive charge, such as many domestic detergents, and are rarely used with herbicides.
- Non-ionic surfactants are the most commonly used agricultural surfactants. They

[15] G Brooke, C McMaster (2014) Weed control in winter crops 2014. NSW DPI Management Guide. NSW Department of Primary Industries. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/123157/Weed-control-in-winter-crops-2014.pdf

are non-reactive (no electrical charge). They remain on the leaf once dry and allow 'rewetting' after rain, permitting additional herbicide uptake. Examples include BS 1000, Agral® 600.

Crop oils

Most crop oils contain emulsifiers to allow them to mix with water and some contain various levels of surfactants.

Some claims regarding oil adjuvants include reduced rain-fast periods, more uniform droplet size (drift reduction), less spray evaporation and better penetration of herbicide into waxy leaves.

Oils can be divided into three main groups:

- Mineral oils are usually a blend of mineral oil and non-ionic surfactant. Products such as Ad-Here and D-C-Tron® have low levels of surfactant, whereas Uptake™ and Supercharge® have higher levels. These products have lower potential for crop phytotoxicity because they are more refined than vegetable oils.
- Vegetable oils are a blend of vegetable oils and non-ionic surfactant and are sometimes called crop oil concentrates. Examples include Synertrol and Codacide.
- Esterified vegetable oils are the most commonly used products. They are produced by reacting vegetable oil with alcohol, then blending with a high level of non-ionic surfactant. The physical and chemical properties are quite different from those of vegetable oil. Superior wax-modifying characteristics and penetrating ability are claimed. These products should be used strictly according to the label with selective herbicides. Hasten™ and Kwickin™ are examples of these products.

Penetrants

These products are specific compounds that help to dissolve waxy cuticles.

Acidifying–buffering agents

These products help to lower the pH of the spray solution, i.e. they make solutions more acidic. Most herbicides are most stable when the pH of the solution is 6–7 (neutral or slightly acidic). Examples include Spraymate™ LI 700 and Primabuff BB5.

Compatibility agents

These materials reduce the likelihood of antagonism from other agents in the spray solution. The most commonly used compatibility agent is ammonium sulfate. It is also used to neutralise the effect of hard water on amine formulations such as glyphosate. Examples of these products are Spraymate™ Liaise and Liquid Boost.

Some products combine a number of the above roles, for example, Hot-Up™ contains surfactant, a compatibility agent and oil.

A range of other adjuvants can be added to herbicides during formulation to improve efficacy and increase crop safety or ease of herbicide use. These include thickeners, spreaders, stickers, anti-foamers and safeners.

6.6.2 Factors affecting adjuvant use

Crop safety

Addition of an adjuvant can reduce herbicide selectivity and thereby increase crop damage. This is not an issue for fallow and pre-emergent herbicides.

Effectiveness or activity

Adjuvants are usually added to increase the effectiveness of herbicides; however, the wrong type or rate can reduce effectiveness, such as decreasing herbicide retention on leaves.

Water hardness

Hard water can lead to poor mixing of the chemical with water. This particularly occurs with emulsifiable concentrates. High levels of calcium and magnesium ions bind with the amine formulations, causing them to be less soluble and therefore less effective.

Water temperature

Low water temperature can lead to gelling in the tank. High-concentration herbicides might not mix, and surfactants might perform badly. [16]

6.7 Herbicide resistance

Heavy reliance on the very effective grass and/or broadleaf herbicides since the 1980s has seen the development of herbicide resistance across southern Australia in a range of cropping weeds, including annual ryegrass, wild oats, Indian hedge mustard, wild radish, wild turnip, prickly lettuce, barley grass, awnless barnyard grass, liverseed grass and capeweed.

Herbicide resistance is a major threat to northern Australian grain growers; however, it need not spell the end of profitable cropping. Delaying the onset of resistance and/or reducing the impact of herbicide-resistant weed populations calls for the implementation of a wide range of weed-control strategies, which will in turn help to sustain profitable grain production.

The threat of herbicide resistance does not mean that herbicides should not be used. It does mean that growers should avoid over-reliance on herbicides that have the same mode of action (MOA) on plants. All herbicide labels now indicate the herbicide group to which the active ingredient belongs.

[16] G Brooke, C McMaster (2014) Weed control in winter crops 2014. NSW DPI Management Guide. NSW Department of Primary Industries. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/123157/Weed-control-in-winter-crops-2014.pdf

Table 5: List of confirmed resistant weeds in northern NSW (2014)
Tony Cook, NSW DPI)

Weed	Herbicide group	Areas with resistance in NSW	Future risk	Detrimental impact
Wild oats	A - e.g. Topik & Wildcat B - e.g. Atlantis Z - e.g. Mataven	Spread across the main wheat growing areas. More common in western cropping areas	Areas growing predominantly winter crops	HIGH
Paradoxa grass	A - e.g. Wildcat	North and west of Moree	Areas growing predominantly winter crops	HIGH
Awnless barnyard grass	C – e.g. triazines			MODERATE
	M - e.g. glyphosate	Mainly between Goondiwindi and Narrabri	Zero or minimum tilled farms with summer fallows	VERY HIGH
Charlock, Black bindweed, Common sowthistle, Indian hedge mustard, Turnip weed	B – e.g. Glean & Ally	Spread across the main wheat growing areas	Areas growing predominantly winter crops	MODERATE
Annual ryegrass	M - e.g. glyphosate	Group M widespread in Liverpool Plains.	Areas with predominantly winter fallows	HIGH
	B - e.g. Glean A - e.g. Verdict	A and B resistance in central west NSW	Winter cropping areas	HIGH
Fleabane	M - e.g. glyphosate	Spread uniformly across the region	Cotton crops and zero of minimum tilled systems	MODERATE
Wild Radish	I – e.g. 2,4-D amine	Central West NSW	Continuous winter cereal cropping	HIGH
Windmill Grass	M - e.g. glyphosate	Central West NSW	Continuous winter cropping and summer fallows	HIGH
Liverseed Grass	M - e.g. glyphosate	A few isolated cases	Zero or minimum tilled systems	MODERATE
Sowthistle	M – e.g. glyphosate	Liverpool Plains	Winter cereal dominated areas with minimum tillage.	HIGH

6.7.1 Preventing herbicide resistance

To prevent herbicide resistance, a combination of cultural, chemical and management controls should be rotated. Aim to use as many different methods of weed control as practical in the overall paddock management, including:

- rotation of herbicide groups
- use of knockdown herbicides for seedbed preparation
- strategic tillage

- crop competition
- crop rotation
- grazing
- hay making
- pasture topping
- seed capture and destruction at harvest

Care is needed when introducing control methods into the overall paddock plan. For example, weed numbers, especially resistant populations, can increase dramatically under mungbean because of poor competition by the crop.

6.7.2 Monitoring

Monitoring of weed populations before and after any spraying is an important management tool:

- Keep accurate records.
- Monitor weed populations and record results of herbicide used.
- If herbicide resistance is suspected, prevent weed seedset.
- If a herbicide does not work, find out why.
- Check that weed survival is not due to spraying error.
- Conduct your own paddock tests to confirm herbicide failure to determine which herbicides are still effective.
- Obtain a herbicide-resistance test on seed from suspected plants, testing for resistance to other herbicide (MOA) groups.
- Do not introduce or spread resistant weeds in contaminated grain or hay.

Regular monitoring is required to assess the effectiveness of weed management and the expected situation following weed removal or suppression. Without monitoring, we cannot determine the impact of a management program or assess how it might be modified in the future for improved results.

Effective weed management begins with monitoring weeds to assess current or potential threats to crop production, and to determine best methods and timing for control measures.

Regular monitoring and recording details of each paddock allows the grower to:

- spot critical stages of crop and weed development for timely cultivation or other intervention;
- identify the weed flora (species composition), to help determine best short- and long-term management strategies; and
- detect new invasive or aggressive weed species while the infestation is still localised and eradication is possible.

The ‘weed scout’ watches for critical aspects of the weed–crop interaction, such as:

- weed-seed germination and seedling emergence

- weed growth sufficient to affect crops if left unchecked
- weed density, height and cover relative to crop height, cover and stage of growth
- impacts of weed on crops, including:
  - harbouring pests, pathogens, or beneficial organisms
  - modifying microclimate, air circulation, or soil conditions
  - direct competition for light, nutrients, and moisture
- flowering, seedset, or vegetative reproduction in weeds
- efficacy of cultivations and other weed-management practices

Information gathered through regular and timely field monitoring helps growers to select the best tools and timing for implementing weed control tactics. Missing vital cues in weed and crop development can lead to costly efforts to rescue a crop, which may not be fully effective. Good paddock scouting can help the grower to achieve the most effective weed control for the least fuel, labor, chemical, crop damage and soil disturbance.

Weed monitoring, a practical approach

Check each paddock regularly and often enough to identify critical stages of crop and weed development for timely intervention and to evaluate efficacy of weed-management practices. This weed scouting can be done whenever you scout for insect pests and beneficials, or enter the paddock to plant, tend, irrigate or harvest crops. Scout for weeds every few days during crop germination, emergence and early establishment. Later, scouting once a week is usually sufficient.

To scout weeds, walk slowly through the paddock, examining any vegetation that was not deliberately planted. In larger paddocks, walk back and forth in a zigzag pattern to view all parts of the paddock, noting areas of particularly high or low weed infestation. Identify weeds with the help of a good weed guide or identification key for your region. Note which weed species are most prominent or abundant.

Note how each major weed is distributed through the paddock. Are the weeds randomly scattered, clumped or concentrated in one part of the paddock?

Keep records of your weed scouting in a field notebook. Prepare a page for each paddock or crop sown, and take simple notes of weed observations each time the paddock is monitored. Your notes will become a timeline of changes in the weed flora over the seasons and in response to crop rotations, cover crops, cultivations and other weed control practices. Many growers already maintain separate records for each paddock. Weed observations (species, numbers, distribution, size) can be included with these.

When to scout, and what to look for in a new paddock or farm

An important aspect of purchasing farmland is to look at the weeds. Presence of highly aggressive or hard-to-kill weeds, intense weed pressure, stressed and nutrient-deficient weeds, or a weed flora indicative of low or unbalanced soil fertility or pH may foretell problems that should be considered when deciding whether to buy or rent, or how much to offer.

During your first 1–2 years on a new farm or paddock, study the weeds carefully throughout the season, and be sure to get correct identification of the 5–10 most common weeds. Note what weeds emerge, grow or reproduce during different parts of the annual cropping cycle:

- which weeds in which season
- after primary tillage and during seedbed preparation
- after crop planting
- during crop growth and maturation
- after harvest
- during cover-crop emergence and establishment

Questions to ask include:

- What are the main species of weeds present at different times of year?
- When does each weed species emerge, flower and set seed?
- Which paddocks or areas have the worst weed pressure, and the least?
- Are any particularly troublesome or invasive species present?

Make the same observations again a few years later to track changes in weed flora in response to management practices.

Monitoring fence-lines and paddock-margin ecosystems

In addition to scouting production paddocks, monitor and manage fence-lines, uncultivated paddock margins and alleys between crop rows. These areas can become complex ecosystems with native and introduced weeds, grasses and clovers, and a diversity of plant-eating, predatory and parasitic insects.

Such areas of natural vegetation can be valuable reservoirs for beneficial insects and wildlife; they can also harbor weeds or other pests that can invade the paddock.

Use the following questions to determine when it is time to treat paddock margins or alleys:

- Are any of the weed species in paddock margins emerging or reproducing within the cropping area?
- Are there any particularly troublesome weeds in the paddock-margin flora?
- Are any undesirable weed species in the margin or alley bolting or beginning to flower?
- Is herbicide resistance developing in fence-lines that have been regularly treated with knockdown herbicides over several years?

6.7.3 Herbicide resistance in summer crops

The best investment a grain grower can make is to test any weedy outbreak suspected of having herbicide resistance. It provides valuable information about which herbicides do not work and, more importantly, which herbicides are effective. An approximate cost of a broad-spectrum test is $400–500. This would include at least six or seven herbicides. This cost is insignificant compared with a widespread spray failure on 200 hectares that costs $30/ha in herbicides, totaling $6,000 in wasted herbicide, not including crop yield losses and the blowout in weed seed for future years.

Two types of tests are available: a quick test and a seed test. The quick test involves live seedlings being sent to the test provider for re-potting and spraying. Once the plants have fully recovered, they are sprayed with herbicides of your choice. Results are usually reported 4–8 weeks after arrival at the testing facility. This is often too late to enable re-treatment of the 'suspect' patches, but does provide early knowledge about the nature of the problem, and therefore, what is likely to work in the future. One disadvantage of the quick test is that it cannot test for resistance to pre-emergence herbicides, because the plants are already emerged.

A seed test requires seed to be sent to the provider and often involves breaking seed dormancy upon arrival. It is a particularly useful test if you require resistance testing to pre-emergence herbicides. The turnover time is ~4 months. [17]

Herbicide resistance test providers:

Plant Science Consulting
Ph: 0400 664 460
Email: info@plantscienceconsulting.com
www.plantscienceconsulting.com
Postal: 22 Linley Avenue,
Prospect SA 5082
Offer both Seed & Quick tests

Charles Sturt University
Ph: (02) 6933 4001
Postal: Herbicide Resistance Testing,
School of Agricultural & Wine Sciences
Locked Bag 588
Wagga Wagga NSW 2678
Offer Seed tests only.

6.8 Evolution of herbicide resistance

Herbicide resistance evolves following the intensive use of herbicides for weed control.

In any weed population, a small number of individuals are likely to be naturally resistant to herbicides because of genetic diversity, even before the herbicides are used. When a herbicide is used, these individuals survive and set seed, whereas the majority of susceptible plants are killed. Continued use of a herbicide or herbicide group will eventually result in a significant fraction of the weed population with resistance.

Four main factors influence the evolution of resistance:

- **Intensity of selection pressure.** This refers to how many weeds are killed by the herbicide. It is good practice to use robust labelled rates of herbicides to control weeds, as this will lead to the highest and most consistent levels of weed control. Failure to control weeds adequately will lead to increases in weed populations and put pressure on all herbicides used.
- **Frequency of use of a herbicide or MOA group.** For most weeds and herbicides, the number of years of herbicide use is a good measure of selection intensity. The more often a herbicide is applied, the higher the selection pressure and the higher the risk of herbicide resistance developing.
- **Frequency of resistance present in untreated populations.** If the frequency of resistant genes in a population is relatively high, such as with Group B herbicides,

[17] T Cook (2014) Herbicide resistance management. In Weed control in winter crops 2014. (G Brooke, C McMaster) NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/123157/Weed-control-in-winter-crops-2014.pdf

resistance will occur quickly. If the frequency is low, such as with Group M herbicides, resistance will occur more slowly.

- **Biology and density of the weed.** Weed species that produce large numbers of seeds and have a short seedbank life in the soil will evolve resistance faster than species with long seedbank lives. Weed species with greater genetic diversity are more likely to evolve resistance. Resistance is also more likely to be detected in larger weed populations. [18]

Herbicide resistance has developed a strong foothold in Australian agriculture since it was first reported in annual ryegrass in 1982. It has spread and diversified to become a key constraint to crop production in all states with a history of intensive herbicide use.

Today, resistance has been confirmed in 38 grass and broadleaf weed species. More worrying, resistance has developed to 11 distinctly different herbicide chemical groups. This significantly reduces herbicide options for the grower. Cases of multiple resistances have been commonly reported, where, for example, annual ryegrass proves resistant to two or more chemical groups.

6.8.1 Mode of action (MOA)

Importance of MOA

The main reason why resistance has developed is the repeated and often uninterrupted use of herbicides of the same MOA. Selection of resistant strains can occur in as little as 3–4 years if attention is not paid to resistance management. Note that the resistance risk is the same for products having the same MOA. If you continue to use herbicides with the same MOA, and do not follow a resistance-management strategy, you are creating future problems for yourself. Mode of action matters.

MOA labelling in Australia

To facilitate management of herbicide-resistant weeds, all herbicides sold in Australia are grouped by MOA, indicated by a letter code on the product label. MOA labelling is based on the resistance risk of each group of herbicides. Australia was the first country to introduce compulsory MOA labelling on products. The letters and codes used in Australia are unique because they were the first, they are compulsory and they reflect the relative risk of resistance evolving in each group. Since the introduction of MOA labelling in Australia, other countries have adopted MOA classification systems. Caution should be shown if cross-referencing MOA between Australia and other countries, because many countries use a different classification system.

The herbicide MOA grouping and labelling system in Australia was revised in 2007. This is the first major revision of the classification system since its introduction.

The original groupings were made several years ago based on limited knowledge about modes of herbicide action. Groupings have now been changed to improve their accuracy, based on increased knowledge, to enable informed decisions about herbicide rotation

[18] CropLife Australia (2011) Herbicide resistance management strategies—2011. CropLife Australia, http://www.croplife.org.au/files/resistancemanagemen/herbicides/2011%20Herbicide%20Resistance%20Management%20Strategies.pdf

and resistance management. The general intent of grouping based on risk has not changed; however, six new herbicide MOA groups were created to group herbicides more accurately. [19]

6.8.2 Herbicide grouping by MOA and ranking by resistance risk

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

GROUP	G	HERBICIDE

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

More information

CropLife Australia (2011) Herbicide resistance management strategies—2011. CropLife Australia, http://www.croplife.org.au/files/resistancemanagemen/herbicides/2011%20Herbicide%20Resistance%20Management%20Strategies.pdf

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

Specific guidelines are also available for the herbicides of MODERATE RESISTANCE RISK: Group C (annual ryegrass, wild radish and silver grass), Group D (annual ryegrass and fumitory), Group F (wild radish), Group I (wild radish and Indian hedge mustard), Group J (serrated tussock and giant Parramatta grass), Group L (annual ryegrass, barley grass, silver grass, square weed and capeweed), Group M (annual ryegrass, barnyard grass, fleabane, liverseed grass and windmill grass), Group Q (annual ryegrass), and Group Z (wild oats and winter grass). [20]

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

6.9 Avoiding contamination with seeds that are prohibited or difficult to grade-out

Weed seeds in the harvested sample create a number of serious problems in mungbean:

- They significantly increase grading costs and percentage grading losses.
- Heavy discounts apply to weed seeds that are difficult to grade-out.
- Samples containing prohibited seeds cannot be sold by classification, and can only be sold by forwarding a sample to the intending buyer. This is a much slower process, and often results in delayed payment to growers.

[19] CropLife Australia (2011) Herbicide resistance management strategies—2011. CropLife Australia, http://www.croplife.org.au/files/resistancemanagemen/herbicides/2011%20Herbicide%20Resistance%20Management%20Strategies.pdf

[20] CropLife Australia (2011) Herbicide resistance management strategies—2011. CropLife Australia, http://www.croplife.org.au/files/resistancemanagemen/herbicides/2011%20Herbicide%20Resistance%20Management%20Strategies.pdf

6.9.1 Declared or prohibited weed seed

Prohibited weed seeds for Queensland and New South Wales are listed in Tables 6 and 7.

Table 6: Prohibited weed seeds—Queensland

Common name	Scientific name
African boxthorn	*Lycium ferocissimum*
Alligator weed	*Alternanthera philoxeroides*
Badhara bush	*Gmelina asiatica*
Bitter sneezeweed	*Helenium amarum*
Blackberry	*Rubus* spp.
Boneseed	*Chrysanthemoides monilifera*
Bramble	*Rubus* spp.
Broomrape	*Orobanche* spp.
Chinee apple	*Ziziphus mauritiana*
Clockweed	*Gaura* spp.
Cottontails	*Froelichia floridana*
Crofton weed	*Ageratina adenophora*
Deenanath grass	*Pennisetum pedicellatum*
Dinebra	*Dinebra retroflexa*
Dodder	*Cuscuta* spp.
Field bindweed	*Convolvulus arvensis*
Giant foxtail	*Setaria faberi*
Giant sensitive plant	*Mimosa invisa*
Giant sensitive tree	*Mimosa pigra*
Groundsel bush	*Baccharis halimifolia*
Harrisia cactus	*Eriocereus* spp.
Hemlock	*Conium maculatum*
Hoary cress	*Cardaria draba*
Indian hemp	*Cannabis sativa*
Indian jujube	*Ziziphus mauritiana*
Itch grass	*Rottboellia cochinchinensis*
Java bean	*Cassia obtusifolia*
Johnson grass	*Sorghum halepense*
Knobweed	*Hyptis capitata*
Lesser jack	*Emex spinosa*
Mesquites	*Prosopis* spp.
Mexican poppy	*Argemone* spp.
Mission grass	*Pennisetum polystachion*
Mist flower	*Ageratina riparia*
Navua sedge	*Cyperus aromaticus*
Nutgrass	*Cyperus rotundus*
Opium poppy	*Papaver somniferum*
Parthenium weed	*Parthenium hysterophorus*
Prickly acacia	*Acacia nilotica*
Prickly pear	*Opuntia* spp.
Ragweed	*Ambrosia* spp.
Red rice	*Oryza rufipogon*

Common name	Scientific name
Rubber vine	*Cryptostegia grandiflora*
Russian knapweed	*Acroptilon repens*
Saffron thistle	*Carthamus lanatus*
Silver-leaved nightshade	*Solanum elaeagnifolium*
Skeleton weed	*Chondrilla juncea*
Sowthistle	*Sonchus arvensis*
Spear thistle	*Cirsium arvense*
Spiny emex	*Emex australis*
St John's wort	*Hypericum perforatum*
Thornapple	*Datura* spp.
Witchweed	*Striga* spp.
Yellow nutgrass	*Cyperus esculentus*

Table 7: Prohibited weed seeds—New South Wales

Declared weeds		Prohibited seeds	
Common name	**Scientific name**	**Common name**	**Scientific name**
Australian bindweed	*Convolvulus erubescens*	African feather grass	*Pennisetum macrourum*
Bugloss	*Echium* spp.	Black bindweed	*Fallopia convolvulus*
Bulbous oatgrass	*Arrhenatherum elatius*	Blue heliotrope	*Heliotropium amplexicaule*
Common heliotrope	*Heliotropium europaeum*	Broomrape	*Orobanche* spp.
Docks	*Rumex* spp.	Buffalo burr	*Solanum rostratum*
Glaucous star thistle	*Carthamus glaucus*	Burr grass	*Cenchrus brownii*
Hexham scent	Melilotus indicus	Burrs	*Xanthium* spp.
Hoary cress	*Cardaria draba*	Caltrop	*Tribulus terrestris*
Horehound	*Marrubium vulgare*	Cape tulips	*Homeria* spp.
Khaki weed	*Alternanthera pungens*	Cardoon	*Cynara cardunculus*
Mexican poppy	*Argemone mexicana*	Carolina horse nettle	*Solanum carolinense*
Mintweed	*Salvia reflexa*	Charlock	*Sinapis arvensis*
Mustard	*Sisymbrium* spp.	Clockweed	*Gaura parviflora*
Oat (wild, black)	*Avena* spp.	Colombus grass	*Sorghum X almum*
Onion grass	*Romulea* spp.	Dark blue snakeweed	*Stachytarpheta urticifolia*
Onion weed	*Asphodelus fistulosus*	Dodders	*Cuscuta* spp.
Paterson's curse	*Echium plantagineum*	Espartillo	*Stipa brachychaeta*
Saffron thistle	*Carthamus lanatus*	Field bindweed	*Conolvulus arvensis*
Skeleton weed	*Chondrilla juncea*	Gallon's curse	*Cenchrus biflorus*
Slender thistle	*Carduus* spp.	Giant foxtail	*Setaria faberi*
Spear thistle	*Cirsium vulgare*	Golden thistle	*Scolymus hispanicus*
St. Barnaby's thistle	*Centaurea solstitialis*	Gooseberries	*Physalis* spp.
Three-cornered jack	*Emex australis*	Groundsel bush	*Baccharis halimifolla*
Turnip weed	*Rapistrum rugosum*	Hemlock	*Conium maculatum*
Variegated thistle	*Silybum marianum*	Indian hemp	*Cannabis sativa*
Wild turnip	*Brassica tournefortii*	Johnson grass	*Sorghum halepense*
Yellow burrweed	*Amsinckia* spp.	Mesquite	*Prosopis* spp.
		Mignonette	*Reseda lutea*, *R. luteola*
		Mossman river grass	*Cenchrus echinatus*

Declared weeds		Prohibited seeds	
Common name	Scientific name	Common name	Scientific name
		Nodding thistle	*Carduus nutans*
		Nutgrass	*Cyperus rotundus*
		Opium poppy	*Papaver somniferum*
		Oxalis	*Oxalis* spp.
		Parthenium weed	*Parthenium hysterophorus*
		Perennial thistle (spear)	*Cirsium arvense*
		Ragweed	*Ambrosia* spp.
		Ragwort	*Senecio jacobaea*
		Red rice	*Oryza rufipogon*
		Russian knapweed	*Acroptilon repens*
		Serrated tussock	*Nassella trichotoma*
		Silver-leaved nightshade	*Solanum elaeagnifolium*
		Smallflower opium poppy	*Papaver somniferum* ssp. *setigerum*
		Smoothstem turnip	*Brassica oxyrrhina*
		Soldier's thistle	*Picnomon acarna*
		Sowthistle	*Sonchus arvensis*
		Spotted thistle	*Scolymus maculatus*
		Spiny burr grass	*Cenchrus incertus*
		Spiny burr grass	*Cenchrus longispinus*
		Star thistle	*Centaurea calcitrapa*
		St John's wort	*Hypericum perforatum*
		Stinkwort	*Dittrichia graveolens*
		Texas blueweed	*Helianthus ciliaris*
		Thistles	*Onopordum* spp.
		Thornapple	*Datura* spp.
		Wild radish	*Raphanus raphanistrum*
		Witch weed	*Striga* spp.
		Yellow nutsedge	*Cyperus esculentus*

6.9.2 Volunteer wheat and barley seeds

Wheat and barley seeds are difficult to remove during grading and can result in heavy discounts when being traded in the premium sprouting and cooking grade markets.

Contamination is most likely in double-crop situations where mungbean follow wheat and barley. Delaying planting until a kill can be achieved on volunteer cereals will often rectify the problem. Alternatively, a Group A herbicide can be used in-crop.

6.9.3 Grain sorghum seed

Sorghum seed is extremely difficult to remove by grading. Volunteer sorghum plants should be removed with a grass herbicide, or hand rogued prior to harvest in the case of very light, scattered infestations.

6.9.4 Thornapple seed/false castor oil seed (*Datura stramonium*)

Similar comments as for sorghum seed.

6.9.5 Bellvine, cowvine, morning glory seeds

These weed seeds are very difficult to grade out of the smaller seeded mungbean varieties (i.e. Celera and Green Diamond).

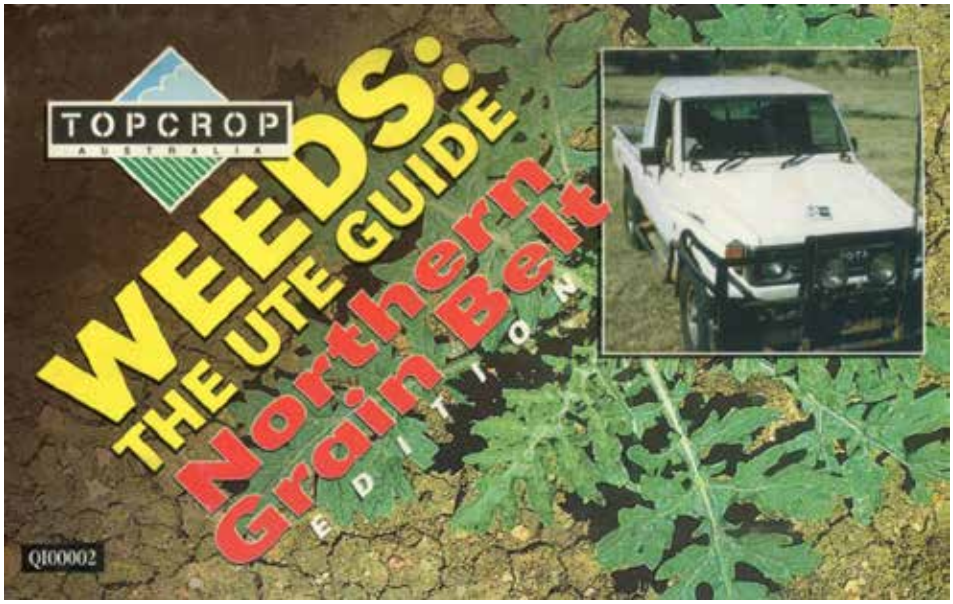
6.10 Rainfastness and stock and harvest withholding periods

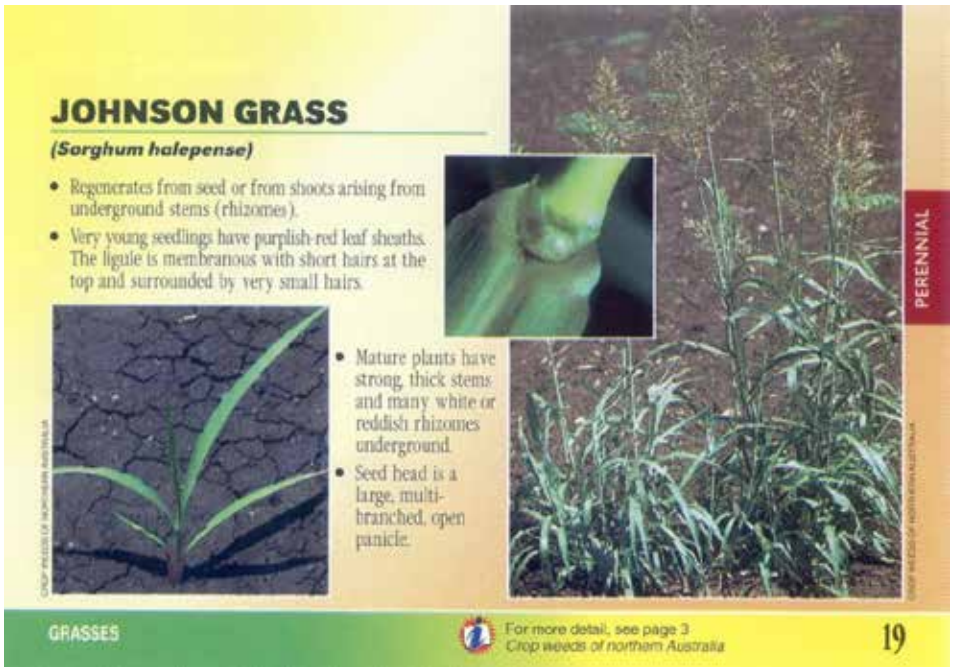
- Harvest withholding periods. This is the number of days you must wait after spraying before harvesting grain, to ensure that grain is free of pesticide residues.
- Rainfastness. This describes the time interval required between herbicide application and rainfall. Avoid applying herbicide when rain is imminent. However, certain herbicides may not be affected by some rain during or after spraying.
- Stock-grazing or fodder-production withholding periods. This is the number of days you must wait after spraying before allowing stock to graze the area, to ensure that animal produce is free of pesticide residues. Check latest MRL data with individual companies for produce to be sold on the export market. [21]

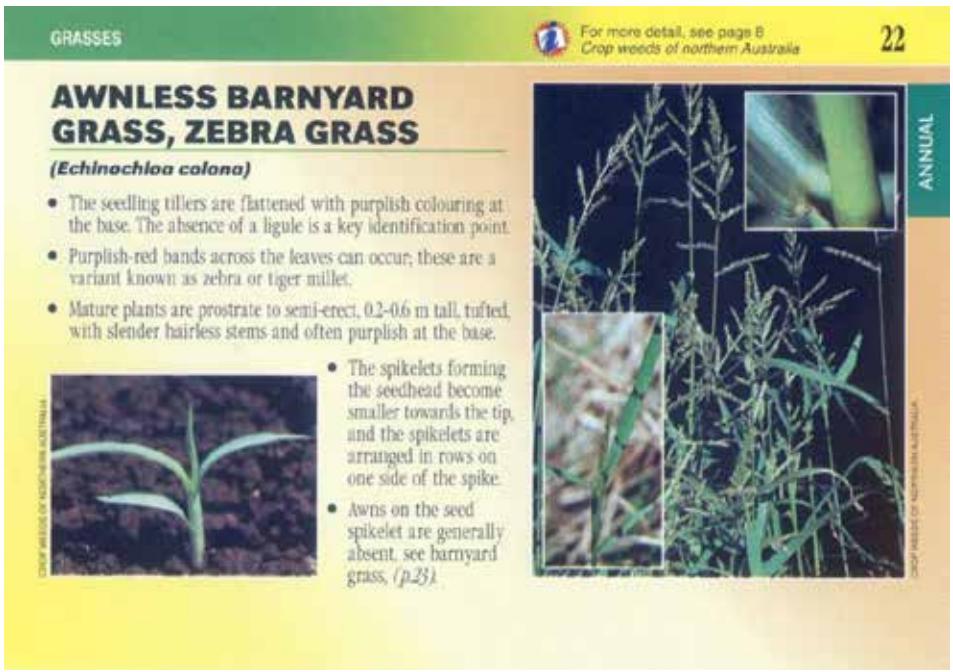
[21] G Brooke, C McMaster (2012) Weed control in winter crops 2012. NSW DPI Management Guide. NSW Department of Primary Industries. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/123157/Weed-control-in-winter-crops-2014.pdf

6.11 Appendix. Common summer grass weed identification

Reprinted courtesy of: 'Weeds: The ute guide—Northern grain belt' (available from the GRDC Book Shop: http://www.grdc.com.au/Resources/Publications).







GRASSES

For more detail, see page 8
Crop weeds of northern Australia

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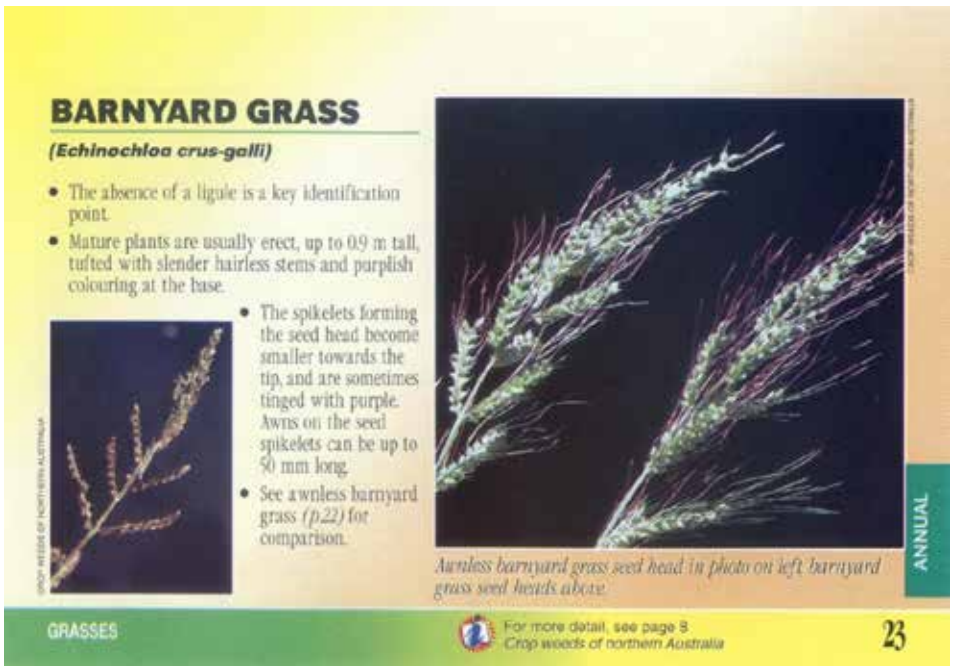
AWNLESS BARNYARD GRASS, ZEBRA GRASS

(Echinochloa colona)

- The seedling tillers are flattened with purplish colouring at the base. The absence of a ligule is a key identification point.
- Purplish-red bands across the leaves can occur; these are a variant known as zebra or tiger millet.
- Mature plants are prostrate to semi-erect, 0.2-0.6 m tall, tufted, with slender hairless stems and often purplish at the base.
- The spikelets forming the seedhead become smaller towards the tip, and the spikelets are arranged in rows on one side of the spike.
- Awns on the seed spikelet are generally absent, see barnyard grass, *(p.23)*.

ANNUAL



BARNYARD GRASS

(Echinochloa crus-galli)

- The absence of a ligule is a key identification point.
- Mature plants are usually erect, up to 0.9 m tall, tufted with slender hairless stems and purplish colouring at the base.
- The spikelets forming the seed head become smaller towards the tip, and are sometimes tinged with purple. Awns on the seed spikelets can be up to 50 mm long.
- See awnless barnyard grass *(p.22)* for comparison.

Awnless barnyard grass seed head in photo on left barnyard grass seed heads above

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GRASSES

For more detail, see page 8
Crop weeds of northern Australia

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For more detail, see page 9
Crop weeds of northern Australia

SUMMER GRASS

(Digitaria ciliaris)

- Seedlings are bluish-green. A key identification point is that the underside of leaves is very hairy as well as the leaf sheath. The ligule is papery and 1-2 mm long in the mature leaf.

- Mature plants are sprawling, up to 1 m tall. Stems take root where joints touch the ground.
- The leaf blades are hairless or sparsely hairy at the base. The leaf sheaths are hairy whereas the true stems are hairless with a reddish tinge.
- Seed heads have four to nine thin spikes, spreading from the top of slender, erect stalks.

ANNUAL

UROCHLOA, LIVERSEED GRASS

(Urochloa panicoides)

- Seedlings are yellowish-green, with hairs on the leaf sheaths and leaf margins. A key identification feature is the very broad leaves. The ligule is a low, papery rim, capped with short hairs.
- Mature plants are prostrate or ascending, up to 0.6 m tall, and tufted. Stems can sometimes take root where joints touch the ground.

- Leaves are usually hairy, especially on the margins, and margins are crinkled.
- The seed head has two to seven spikes arising from the main stem at well spaced intervals. Seeds occur in two rows on one side of the spike.

ANNUAL

For more detail, see page 11
Crop weeds of northern Australia

For more detail, see page 22
Crop weeds of northern Australia

DINEBRA

(Dinebra retroflexa)

- Seedlings are hairless with a purplish-red base. The veins of the leaf sheaths and a small patch at the join of the leaf and the leaf sheath are also purplish-red. The ligule is papery and minutely split at the end, and is 1-1.5 mm long in the mature leaf.
- Mature plants are tufted and grow up to 0.6 m tall. Flowering stems are purplish-red and sprawling.

- The seed head has alternate spikes, initially perpendicular to the stem then hanging down at an angle. Seeds have a short awn and are red-brown at maturity.

ANNUAL

CROWSFOOT GRASS

(Eleusine indica)

- Young seedlings are bluish-green. The leaves remain close together and the leaf sheath is flattened, giving each tiller a flattened appearance. The ligule is short and papery, with scattered short hairs and is difficult to see with the naked eye.
- Mature plants form a tussock, with stems usually 0.3-0.6 m tall. Leaves are hairless with blunt tips.
- Seed heads are made up of one to fifteen long, thin spikes arising from the top of the stem. One spike is usually lower on the stalk than the rest.

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Crop weeds of northern Australia

GRASSES

For more detail, see page 178
Pasture plants of southern inland QLD

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WINDMILL GRASS, UMBRELLA GRASS, STAR GRASS

Chloris truncata

- Also known as blow-away grass.
- Mature plants usually grow 0.15–0.45 m tall and form a dense tuft of folded leaves, with seed heads on short stems about as long as the seed head spikes. Scattered long hairs occur on the leaf blade margins where the **blade meets the sheath. Stem bases are flat (in cross-section).**

- Seed head of about six to nine spikes radiating from a common point at the end of the stem, the spikes usually 0.12–0.2 m long and hairy at the base.
- Seeds are flat on one end, distinguishing it from slender chloris *(C. divaricata)* whose seeds have a rounded end.

ANNUAL

FEATHERTOP RHODES GRASS

(Chloris virgata)

- Seedlings are erect with stems having a flattened appearance (in cross-section). In older seedlings, the tillers are obviously flat in cross-section. The ligule is a low membranous rim that splits to resemble a cap of tiny hairs. There are tufts of long hairs on the leaf blade margins where the blade joins the sheath.

- Mature plants are tufted, branched, erect or semi-prostrate, with stems that can take root where the joints touch the ground.
- The seed head is silvery white with spikes held erect (unlike rhodes grass which has spreading, brown spikes).

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GRASSES

For more detail, see page 12
Crop weeds of northern Australia

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GRASSES

For more detail, see page 13
Crop weeds of northern Australia

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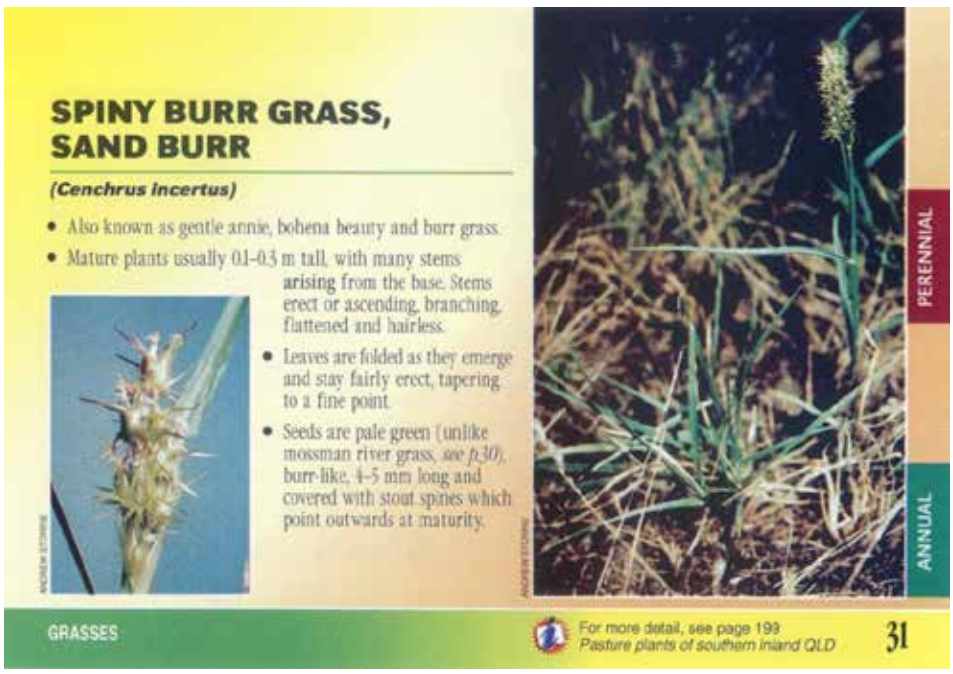
MOSSMAN RIVER GRASS, MOSSMAN BURR GRASS

(Cenchrus echinatus)

- Seedlings are erect and hairless with purplish-red leaf sheaths, particularly in older seedlings. The ligule is a rim of hairs, and several scattered hairs occur on the leaf margin near the base.
- Mature plants can form prostrate or ascending tufts with erect stems, hairless joints and stiff leaves.
- Spike-like seed heads have burrs. Burrs fall off easily when mature.
- Can be distinguished from spiny burr grass *(see p.31)* by a purple tinge to some plant parts including the seed head.

ANNUAL



SPINY BURR GRASS, SAND BURR

(Cenchrus incertus)

- Also known as gentle annie, bohena beauty and burr grass.
- Mature plants usually 0.1–0.3 m tall, with many stems arising from the base. Stems erect or ascending, branching, flattened and hairless.
- Leaves are folded as they emerge and stay fairly erect, tapering to a fine point.
- Seeds are pale green (unlike mossman river grass, *see p.30*), burr-like, 4–5 mm long and covered with stout spines which point outwards at maturity.

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GRASSES

For more detail, see page 199
Pasture plants of southern inland QLD

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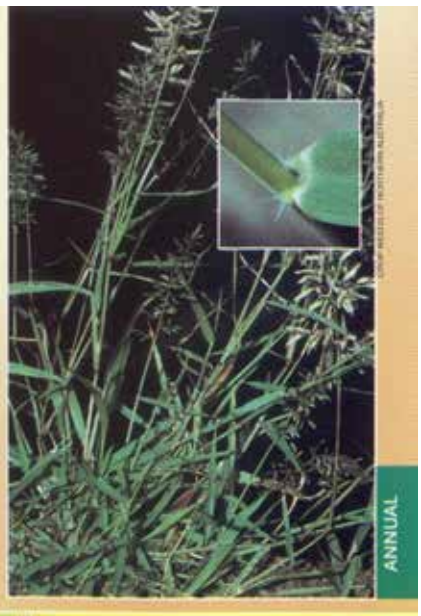
STINK GRASS, BLACKGRASS

(Eragrostis cilianensis)

- Seedlings are erect and bright green with purplish-red leaf sheaths. As the seedlings age they become sprawling and the leaf sheath colour reduces to purplish-red veins. The ligule is a rim of short hairs. Longer hairs occur on the leaf blade margins where the blade meets the sheath.

- Glands on the leaf margins and mid-veins give off an unpleasent smell.
- Mature plants are loosely tufted, up to 0.9 m tall, with erect or ascending stems. Leaf blades are usually hairless.
- Seed head is composed of flattened, spear-shaped spikes.



GRASSES

For more detail, see page 21
Crop weeds of northern Australia

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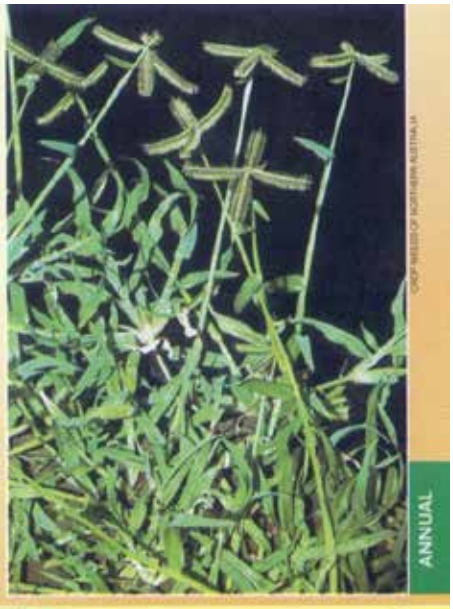
COAST BUTTON GRASS

(Dactyloctenium aegyptium)

- The seedling is initially erect but later sprawling. The base of the seedling is red (green in button grass, *see p.34*). The ligule is a low, papery rim capped with short hairs.
- A key identification feature is the long, obvious hairs scattered along the leaf margins, especially close to the leaf sheath.
- Mature plants can grow up to 0.7 m tall.

- The seed head has one to nine spikes, 12-65 mm long (usually considerably longer than button grass).



GRASSES

For more detail, see page 19
Crop weeds of northern Australia

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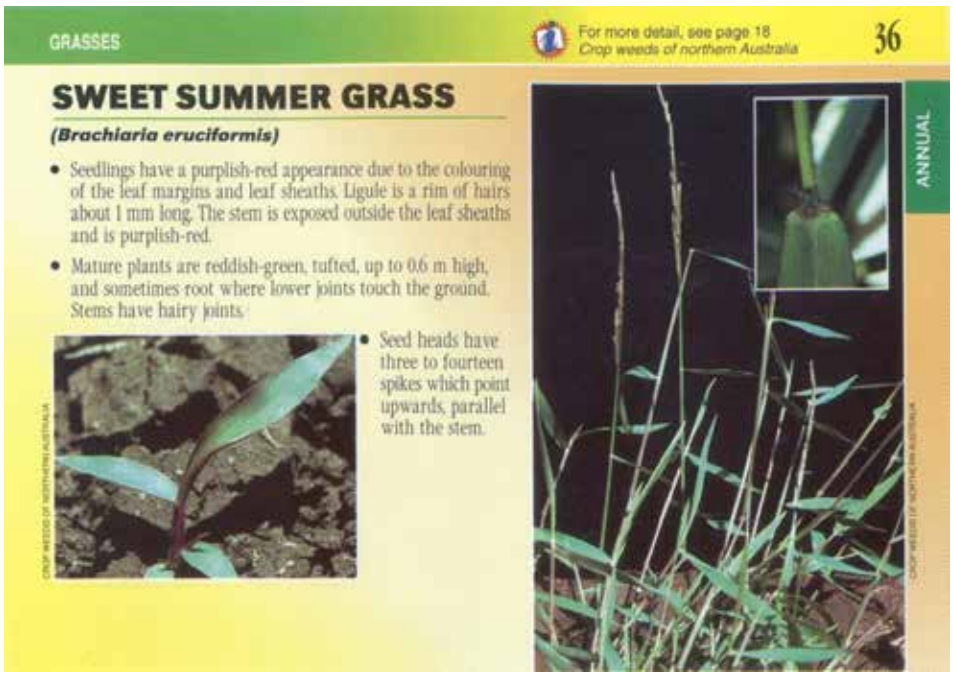

GRASSES

For more detail, see page 18
Crop weeds of northern Australia

36

SWEET SUMMER GRASS

(Brachiaria eruciformis)

- Seedlings have a purplish-red appearance due to the colouring of the leaf margins and leaf sheaths. Ligule is a rim of hairs about 1 mm long. The stem is exposed outside the leaf sheaths and is purplish-red.
- Mature plants are reddish-green, tufted, up to 0.6 m high, and sometimes root where lower joints touch the ground. Stems have hairy joints.
- Seed heads have three to fourteen spikes which point upwards, parallel with the stem.

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VELVET-LEAFED SUMMER GRASS

(Brachiaria windersii)

- Seedlings are yellowish-green.
- A key identification point is the velvet-like feel of the leaves due to a coating of fine hairs. The ligule is a rim of rather long hairs.
- Mature plants are tufted, yellowish-green with sprawling stems which do not root at the nodes.
- The seed head has branches that are arranged alternately around the stem at an angle perpendicular to the stem or sometimes drooping slightly.

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GRASSES

For more detail, see page 16
Crop weeds of northern Australia

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SECTION 7

Insect management

More information

http://ipmguidelinesforgrains.com.au/crops/summer-pulses/mungbean/

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/09/Insect-thresholds-for-key-insects-in-sorghum-sunflower-mungbeans-What-are-they-based-on-and-when-and-how-can-they-be-modified

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Taking-the-angst-out-of-thresholds-in-the-computer-age

http://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-101/Podborers-wing-to-the-west

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 podfill. Crops that 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 usually also support quite high populations of beneficial insects, a consideration when selecting insect control measures. [1]

Mungbean are a high-value summer pulse crop in which seed quality is paramount if top prices are to be realised. Indeed mungbean are often referred to as a horticultural pulse. Although mungbean are attacked by a number of serious pests, top yield and quality can be achieved with timely and appropriate pest control. However, injudicious over-spraying can lead to secondary pest outbreaks and an increase in pest-management costs. Incorrect spraying also increases the risk of pesticide resistance. Mungbeans are most susceptible to pest attack from budding to late pod-ripening.

The major mungbean insect pests are mirids (*Creontiades sp.*), *Helicoverpa*, podsucking bugs, bean pod borer (*Maruca vitrata*) and lucerne seed web moth *(Etiella*).

Mungbean share many of the same pests that affect other pulse crops, including soybeans. However, unlike soybeans, mungbean (and adzuki beans and navy beans) are susceptible to bean fly attack during the seedling stage. Spring mungbean are also attacked by seedling (cereal) thrips, but they usually have negligible impact on yield or maturity; low spring temperatures are the real reason why early-season mungbean crops often exhibit poor growth.

The indeterminacy of mungbean (i.e. overlapping of flowering and podding) makes them more susceptible to mirid and *Helicoverpa* attack than more determinate legumes such as soybeans. Mirids attack the buds and flowers, resulting in reduced podset, and they attack developing seeds. *Helicoverpa* (mainly *H. armigera*) attack buds, flowers, pods and seeds. Under favourable growing conditions, however, mungbeans can compensate for considerable flower and pod damage by setting new flowers and pods.

[1] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

Because of their relatively large flowers and their indeterminacy, mungbean are attractive hosts for bean pod borer, a caterpillar pest that feeds initially inside flowers before moving to the pods. Bean pod borer is a pest mainly in tropical and coastal regions, but in wetter seasons, has been reported in damaging numbers as far west as Surat (~450 km west of Brisbane).

Mungbean are susceptible to the same podsucking bugs that attack other summer pulses. Major podsucking bug species are the green vegetable bug *Nezara viridula*, the redbanded shield bug (*Piezodorus oceanicus*), and the large and small brown bean bugs (*Riptortus* and *Melanacanthus* spp., respectively). Thresholds for bugs are low in mungbeans; only 2% seed damage can downgrade the value of harvested seed by ≥$100/t.

Mungbean are more susceptible than soybeans to looper damage, because their flowers are larger and developing pods more succulent. However, loopers are less voracious flower feeders than *Helicoverpa*.

Mungbean are not a suitable host for silverleaf whitefly (SLW, *Bemisia tabaci*). Although SLW adults are frequently seen in mungbean in Central Queensland and coastal areas, the development of SLW nymphs on mungbean leaves is very poor. Nonetheless, SLW are a threat to Australian mungbeans because they can transmit *Mungbean yellow mosaic virus* (MYMV), a disease not yet present in Australia.

Bruchids are a major storage pest if best-practice post-harvest storage is not practiced. Mungbean are often infested in the field but infestations not detected until ≥3 months post-harvest. Infestations can also be initiated post-harvest if harvesting equipment and storage facilities are not regularly cleaned to remove old seed (a major risk factor). Bagged planting seed kept for any length of time out of cold storage is at particular risk.

In a typical inland crop, growers should budget for one dimethoate spray against mirids, one spray against *Helicoverpa* (most likely indoxacarb or thiodicarb), and one pyrethroid spray against podsucking bugs.

In coastal crops, one early dimethoate spray against bean fly and one indoxacarb or methomyl spray against bean pod borer may also be needed.[2]

7.1 Steps in the pest management process

1. Planning

- Be aware of the pests likely to attack the crop in your region and become familiar with what the pest and beneficial insects look like, damage symptoms, and time of attack.
- Study the latest sampling protocols and plan the logistics of sampling.
- Be aware of the latest management options, including pesticide permits and registrations in mungbeans, and of any use and withholding period restrictions.

2. Sampling

- Scout crops thoroughly and regularly during at-risk periods and record your counts.

[2] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

3. Decisions

- Make rational spray decisions based on economic thresholds, crop growing conditions, the number of beneficial insects, the risk of flaring non-target pests, and pesticide withholding periods.

4. Action

- Ensure aerial operators are informed of your plans and that ground-rig spray equipment is calibrated and set up for best-practice guidelines.
- Ensure that all applications are applied at the right time of day.
- Ensure that water used for spraying is of a suitable quality (e.g. not high pH).
- Record all spray details including rates, spray volume, pressure, nozzles, meteorological data, time of day.

5. Re-assessing and documenting results

- Assess crops after spraying (within 3–4 days) and record data for future reference.
- Record any environmental factors capable of causing damage similar to insect damage; for example, high temperatures and moisture stress reduce podset, a symptom also resulting from mirid damage.
- Record any flaring of secondary pests following the application of non-selective pesticides. [3]

7.2 When are mungbean at greatest risk?

Identifying when mungbean crops are susceptible to pests is the first step in good pest management. Insect pests can attack the mungbean plants at any stage from seedling to harvest.

However, the crop is most susceptible to pest attack from budding onwards (Figure 1). In summer, and in Central Queensland, budding can occur as early as 28–35 days after planting. In spring plantings, budding usually occurs 50–55 days after planting.

Crops must be monitored at least once per week during vegetative growth, preferably twice weekly, to determine exactly when the crop is entering its first susceptible stage, i.e. budding. Because the first buds are borne below the top of the canopy, the start of this stage can be determined only by assessing plants within the crop, not by looking at a crop from the road. [4]

7.2.1 Why crop check?

Correct and timely crop checking at susceptible stages is essential to:

- monitor changes in pest populations
- monitor crop growth development and the onset of critical crop stages
- minimise the risk of crop damage

[3] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[4] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

More information

http://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-108-Jan-Feb-2014/Whats-in-store-for-summer-pests

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/09/Insect-thresholds-for-key-insects-in-sorghum-sunflower-mungbeans-What-are-they-based-on-and-when-and-how-can-they-be-modified

http://ipmguidelinesforgrains.com.au/crops/summer-pulses/mungbean/

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

- maximise the chance of effective control of pests (*'spray small or spray fail')*
- detect spray failures

Check crops twice weekly to detect any unusual early pest activity and to pick the start of budding. Be particularly vigilant from budding to late pod-ripening to detect major pests, especially mirids, *Helicoverpa*, bean pod borer and podsucking bugs. [5]

Figure 1: Mungbean are at greatest insect damage risk from budding onwards.

7.3 Insects attacking mungbean at each crop stage

Insects can attack mungbeans at any stage of crop development.

7.3.1 Seedling pests

- Seedling or cereal thrips. These are usually more of a problem in spring mungbean. Unless extremely severe, seedling thrips damage has little to no effect on yield or crop maturity. In cold springs (mean temperature <18°C), slow plant growth and stunting is often incorrectly attributed to thrips. [6]

7.3.2 Vegetative and leaf-feeding pests

- *Helicoverpa* can occur at this stage, particularly in Central Queensland. Although vegetative mungbean are not attacked as frequently as vegetative soybeans, be vigilant for high populations (5/m^2), which can inflict severe damage, attacking terminals and auxiliary buds, the precursors to the floral buds.
- Loopers are usually not a problem at this stage, with populations peaking during the flowering and podding stages.
- Legume webspinners (*Omiodes diemenalis*) web leaves together but are rarely of concern. They mainly occur in coastal regions. Populations usually peak during the later flowering and podding stages.
- SLW may be noticed in crops in at-risk areas (e.g. Central Queensland). Mungbeans are not a suitable host, and the crop can therefore be planted in 'high-risk' SLW areas.
- Mirids populations are usually low in vegetative crops, but even high populations have no economic impact at this stage. [7]

[5] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[6] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[7] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

7.3.3 Budding and flowering pests

- Mirids are a key mungbean pest, attacking buds and flowers and causing them to abort. It is therefore critical to scout crops weekly so as not to miss the start of budding. Although the threshold for mirids is very low (typically ~0.5/m^2), it is based on mirid activity over a 28-day at-risk period. Consequently, above-threshold populations can be tolerated for a short period (up to 7 days) because the crop will readily compensate for early mirid damage under favourable growing conditions. However, yields will be reduced if you do not spray to prevent prolonged above-threshold mirid activity.
- With the onset of budding, the crop is at greatly increased risk of *Helicoverpa* attack. Under favourable growing conditions, mungbean can compensate for at least moderate damage during budding–flowering, because the crop is able to set replacement buds and flowers. However, severe damage, particularly in droughted or late-season crops, may result in significant yield loss.
- Podsucking bugs, e.g. green vegetable bug, can arrive at budding, but significant damage is confined to the podfill/pod-ripening stages. However, podsucking bugs will start to breed as soon as they move into flowering crops.
- Loopers are normally leaf feeders in soybeans, but larger larvae may attack mungbean flowers. High populations of looper can be damaging, but not as damaging pro-rata as *Helicoverpa*.
- Flower thrips cause flower abortion and twisted pods. Thrips are also vectors of *Tobacco streak virus* (TSV), which has severely damaged some mungbean crops in Central Queensland. Based on experience in other crops, however, the incidence of TSV is unlikely to be reduced by spraying for thrips, because very few thrips are required to spread viral diseases such as TSV.
- Bean pod borer is a major pest in the coastal tropics and subtropics. Young larvae infest flowers before invading pods. Infested flowers are often webbed together. Pod borer is more prevalent in coastal Queensland, the South Burnett, eastern Central Queensland (e.g. Biloela), and coastal New South Wales (NSW). In recent wetter seasons, damaging outbreaks have been observed as far west as Surat in southern Queensland.
- Adult populations of SLW may be higher than at pre-budding, but have no economic impact. However, because SLW can transmit MYMV, it would pose a risk to mungbean should the virus enter Australia.[8]

7.3.4 Early podding to pod maturity

- Podsucking bugs cause 'oversoaks', shriveled and distorted seed, and can severely reduce yield and seed quality. Podsucking bugs can damage even seeds in black pods that are nearing harvest maturity. Such late damage by bugs reduces seed quality but not yield. Only 2% seed damage is tolerable in mungbean, and bug thresholds are based on seed quality, not yield.
- *Helicoverpa* larvae consume developing pods and damage seeds in large pods. Undamaged seeds in *Helicoverpa*-damaged pods are often weather-damaged or

[8] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

stained, but the rate of seed staining is usually too low to be of concern. This is because the yield-based *Helicoverpa* threshold cuts in well before percentage seed staining reaches critical levels in all except very low-yielding crops with fewer total seeds (% staining = no. of stained seeds × 100/total seeds).

- Mirids can damage developing pods and seeds but normally attack late buds and flowers.
- Medium-sized larvae of bean pod borers leave the flowers to attack the pods. Entry points are often where flowers touch pods. Pod borers are major pests of mungbean in the tropics and coastal–subcoastal regions.
- *Etiella* (lucerne seed web moth) attack well-developed pods. The first signs of attack are virtually impossible to detect. Entry holes into pods are only 0.2 mm in diameter and the eggs are very small. *Etiella* larvae complete their development in a single pod before exiting to the ground to pupate. *Etiella* are usually first noticed when the larvae leave the pods, making an exit hole about 3 mm in diameter. *Etiella* cannot develop in harvested seed. Any larvae in freshly harvested seed are a carryover from the field and they will not re-infest seed in storage. However, their pale frass is often mistaken for bruchid eggs. *Etiella* are mainly a spasmodic dry-season pest and have not been an issue in recent wetter seasons.
- The cowpea bruchid (*Callosobruchus maculatus*) can infest nearly mature and dry pods in the field. Cowpea bruchid can also breed in storage. Infested pods and seeds are recognised by the presence of very white eggs on their surface, and by round exit holes made by emerging beetles. The cowpea bruchid was originally more common in Central Queensland but is now widely reported in southern Queensland and NSW. If infestations are likely, or are seen in the field, harvest crops as soon as possible. There are no registered pesticides for in-field bruchid infestations, which are frequently too low to detect anyway.
- SLW populations often peak during mid podfill in susceptible legume hosts such as soybeans, but as at other stages, they are not a threat in mungbeans.[9]

7.3.5 Post-harvest pests

Bruchids also infest mungbean post-harvest, and are usually undetected until months after intake. The most common bruchid in mungbeans is the cowpea bruchid, which can re-infest seed in storage (Figure 2). Very high populations of bruchid can develop in storage, even where populations at intake are very low.

The only registered treatment of harvested seed is phosphine fumigation. Key factors in bruchid management are storage facility hygiene, to reduce the risk of post-harvest infection, and gas-tight storages for effective fumigation. Old planting seed of mungbean (in bags) is at greatest risk from bruchid attack.

Cowpea bruchids are sometimes erroneously referred to as cowpea weevils. However, bruchids are in a different beetle family from the true weevils.

[9] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Figure 2: Cowpea bruchid eggs, adult and damage.

7.4 Mirid population dynamics in mungbean

It is often thought that mirids only arrive in the crop on north-west winds or after storms. However, many damaging mirid populations are the result of in-crop breeding. Mirids can be found in mungbeans as early as the early vegetative stage but usually remain below threshold until the onset of budding, after which they can increase exponentially (Figure 3). Mirids are sometimes well above threshold prior to budding but do not cause any damage until budding–flowering commences. Mirids do not 'tip' mungbean seedlings (as in cotton). Mirid feeding can shorten the internodes of vegetative mungbean; however, noticeable shortening has been measured only under very heavy mirid pressure, equivalent to >30 mirids/m^2.

Mirid adults from surrounding crops may also infest mungbean crops at budding. Vegetative crops must be checked weekly to pinpoint the onset of the critical stage. At budding, mungbean become attractive to other major pests, particularly *Helicoverpa* and pod borer.

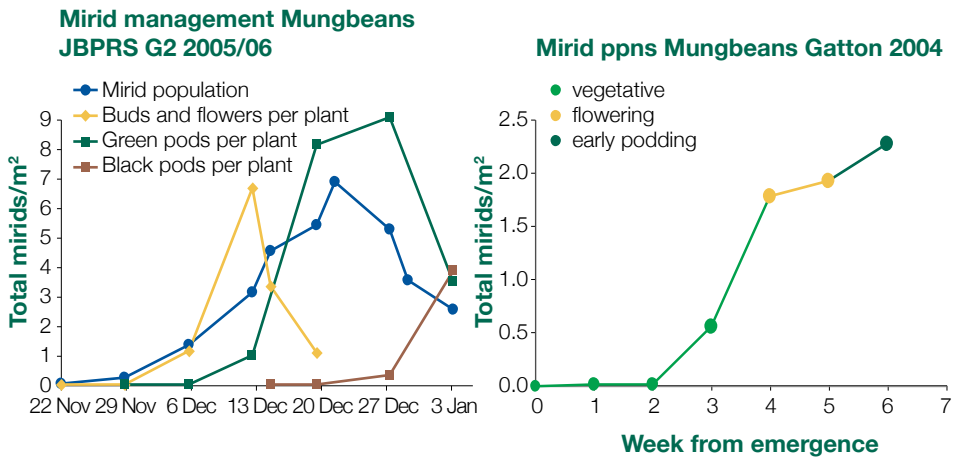


Figure 3: Mirid build up in summer mungbeans. In the Kingaroy crop, the population was below threshold at the start of budding but rose rapidly thereafter, peaking at 7/m^2 by peak podding and declining as the crop matured. However, in the Gatton crop, mirids were well above threshold at the start of budding.

7.5 Seedling thrips dynamics

The key issue with seedling thrips is that damage is inflicted to developing leaves hidden in the seedling apex. However, damage symptoms are not manifested until the first trifoliate leaves emerge and expand, by which time thrips populations are declining and spraying is ineffective (Figures 4 and 5). [10]

Figure 4: Severe damage by thrips to first trifoliolate leaves in a crop at Oakey, Queensland.

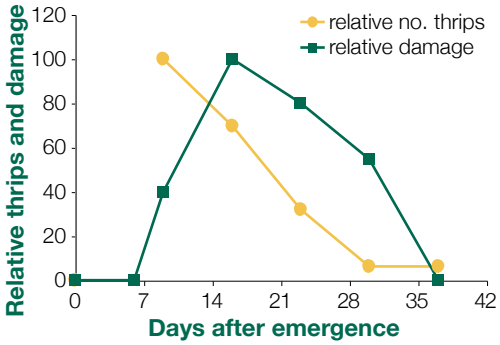


Figure 5: Changes in thrips populations relative to damage symptoms in spring-planted seedling mungbean.

[10] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

7.6 Mungbean pests: Identification, biology, damage and natural enemies

7.6.1 Mirids (Hemiptera: Miridae)

Green mirid, *Creontiades dilutus* (Stål)

Brown mirid, *Creontiades pacificus* (Stål)

Distribution: The green mirid is endemic to, and widespread throughout, Australia. The brown mirid also extends into Asia.

Identification: Mirid adults are elongated pale green or brown bugs 6–7 mm long with long legs (especially the hind legs) and long antennae. Some green mirid specimens may have reddish flecking on the body and the legs (Figure 6). Adult brown mirids have two distinct colour forms. The brown form is predominantly light brown with darker pigmentation on the hind legs, whereas the green form is mostly bright green but with dark red (purple-brown) pigmentation of the head, thorax and hind legs (Figure 7).

The nymphs are smaller than adults and elliptical shaped and lack wings. Young nymphs have antennae much longer than their body. First-instar nymphs are pale brown–orange in colour but later instars are pale green. Green mirid nymphs have pale antennae and brown mirid nymphs have distinctive reddish (brown) and white banding of the antennae (Figure 8). Mirid eggs are pale and elongated.

May be confused with: Nymphs may be confused with nymphs of the small predatory mirid *Tytthus chinensis*. Nymphs of the latter species are small (≤3 mm max. length) and green but are more elongated, have shorter antennae (in relation to their body), and have red eyes (Figure 9). Adult *Tytthus chinensis* are black. Brown mirid nymphs may also be confused with those of the relatively uncommon crop mirid *Sidnia kinbergi*, which has banded but shorter antennae. Crop mirid adults are darker and stouter than green mirids (Figure 10).

Hosts: As well as mungbeans, mirids attack adzuki beans, cowpeas, lima beans, navy beans, peanuts, pigeon peas, and soybeans. Mirids are also recorded from many field and horticultural crops, pasture legumes and weeds (e.g. rattle pods and phasey bean).

Life cycle on summer pulses: Mirids may be present at any stage from seedlings to podding. Mirid populations are typically (but not always) low during the vegetative phase, but increase rapidly after budding. Over 80% of mirids in flowering crops may be nymphs and populations >10/m^2 are not uncommon. Populations usually decline as pods mature. Eggs are laid singly into plant tissue with a small area of the egg exposed. There are usually five nymphal stages. Mirid development (from egg hatch to adult) is very rapid, taking only 12–16 days at 30°C. Egg development is relatively slow, as long as 7–10 days.

Risk period: Crops are at greatest risk from budding until mid-podding. Recent trials suggest that mirids may be more damaging during late flowering/mid-podding when mirid populations are higher and plants are less able to compensate for damage.

Figure 6: Green mirid adult.

Figure 7: Brown mirid adult.

Figure 8: Third instar brown mirid.

Figure 9: Tytthus nymph.

Figure 10: Crop mirid adult (4 mm).

Damage: Low mirid populations (≤1/m^2) are often present in vegetative crops but there is no evidence they cause 'tipping' of vegetative terminals or yield loss. In reproductive crops, mirids attack buds, flowers, small pods and seeds. Medium and large mirid nymphs (instars 3–5) are as damaging as adults. Small mirid nymphs (instars 1 and 2) are less damaging than large nymphs; however, small nymphs will soon be larger nymphs (within 3–5 days at 30°C). Severe mirid damage can result in fewer pods being set per raceme, and/or fewer seeds developing in pods (Figure 11). Note that thrips, high temperatures and moisture stress can produce similar symptoms, i.e. bud, flower and small pod abortion, and fewer harvestable seeds.

Monitoring: Mirids are very mobile pests and in-crop populations can breed very rapidly. Crops should be inspected twice weekly from budding until post-flowering. In row crops, the preferred method is beat sheeting. In broadcast or narrow-row mungbean crops, sweep netting is a viable option for mirids but is inadequate (problematic) for other key pests.

Thresholds: Thresholds for mirids in mungbean vary from 0.3 to 0.6/m^2, depending on application costs and mungbean prices.

Cultural control: Shortening a crop's flowering period reduces the risk of mirid damage. This can be done by planting on a full moisture profile and by watering crops just before budding. Consider planting crops in rows of at least 50 cm (as opposed to broadcast planting) to facilitate easier pest sampling.

Natural enemies: Spiders, ants, predatory bugs, predatory wasps and predatory mites

have been observed attacking mirids in the field. Naturally occurring fungi (e.g. *Beauveria*) may also infect and kill mirids, but are rarely observed in the field. [11]

Figure 11: Severe mirid damage to advanced pods.

7.6.2 Green vegetable bug (GVB), *Nezara viridula* L. (Hemiptera: Pentatomidae)

Distribution: A cosmopolitan pest found in all tropical, subtropical and warmer temperate regions of the world. GVB was accidentally introduced into Australia in 1916. It occurs in all Australia states and territories but is more common in warmer coastal regions.

Pest status: Major, widespread and regular. GVB is the most damaging podsucking bug in mungbean by virtue of its abundance, widespread distribution, rate of damage and rate of reproduction. It is one of the most recognised agricultural pests in Australia.

Identification: Adults are bright green and shield-shaped, and are 13–15 mm long (Figure 12). Adult GVB have three small white spots at the front of the scutellum (i.e. between their shoulders). Overwintering adults are purple-brown. Yellow or orange variants are occasionally seen. When disturbed, GVB emit a foul smell to deter predators.

Eggs are laid in rafts (50–100 eggs per raft) and are circular in cross-section (Figure 13). Newly laid eggs are cream but turn bright orange prior to hatching. Parasitised eggs are black.

[11] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Nymphs are variable in colour. Newly hatched nymphs (1.5 mm long) are orange and brown (sometimes black). Later instars are either green or black, with white, cream, orange and red markings. Final (5th) instar nymphs have reduced patterning (i.e. more base colour, green to black), and have prominent wing buds (Figure 14). Younger nymphs are round or oval rather than shield-shaped and usually aggregate in large clusters. Older nymphs are more widely dispersed.

Figure 12: Green vegetable bug adult.

Figure 13: Green vegetable bug egg raft about to hatch with 113 eggs.

Figure 14: From left to right: 2nd, 3rd, 4th and 5th instar green vegetable bug nymphs (2, 5, 8 and 12 mm, respectively). (Photo: Joe Wessels, DAFF Qld)

May be confused with: Adults may be confused with the redbanded shield bug, which has a red or white band across its 'shoulders', and the green stink bug (*Plautia affinis*), which is green and brown. The latter species is of very minor importance in mungbean. Nymphs of these species are different in colour to GVB nymphs. Parasitised GVB eggs may be confused with eggs of the predatory shield bugs *Cermatulus nasalis* and *Oechalia schellenbergii*, but lack the spines that ring the top of the eggs of these species (Figure 15).

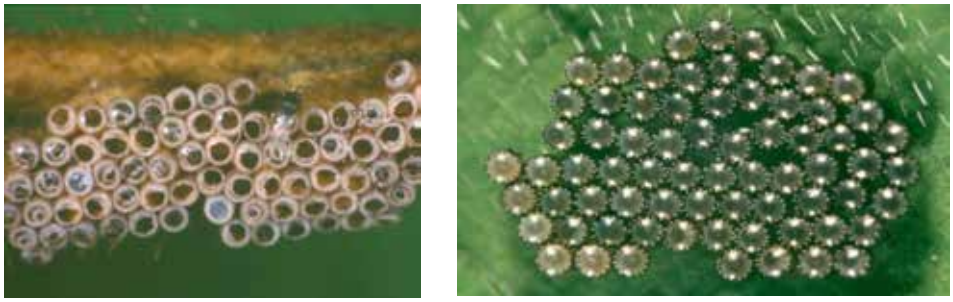


Figure 15: Left: Parasitised green vegetable bug egg raft with emerging Trissolcus. Right: Predatory bug egg raft. Note spines.

Host range: Mungbean are a favoured host but GVB attack all summer and winter pulses (except chickpeas). GVB is also a major pest in cotton and many horticultural crops including tomatoes, silver beet, maize, capsicums and pecans.

Life cycle: Typically invade summer legumes at flowering. The eggs are laid in large rafts containing 50–120 eggs and hatch after 6 days at 25°C.

Nymphs usually do not reach a damaging size until mid to late podfill. Usually only one generation develops per mungbean crop. Nymphs require pods containing seeds to complete their development, and the podding phase of most summer legumes is only slightly longer in duration than the life cycle of the GVB. There are five nymphal instars with a total development time of 30 days. Development is faster at temperatures >25°C but there is considerable mortality at temperatures >35°C. Three or four generations occur during summer. Adults overwinter, often sheltering (but not feeding) in yet-to-be harvested maize crops, under bark on trees, or in farm buildings.

Risk period: GVB typically invade mungbean at flowering, but crops are at greatest risk during late podding. 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 podfill (when nymphs have reached or are near adulthood).

Damage: GVB are primarily pod feeders with a preference for pods containing well-developed seeds. They may attack buds and flowers, but mungbeans can compensate for this early damage. Damage to young pods produces deformed and shriveled seeds, reducing yield. However, late damage results in seeds that are blemished and difficult to grade out, thus downgrading harvested seed quality (Figure 16). GVB and other podsucking bugs can even damage pods that have darkened and hardened just prior to harvest.

Bug-damaged seeds are more prone to weathering than undamaged seeds, and crops in high-rainfall coastal regions are likely to suffer greater reductions in quality than those in drier, inland regions.

Sampling and monitoring: Crops should be inspected twice weekly from budding until close to harvest. Sample for GVB in the early–mid-morning when bugs bask at the top of the crop. Beat-sheet sampling is the most efficient monitoring method for these and other podsucking bugs. At least five sites (with five non-consecutive row-metres sampled per site) should be sampled throughout a crop to determine adult populations accurately. Nymphs

are more difficult to sample accurately as their distribution is extremely clumped, particularly during the early nymphal stages (1st–3rd instar). Ideally, at least 10 sites (with five non-consecutive row-metres sampled per site) should be sampled to assess populations of small nymphs adequately. Sampling too few sites may under- or overestimate nymphal populations.

Figure 16: Green vegetable bug damage to mungbean seeds. Note sting marks on both seeds and distortion of left seed.

Thresholds: Podsucking bug thresholds in mungbeans are determined by seed quality, the maximum bug damage permitted being only 2%. GVB thresholds in typically range from 0.3 to 0.6/m^2 depending on the crop size (no. of seeds/m^2). Crop size needs to be determined as: percentage seed damage = no. of damaged seeds × 100/(no. seeds per m^2). Where other podsucking bug species are present, and/or where nymphs are present, convert these to adult green vegetable bug equivalents (as per guidelines in *Economic threshold theory and practice* below).

Natural enemies: Eggs are often parasitised by a tiny introduced wasp *Trissolcus basalis* (a classic example of biological control). Parasitised eggs are easily recognised because they turn black. They are easily confused with predatory bug eggs, but do not have a ring of spines around the top of each egg (see Figure 15 above). Nymphs are attacked by ants, spiders and predatory bugs. Final (5th) instar larvae and adults are parasitised by the recently introduced tachinid fly *Trichopoda giacomellii* (Figure 17), which has spread to Central Queensland and possibly the Burdekin, and as far south as central NSW. [12]

[12] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Figure 17: Left: Trichopoda eggs on green vegetable bug. Right: male Trichopoda (8 mm).

7.6.3 Redbanded shield bug (RSBS), *Piezodorus oceanicus* Montrouzier (Hemiptera: Pentatomidae)

In Australia, RSBS were previously named as *Piezodorus hybneri* (Gmelin), and more recently as *P. grossi*.

Distribution: Australia and possibly parts of South East Asia.

Pest status: Major, widespread and reasonably regular. RSBS is 75% as damaging as GVB but is usually not as abundant. RBSB is difficult to control with current bug pesticides.

Identification: RBSB adults are shield-shaped and are pale green with a coloured band across their shoulder. Most females have a pink (not red) band across their shoulders and pink lines along their sides (Figure 18). By contrast, most males have an off-white band across the shoulders and pale yellow lines along their flanks. They are noticeably smaller than similarly shaped GVB, being only 8–10 mm long.

RBSB lay a distinctive, twin-row raft containing 15–40 eggs. Eggs are dark, elliptical in cross-section, and ringed on top by small spines.

Newly hatched nymphs are orange with black markings and are similar to newly hatched nymphs of many other shield bugs. However, newly hatched RBSB nymphs (and nymphs of other shield bugs) can be readily identified by examining the egg raft they emerge from. Larger nymphs are pale green with dark red and brown markings in the centre of their back (Figure 19). Late autumn nymphs may turn a pale pinkish brown with markings not so dark.

May be confused with: RBSB adults are similar in shape to GVB but are smaller and paler, with pink, white or yellow bands absent in GVB adults. The eggs and most nymphal stages are quite different from those of other shield bugs in pulse crops.

Host range and risk period: As for GVB.

Life cycle: Eggs take 4–5 days to hatch. RBSB has five nymphal stages. Total

development time (eggs–adult) is 18–35 days depending on temperature. In Queensland, RBSB most likely has four generations per year.

Damage: Damage symptoms are similar to those caused by GVB, with early damage reducing yields, and later damage reducing the quality of harvested seeds.

Thresholds: The damage potential of RBSB has recently been upgraded in mungbeans. Adult RBSB are now rated as equivalent to 0.75 of a GVB. Nymphs are less damaging than adults and are converted to adult equivalents (AEQ) as per guidelines for GVB (refer to *Economic threshold theory and practice*).

Monitoring: As for GVB, beat-sheeting is the preferred sampling method. Look for the distinctive twin-row egg rafts.

Natural enemies: As for GVB. Eggs may be parasitised by the tiny wasp, *Trissolcus basalis*. Adults are infrequently parasitised by the recently introduced tachinid fly, *Trichopoda giacomelli*.[13]

Figure 18: Left: female redbanded shield bug (9 mm); right: male RBSB.

Figure 19: 4th instar RBSB nymph (6 mm).

7.6.4 Large brown bean bug, *Riptortus serripes* Fabricius (Hemiptera: Alydidae)

Frequently referred to as the 'brown bean bug' or the 'podsucking bug', the preferred common name now is 'large brown bean bug' to avoid confusion with the small brown bean bug (*Melanacanthus scutellaris*).

Distribution: Native to Australia. Reported from NSW, Northern Territory and Queensland. Similar *Riptortus* species occur in Asia, India and Africa.

[13] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Pest status: As damaging as GVB. More frequent on the coast, with a liking for the *Vigna* legumes, e.g. adzuki beans, cowpeas and mungbeans.

Identification: An elongated dark brown bug 16–18 mm in length (not including legs and antennae) with long antennae and with a bright yellow stripe along each side. The stripe is more pronounced in males and is often paler and less distinct in females, which are 'rounder' in the body than males (Figure 20). The body narrows in the middle and it has a spine on each 'shoulder'. It also has large robust and spiny hindlegs. The bright orange top of the abdomen is strikingly revealed when the large brown bean bug is flying.

Eggs are a dark purple-brown and are laid singly or in small clusters. They are slightly elliptical with a flattened top and rounded base and are 1.5 mm across. Nymphs are dark brown and are similar in outline to ants (Figure 21). However, close inspection shows that they lack the very narrow 'waist' and biting mouthparts (jaws) typical of ants.

May be confused with: May be confused with the small brown bean bug, which is considerably smaller (10–12 mm long) and not as robust, and with the rice or paddy bug *Leptocorisa acuta*. Rice bugs are pale green or brown, reach 15 mm in length, and are very slender with thin hindlegs. *Riptortus* and *Melanacanthus* nymphs are difficult to distinguish. However, later instar *Melanacanthus* nymphs can be distinguished by their more elongated abdomens, which have six or more small dark spots on their dorsal surface. *Riptortus* adults are often confused with assassin bugs (*Pristhesancus* sp.) and the nymphs with assassin bugs and ants. Assassin bugs are distinguished by their very narrow head, and their broad concave abdomen (Figure 22). Ants have biting mouthparts.

Life cycle: Large brown bean bugs typically invade summer legumes at flowering. They lay scattered eggs rather than egg rafts and have five nymphal stages. Nymphs usually reach a damaging size during mid–late podfill. Development times for eggs and nymphs are ~8 and 17 days, respectively (25 days total) at 26°C. Under laboratory conditions, individual females have laid up to 600 eggs over a 94-day period. In Queensland, large brown bean bug most likely has four generations per year. Overwintering individuals often shelter in curled up dead leaves.

Host range and risk period: As for GVB.

Figure 20: Female large brown bean bug (Riptortus) (16 mm).

Figure 21: Left: 1st instar Riptortus nymph (2.5 mm); right: 4th instar nymph (9 mm).

Figure 22: Assassin bug nymph (16 mm).

Damage: As damaging as GVB. Damage is similar to that caused by GVB, with early damage reducing yield, and later damage reducing the quality of harvested seed.

Monitoring: The beat sheet method is not totally satisfactory because both large and small brown bean bugs are flighty, particularly during the hotter parts of the day. Crops should be sampled during the early morning. Crop scouts should also familiarise themselves with the appearance of flying (and escaping) large brown bean bug adults and include these in sampling counts. [14]

7.6.5 Small brown bean bug, *Melanacanthus scutellaris* Dallas (Hemiptera: Alydidae)

Distribution: Native to Australia. Reported from NSW, Queensland, Western Australia and probably Northern Territory.

Pest status: Major—as damaging as GVB.

Identification: Small brown bean bug is an elongated brown bug 10–12 mm in length (not including legs and antennae) with a cream stripe along each side. This stripe is less distinct in females, which are 'rounder' than males (Figure 23). Males also have a prominent pale patch in the scutellum. Has a short spine on each 'shoulder' (less pronounced than on large brown bean bug), and has moderately robust and spiny hindlegs (thinner than those of large brown bean bug).

Eggs are laid in small clusters and are shiny olive-green (Figure 24). They are slightly elliptical with a flat top and a rounded base and are 1.0 mm across.

The nymphs are dark brown to black and are similar in outline to ants (Figure 25). However,

[14] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

close inspection shows they lack the very narrow 'waist' that is typical of ants, and have sucking rather than biting mouthparts.

May be confused with: May be confused with large brown bean bug and with rice or paddy bugs.

Life cycle: Small brown bean bugs typically invade summer legumes at flowering. They lay scattered single eggs. There are five nymphal stages and nymphs usually reach a damaging size by mid–late podfill. Development times for eggs and nymphs are ~ 6 and 20 days, respectively, at 26°C. Under laboratory conditions, individual females have laid up to 300 eggs over a 58-day period. Potentially, two generations could develop per summer pulse crop but usually there is one generation.

Damage: As damaging as GVB and the large brown bean bug.

Monitoring: Beat sheet sampling may underestimate numbers of small brown bean bug, because they quickly fly away when disturbed. Crops should be sampled during the early morning and crop scouts should familiarise themselves with the appearance of flying (and escaping) small brown bean bug and include these in sampling counts.

Figure 23: Female small brown bean bug (12 mm).

Figure 24: Small brown bean bug eggs.

Figure 25: Small brown bean bug 1st instar nymph (1.7 mm).

7.6.6 Brown shield bug (BSB), *Dictyotus caenosus* Westwood (Hemiptera: Pentatomidae)

Distribution: Native to Australia.

Pest status: Minor; equivalent to 0.2 GVB.

Identification: Adult BSB are shield-shaped and are matt mid brown (i.e. not glossy) (Figure 26). At 8 mm long, they are noticeably smaller than GVB.

BSB lay eggs in either small twin-row or small irregular rafts containing 10–16 eggs (Figure 27). The eggs are pale cream and similar in shape to GVB eggs.

Newly hatched nymphs are orange with black markings and very similar to newly hatched nymphs of many other shield bugs. Larger nymphs have a dark brown (sometimes almost black) head and thorax (Figure 28). Their pale-brown abdomen has a central dark patch with transverse white band. There is also a transverse pale band at the front of the abdomen.

May be confused with: Adults may be confused with adults of the glossy shield bug, *Cermatulus nasalis*, which is slightly larger and is a predatory species, as well as with the spined predatory bug *Oechalia schellenbergii* (Figure 29). BSB eggs and nymphs are quite different in appearance to those of *Cermatulus* and *Oechalia* (Figure 30).

Life cycle: BSB typically invade summer legumes at flowering. Nymphs usually reach a damaging size during mid–late podfill. There are five nymphal stages. Usually only one BSB generation develops per summer legume crop but more than one generation is possible if temperatures are very high.

Damage: BSB damages only 20% as many seeds as the GVB (soybean data).

Monitoring: As for GVB—with a beat sheet. [15]

Figure 26: Brown shield bug adult (8 mm).

[15] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Figure 27: Brown shield bug eggs.

Figure 28: Brown shield bug nymphs (5 mm).

Figure 29: Left: Cermatulus adult, a predator (12 mm); right: Oechalia adult (12 mm; note the spines).

Figure 30: Left: Oechalia nymph; right: Cermatulus nymph (11 mm).

7.6.7 Corn earworm, *Helicoverpa armigera* Hubner; native budworm, *Helicoverpa punctigera* Wallengren (Lepidoptera: Noctuidae)

Helicoverpa armigera is also known in Australia as the cotton bollworm. *Helicoverpa* spp. are sometimes referred to as *Heliothis* or colloquially just 'helis'. However, *Helicoverpa* is correct, to distinguish it from *Heliothis* spp.

Distribution: *Helicoverpa armigera* is present in all Australian states but is more common in the tropics and subtropics. It is also present in much of mainland Europe, Asia and Africa, whereas *H. punctigera* is native to Australia and is more common in inland regions.

Pest status: Major. *Helicoverpa* can severely damage all mungbean crop stages and plant parts.

Identification: Moths have a 35-mm wingspan. Males have straw-coloured forewings and those of females are brown. The forewings of both sexes have dark markings. Hindwings are pale cream with a wide dark outer band. *Helicoverpa armigera* has a distinctive pale patch in the hindwing's dark outer band (Figure 31). This spot is missing in *H. punctigera*.

Eggs are ribbed and globular, 0.6 mm in diameter, and are pale cream (white) when freshly laid. Fertile eggs develop a red (brown) ring after 1–2 days. Eggs turn black before hatching.

Newly hatched larvae are pale with dark heads. Medium larvae are usually brown with darker spots (Figure 32). Large larvae vary from green to brown to orange to black. Larvae usually have numerous fine pale lines along their back, with a wide cream or yellow band along each side. Darker specimens are more common in high-density populations.

Helicoverpa larvae have four pairs of ventral prolegs (not including the anal prolegs), fairly sparse hairs, and do not taper noticeably towards the head (as do loopers). Large larvae can reach 45 mm in length (Figure 33). *Helicoverpa armigera* pupae have well-separated spines at their tail end, whereas spines of *H. punctigera* are close together (Figure 34).

May be confused with: The two *Helicoverpa* species may be confused. Large *H.*

armigera larvae have white hairs behind their head, and *H. punctigera* have dark hairs. Medium *H. armigera* larvae have a dark 'saddle' on the fourth segment and dark legs, as opposed to no saddle and pale legs for *H. punctigera*.

Helicoverpa larvae can be distinguished from soybean loopers by having four pairs of ventral prolegs rather than two pairs, and do not taper noticeably towards the head. Armyworm larvae can be distinguished by a lack of hairs and by bodies that taper at both ends. Medium-sized *H. armigera* larvae may also be confused with cluster caterpillar (*Spodoptera litura*), but have more hairs and lack the latter's distinctive moon spots and hump behind the head. *Helicoverpa* eggs are paler than looper eggs, which have a greenish tinge and are squatter.

Figure 31: Helicoverpa armigera moth. Note diagnostic pale patch on exposed hind wing.

Figure 32: Medium H. armigera larva (12 mm).

Figure 33: Large H. armigera larva (30 mm). Note four pairs of ventral prolegs.

Figure 34: Helicoverpa pupae. Left: H. armigera; right: H. punctigera. Note the spines.

Host range: Extremely polyphagous, attacking all summer legumes, most major field crops (e.g. cotton, sorghum, chickpeas, cereals, maize), as well as many horticultural crops (e.g. tomatoes, sweet corn). Of the summer legumes, soybeans are more attractive crop to *Helicoverpa* during the vegetative stage, but mungbeans are extremely attractive from flowering onwards.

Life cycle: Each female moth lays >1000 eggs. Eggs are laid on leaves, terminals, flowers and stems and they take 2–6 days to hatch (Figure 35). Larvae take 14–21 days to develop in summer and pass through 5–6 instars (usually 5) before leaving the crop to pupate in the soil. In the subtropics and further south, *Helicoverpa* pupating in the autumn diapause until the following spring.

Figure 35: Helicoverpa eggs showing white, brown-ring and dark (about to hatch) phases.

Risk period: Although mungbean can be infested at any stage, crops are most attractive to the moths during budding, flowering and early podding. Vegetative mungbean are at lesser risk than soybeans (Figure 36) but there are instances of even seedling crops being attacked. In subcoastal and inland southern Queensland, summer legumes are at greatest risk from *H. armigera* from mid-December onwards. However, major spring outbreaks of *H. armigera* are not infrequent.

Damage: Larvae attack all aboveground plant parts and can attack mungbean at any stage from seedling to podfill. Mungbean can tolerate up to 33% defoliation with no yield loss, but the habit of attacking the plant's auxiliary buds (the precursors to floral buds) means that *Helicoverpa* are a far more damaging vegetative pest than loopers.

Accordingly, a new vegetative threshold of 4–5 individuals/m^2 has been set, based on recently published soybean data.

From budding onwards, larvae focus on reproductive structures and there is very little leaf damage. *Helicoverpa* are voracious bud feeders and each larva can consume over 150 buds and flowers. Even though well-grown crops can compensate for considerable early damage (80% bud loss), yield losses are likely in small, droughted crops; where growing conditions do not favour the setting of replacement pods; or where there is subsequent *Helicoverpa* damage. Severe early damage can delay harvest maturity and causes uneven pod ripening (Figure 37). In autumn with the onset of cool weather, crops may 'run out of season' to set replacement pods.

During podset–podfill, larvae consume developing pods and bore into filled pods to attack the seeds. Each larva can consume >20 seeds, but yield loss also depends on the number of pods consumed, and the crop's ability to replace damaged pods. Under favourable growing conditions, crops can compensate for significant podding–podfill damage, but more research is needed to predict confidently when this applies. Until then, the current threshold, based on a yield loss of 35 kg/ha per individual/m^2, applies from flowering to late podfill.

Seeds can also be stained by water entering damaged pods. However, seed staining is not an issue because even in a wet year, each larva stains only five seeds, i.e. <10% of the number stained by a GVB. [16]

Figure 36: Helicoverpa damage to soybean leaves with <33% defoliation.

[16] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Figure 37: Late mungbean pod damage by Helicoverpa.

Monitoring: Inspect crops twice weekly, especially from early budding onwards until crops are no longer susceptible to attack (late podding). Increase scouting as crops approach budding; young buds have been completely consumed by very high *Helicoverpa* populations (50/m^2) before flowering proper commences. Beat sheet sampling is by far the preferred and most effective sampling method for small medium to large larvae. Open flowers to check for small larvae. Visually inspect crops for moths and eggs.

Thresholds: A vegetative threshold of 4–5 *Helicoverpa*/m^2 has been set, based on soybean research highlighting the 'greater than previously recognised' impact of *Helicoverpa* damage at the crop stage (Table 1). The current reproductive-stage threshold model applies from flowering to late podfill. The threshold model factors in the 'cost of control' and 'likely crop value', and for an aerially sprayed crop, it is ~1.4 larvae/m^2 (as at August 2012).

Table 1: Economic threshold (ET) chart for Helicoverpa in podding mungbean

Based on a measured yield loss of 35 kg/ha per larva/m^2. Cross-reference the cost of control against crop value to determine ET, e.g. if the cost of control is $40/ha and crop value is $600/t, ET = 1.9. Spray Helicoverpa only if they exceed the threshold, which is the breakeven point

Cost of control = value of damage ($/ha)	Thresholds (larvae/m^2) for conventional pesticides at mungbean crop values listed below ($/t)									
	$350	$400	$450	$500	$550	$600	$650	$700	$750	$800
$20	1.6	1.4	1.3	1.1	1.0	1.0	0.9	0.8	0.8	0.7
$25	2.0	1.8	1.6	1.4	1.3	1.2	1.1	1.0	1.0	0.9
$30	2.4	2.1	1.9	1.7	1.6	1.4	1.3	1.2	1.1	1.1
$35	2.9	2.5	2.2	2.0	1.8	1.7	1.5	1.4	1.3	1.3
$40	3.3	2.9	2.5	2.3	2.1	1.9	1.8	1.6	1.5	1.4
$45	3.7	3.2	2.9	2.6	2.3	2.1	2.0	1.8	1.7	1.6
$50	4.1	3.6	3.2	2.9	2.6	2.4	2.2	2.0	1.9	1.8
$55	4.5	3.9	3.5	3.1	2.9	2.6	2.4	2.2	2.1	2.0
$60	4.9	4.3	3.8	3.4	3.1	2.9	2.6	2.4	2.3	2.1
$65	5.3	4.6	4.1	3.7	3.4	3.1	2.9	2.7	2.5	2.3

Chemical control: Unless there is heavy pressure, biopesticides are the preferred option prior until flowering. In view of recent research, biopesticides could also be considered in well-watered flowering crops with low *Helicoverpa* pressure.

For best results, all ingestion-type products (including biopesticides) require thorough plant coverage and should target larvae <7–12 mm long, depending on the product selected (and the label directions).

See www.apvma.gov.au for current on-label recommendations.

Natural enemies: *Helicoverpa* are attacked by a large number of predators and parasites. Predatory bugs attacking eggs and larvae include: spined predatory bug (*Oechalia schellenbergii*) (Figure 38), glossy shield bug (*Cermatulus nasalis*), damsel bug (*Nabis kinbergii*) (Figure 39), bigeyed bugs (*Geocoris* sp.), apple dimpling bug and assassin bugs. Predatory beetles include red and blue beetle and predatory ladybirds. Other important predators include ants, spiders and lacewings.

Helicoverpa parasites include tiny egg parasite wasps (*Trichogramma* sp.), and caterpillar parasites such *Microplitis* (Figure 40) and *Netelia* (wasps) (Figure 41), as well as numerous species of tachinid flies. With the exception of the egg parasites and *Microplitis*, most parasites above do not kill *Helicoverpa* until they reach the pupal stage. Mice, predatory earwigs and wireworm larvae are significant predators of *Helicoverpa* pupae.

Many of the beneficials above attack other pests. In many crops, the combined action of a number of beneficial species is required to have a 'useful' or significant impact on potentially damaging *Helicoverpa* populations and those of other pests. For all these reasons, it is desirable to conserve as many beneficials as possible.

In addition to beneficial arthropods, naturally occurring viruses (*nuclear polyhedrosis virus,* NPV) can kill *Helicoverpa* in mungbean, but they usually occur where *Helicoverpa* pressure is already high. Look for dead larvae, which characteristically crawl to the top of plants and liquefy (Figure 42). Commercial NPV formulations give the same *Helicoverpa* 'virus death symptoms'. [17]

Figure 38: Oechalia nymph (8 mm).

[17] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Figure 39: Damsel bug adult (12 mm).

Figure 40: Microplitis pupa beside host larva (12-mm Helicoverpa).

Figure 41: Netelia wasp (18 mm).

Figure 42: Helicoverpa larva killed by NPV.

7.6.8 Bean pod borer (BPB), *Maruca vitrata* Fabricius (Lepidoptera: Pyralidae)

Previously known as *Maruca testulalis*.

Distribution: A major cosmopolitan pest found in the Americas, Africa, Southern Europe, India, Asia and Australia. It is found in all parts of Australia but is far more abundant in tropical and subtropical coastal regions.

Pest status: A major pest of mungbean, adzuki beans, cowpeas and navy beans but not an issue in soybeans.

Identification: Moths have a 20–25-mm wingspan and a slender body (Figure 43). They have brown forewings with a white band extending two-thirds down the wing from the leading edge. Inside this band near the leading edge is a white spot. The hindwings are predominantly translucent white with an irregular brown border. When at rest, moths adopt a characteristic pose with outspread wings and the body raised at the front. The eggs are pale cream and flattened. Larvae are pale cream with two rows of distinctive, paired black markings on their back. In the final instar, these markings are often very pale. Larvae can reach 18 mm in length (Figure 44).

May be confused with: Moths may be confused with beet webworm moths (*Spoladea recurvalis*) (Figure 45), but are slightly larger, and have predominantly pale hindwings, as opposed to the predominantly brown hindwings of *S. recurvalis*. Larvae may be confused with legume webspinner larvae but feed inside flowers and pods, not inside webbed leaves.

Host range: Favoured hosts include adzuki beans, mungbean, cowpeas, pigeon peas and navy beans. All these are semi-determinate to indeterminate with flowers and pods both present, at least during the earlier stages of reproductive development. Although reported from soybeans and peanuts, BPB is rarely damaging in these crops because flowering does not overlap with podding in soybeans, and peanuts have underground pods. Favoured weed hosts include *Sesbania*.

Life cycle: Crops may be infested from early budding onwards. The eggs are laid on or in the flowers (inserted between the petals). Young larvae feed inside flowers for 5–7 days (Figure 46). They then move to the pods as mid-sized larvae (Figure 47). Favoured entry points are where flowers and pods are touching. After completing their development (10–15 days from egg hatch), larvae exit pods and pupate in the soil.

Risk period: From early budding until the end of flowering. Indeterminate hosts are very susceptible, with both flowers and pods often present for at least 1 month. In years of bad BPB infestation, there can be sustained and heavy BPB pressure for up to 1 month.

Damage: Seeds within damaged pods are eaten out totally or partially by BPB larvae. Entry holes also let in water, which stains the remaining, non-damaged seeds. In soybeans and peanuts, BPB larvae sometimes tunnel into plant stems. This behaviour has not been observed in mungbeans.

Figure 43: Bean pod borer moth (wingspan 23 mm).

Figure 44: Large BPB larva (16 mm).

Figure 45: Beet webworm moth (20 mm).

Figure 46: Small BPB larva (5 mm).

Figure 47: Typical webbing of flowers by medium larva (10 mm).

Monitoring: The first sign of an impending infestation is the distinctive moths, which fly away when disturbed as you walk through the crop. The first visible sign of damage is the webbing of flowers and buds. However, in the very early stages of an infestation, small larvae are out of sight inside buds and flowers with no external evidence of their presence. Infested pods have a well-defined entry hole (mostly one per larva), usually ringed with distinctive frass (waste).

The most reliable way to assess BPB activity is to open up buds and flowers from as many racemes as possible (from at least 30 flowering racemes randomly across a crop). Divide the total number of BPB detected by the number of racemes sampled, and multiply by the estimated number of racemes per m^2. BPB can also be monitored with a beat sheet, but remember that the beat sheet detects only one-seventh of the total larvae actually present.

Action level: The threshold to date has been a nominal 3 larvae/m^2. However, recent field data suggest a threshold of around 7 larvae/m^2 as detected in the flowers, or 1 larvae/m^2 as detected with a beat sheet. [18]

[18] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

7.6.9 Green-coloured loopers (Lepidotera: Noctuidae): soybean looper (*Thysanoplusia orichalcea*), tobacco looper (*Chrysodeixis argentifera*), vegetable looper (*Chrysodeixis eriosoma*)

Distribution: Soybean loopers are from Asia and were first reported in Queensland in 1976. Vegetable loopers occur in Asia and Australia but tobacco loopers are native to Australia.

Identification: Soybean looper moths are very distinctive, with a large gold patch on each forewing (Figure 48). Tobacco and vegetable looper moths have dark-brown forewings with small silver 'figure-eight' markings. Tobacco looper has fused markings (Figure 49) but in vegetable looper, they are separated. Wingspans are 40 mm.

Looper eggs are pale yellow–green and ribbed, and are flatter than *Helicoverpa* eggs. Larvae move with a distinctive looping action, have only two pairs of ventral prolegs, and a body that tapers noticeably towards the head (Figure 50). Larval colour can vary considerably. Larvae are mostly green with white stripes. However, soybean loopers are more prominently striped, particularly when medium-sized, when they often have very dark stripes. Larvae can reach 45 mm in length. Unlike *Helicoverpa*, which pupate in the soil, loopers usually pupate on the plant in folded leaves in a thin silken cocoon (Figure 51). Pupae are dark above and pale underneath. [19]

Figure 48: Soybean looper moth (40 mm).

Figure 49: Tobacco looper moth.

[19] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Figure 50: Tobacco looper (30 mm).

Figure 51: Soybean looper pupa in loose silken cocoon.

7.6.10 Brown-coloured loopers (Lepidoptera: Noctuidae): bean looper (*Mocis alterna*), three-barred moth (*Mocis trifasciata*)

Distribution: *Mocis* sp. loopers occur in Africa, Asia and Australia. The bean looper is native to Australia.

Identification: Moths have wingspans 30–50 mm, the three-barred moth being the largest of the *Mocis* species. Bean looper moths are grey with dark bands (Figure 52), whereas three-barred moths are brown with darker bands (or bars) (Figure 53). Eggs are globular and pale green and are larger than *Helicoverpa* eggs (Figure 54).

Larvae are variable in colour and can be cream, charcoal, bright orange or brown. The bean looper is particularly variable in colour. Larvae may have dark stripes along their back and often have a cream or yellow band along each side Figure 55). Larvae can reach 40–50 mm in length, three-barred moth larvae being the largest (Figure 56). Larvae have two pairs of ventral prolegs, move with a looping action, and are more slender than *Helicoverpa* and soybean loopers. Distinctive features of *Mocis* larvae are their forward-sloping (prognathous) and striped heads. Larvae pupate inside curled leaves.

The following apply equally to green- and brown-coloured loopers:

Pest status: Usually minor but large populations are damaging.

Host range: The above loopers have been recorded from adzuki beans, mungbean, navy beans and soybeans. Other host crops include lucerne and sunflowers.

Life cycle: Looper eggs hatch in 3–6 days. There are 6 larval stages. Larvae take 2–3 weeks to develop before pupating under the leaves in a loose silken cocoon.

Risk period: Crops can be attacked at any stage but are at greatest risk during flowering and podding when they are least tolerant of defoliation.

Damage: Loopers are predominantly leaf feeders. They are less damaging than *Helicoverpa* because they do not focus on the plants auxiliary buds (the precursors to floral buds) and subsequent reproductive structures. Loopers sometimes attack mungbean flowers, but not with the same intensity as *Helicoverpa*. Looper leaf damage can be differentiated from *Helicoverpa* leaf damage because looper feeding-holes are angular rather than rounded.

Monitoring: Use a beat sheet. Inspect crops twice weekly until crops are no longer susceptible to attack. Twice-weekly inspections are now recommended at all crop stages, so that if required, biopesticides can target smaller larvae.

Figure 52: Bean looper moth (33 mm).

Figure 53: Three-barred moth (45 mm).

Figure 54: Mocis spp. eggs.

Figure 55: Larva of bean looper on mungbean.

Figure 56: Larva of three-barred moth (45 mm long).

Thresholds: In pre-flowering crops, looper control is warranted if defoliation exceeds (or is likely to exceed) 33%. However, tolerable defoliation drops to 15–20% once flowering and podding commences. In flowering adzuki beans, mungbean and navy beans, the provisional threshold is set at 3 looper larvae/m^2. Recent threshold trials suggest higher populations could be tolerated in irrigated crops.

Natural enemies: Loopers are attacked by many predators and parasites (Figure 57). Many of these also attack *Helicoverpa* (e.g. predatory bugs, tachinid flies, braconid wasps and ichneumonid wasps). Loopers are frequently parasitised by braconids (*Apanteles* sp.) and scores of parasite larvae can develop per looper host. The use of Bt for looper control will help to preserve beneficial insects and also reduce the risk of subsequent *Helicoverpa* and mite attack.

Epizootics of a looper NPV are frequently observed in crops with high looper populations. However, larvae are usually not killed by the virus until they are medium–large (instars 4–5). Note that looper NPV is not the same as *Helicoverpa* NPV.[20]

Figure 57: Assassin bug nymph attacking soybean looper larvae.

[20] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

7.6.11 Cluster caterpillar, *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae)

Distribution: Asia, India, New Guinea, New Zealand and Australia. In Australia, *Spodoptera litura* is more common in tropical and coastal regions.

Pest status: Not quite as damaging as Helicoverpa and less frequent. This pest has been reported as causing significant damage to peanuts in the Northern Territory and to soybeans in coastal Queensland.

Identification: The moths are larger than *Helicoverpa* and have a wingspan of 40 mm (Figure 58). Moths have brown forewings with distinctive crisscross cream streaks and translucent white hindwings edged with brown.

The eggs are laid in a furry cream mass on the underside of leaves (Figure 59). Young larvae 'cluster' together and are translucent green with a darker thorax (Figure 60). Mid-sized larvae are smooth-skinned with a pattern of red, yellow and green lines, a dark patch on the hump behind the head, and dark spots along each side. Large larvae are initially brown with three thin, pale-yellow lines down the back: one in the middle and one on each side (Figure 61). They have a row of black dots along each side, and a row of conspicuous dark half-moons along the back. Final-instar larvae are darker and can be >50 mm in length. All larval stages have 4 pairs of ventral prolegs, and are more solidly built than *Helicoverpa*.

May be confused with: Small to medium larvae (10 mm long) may be confused with *Helicoverpa* larvae, but can be distinguished by the 'hump' behind the head and the rows of large dark spots along each side. Large larvae are much 'stouter' than *Helicoverpa* or loopers.

Host range: Polyphagous. Pulse hosts include adzuki beans, mungbean, navy beans, peanuts, pigeon peas and soybeans.

Life cycle: Egg masses are laid on leaves. Young larvae feed on leaves but older larvae may feed on flowers and pods. Larvae pass through 6 larval stages and take 2–3 weeks to develop depending on temperature. Larvae pupate in the soil.

Risk period: Flowering and podding.

Damage: Small larvae leave transparent windows in leaves, but older larvae chew right through. Older larvae may also attack flowers and pods. In soybeans, they attack fewer pods than *Helicoverpa* but their damage potential in mungbean has not been measured. Larvae attack peanut pegs, and in light soils, they attack pods.

Monitoring: As for *Helicoverpa*. Look also for egg masses and clusters of young larvae.

Thresholds: In pre-flowering crops, control is warranted if defoliation exceeds (or is likely to exceed) 33%. However, tolerable defoliation drops to 15–20% once flowering and podding commence. In mungbean and other summer pulses, the threshold post-flowering is 3 larvae/m^2.

Natural enemies: As for *Helicoverpa* and loopers.[21]

Figure 58: Cluster caterpillar moth (40 mm wingspan).

Figure 59: Egg mass of cluster caterpillar.

Figure 60: Small clustering larvae of cluster caterpillar (5 mm).

Figure 61: Large larvae of cluster caterpillar (30 mm).

[21] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

7.6.12 Lucerne seed web moth, *Etiella behrii* Zeller (Lepidoptera: Pyralidae)

In southern Australia, it is referred to as 'lucerne seed web moth', but in Queensland, it is called *Etiella*.

Distribution: *Etiella behrii* is found over the whole of Australia and much of South East Asia and the Pacific Islands.

Pest status: Important peanut pest but spasmodic in mungbeans.

Host range: Can be found in most pulses including peanuts, mungbeans, adzuki beans, lima beans, soybeans, lentils and field peas. Navy beans are not as favoured because of their more succulent pods. Rattle pods are favourite weed hosts.

Identification: The moths are small (12 mm long at rest, wingspan 20–22 mm) and distinctively coloured (Figure 62). They are grey brown in colour with a distinctive stripe along the leading edge of each forewing, and an orange band on each forewing. Hindwings are pale grey in colour. The wings are folded back along the body when resting. Moths have a prominent 'snout' (formed by the labial palps), typical of pyralids.

The eggs are small (0.6 mm diameter), cream and flattened. Small larvae may be cream or pale green with no stripes, and with a dark head. Mid-sized larvae may be pale-green or cream, with pale-brown or reddish stripes. Large larvae are characteristically green with pink or reddish stripes and a brown head (Figure 63). Prior to pupation, larvae can be aqua blue or dark-pink with no stripes.

May be confused with: Moths may be confused with those of other non-pest *Etiella* spp. that feed on rattle pods. The damage in harvested seed is often confused with bruchid damage, and pale frass of *Etiella* is often mistaken for bruchid eggs.

Life cycle: Eggs are laid on pods or under bracts and are very hard to detect. Newly hatched *Etiella* larvae bore straight into pods, usually making a near-invisible entry hole. However, sometimes a bright-orange exudate oozes from entry holes. The lifecycle of Etiella can be completed in 4 weeks at 30°C. Larvae complete their development in a single pod before escaping through a pinhole-sized exit hole (2–3 mm diameter) to pupate in the soil.

Risk period: Crops are at greatest risk during late podding.

Damage: Because *Etiella* larvae consume far less than larger caterpillar species such as *Helicoverpa*, seeds are usually only partially eaten out, often with characteristic pin-hole damage (Figures 64 and 65). Damage is difficult to grade out, and its unattractive appearance reduces seed quality. Larval frass adhering to damaged mungbean seeds is frequently mistaken for bruchid eggs. However, unlike bruchids, *Etiella* are unable to re-infest stored seed.

Monitoring and control: Techniques are being developed to monitor moth activity with light traps or lures, because the moth stage is this pest's most vulnerable stage. No

pesticides are currently registered against *Etiella* in mungbeans and larvae inside pods are unreachable by most insecticides. [22]

Figure 62: Etiella adult (12 mm long).

Figure 63: Large Etiella (10 mm) larva in very small peanut pod.

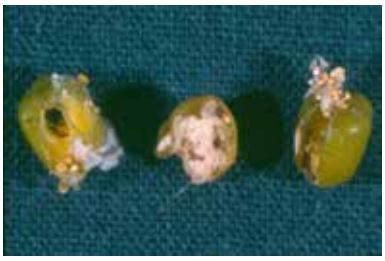


Figure 64: Pin-hole damage from Etiella larvae.

Figure 65: Orange exudate from Etiella entry hole.

[22] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

7.6.13 Legume webspinner, *Omiodes diemenalis* (Lepidoptera: Pyralidae)

Previously (*Lamprosema abstitalis*) also known as bean leafroller.

Pest status: Minor. Widespread in coastal regions but rarely at damaging levels.

Identification: The distinctive moths are brown with yellow patches and have a wingspan of 18 mm (Figure 66). Larvae roll and web leaves together and produce copious quantities of frass. Young larvae are pale green with dark heads. Older larvae are shiny green with pale brown/orange heads and reach 15 mm in length (Figure 67).

May be confused with: BPB larvae but lack black spots. Late final-instar BPB often lose their spots but feed inside webbed flowers and pods, not inside webbed leaves.

Host range: Mungbeans, soybeans, adzuki beans and navy beans.

Risk period and damage: Legume webspinners are widespread in coastal regions but rarely at damaging levels. Crops are usually at greatest risk during early podding. The larvae are leaf feeders, webbing leaves together. Silken webs and frass are indicative of webspinner attack.

Monitoring and control: Larvae will be sometimes detected when beat-sheet sampling. Also inspect webbed leaves and look for the characteristic frass. The threshold is based on tolerable defoliation, i.e. 33% pre-flowering and 15–20% during early podfill. Control is rarely required.[23]

Figure 66: Legume webspinner (wingspan 18 mm).

[23] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Figure 67: Large (14 mm) larva of legume webspinner.

7.6.14 Silverleaf whitefly (SLW), *Bemisia tabaci* (biotype B)

Pest status: SLW is currently not is problem in mungbeans. Mungbeans are a very poor SLW host and very few if any nymphs develop on the crop. However, SLW would pose a threat if the destructive MYMV gained entry into Australia. This is because SLW are a key vector of the virus, and very few SLW are required to transmit the disease.

Distribution: SLW is widespread in tropical and subtropical Australia. SLW is most abundant in coastal–subcoastal regions but can occur in damaging numbers in susceptible crops (cotton, soybeans, cucurbits) in inland regions such Emerald and St George in Queensland, and the North-West Slopes of NSW.

Identification: SLW adults are 1.5 mm long with powdery white wings and a pale orange body (Figure 68). Their folded wings do not quite touch, revealing the body when viewed from above. SLW nymphs (or scales) are pale cream–yellow and are flat and oval-shaped. Nymphs cease feeding and metamorphose to winged adults during the late 4th instar, which is called the pupa or 'red eye' (Figure 69).

Natural enemies: The introduced SLW parasite *Eretmocerus hayati*, together with native parasites, contain SLW populations to sub-economic levels in most susceptible legume hosts in most years. However, in SLW-favourable regions (e.g. Emerald), there will likely be enough SLW to transmit MYMV in most years.

Monitoring and control: Look for adults flying in the crop, or under the leaves. No pesticides are registered for, or needed for, SLW control in mungbean. It is very doubtful whether chemical control would be effective in preventing the transmission of MYMV. The most effective control options are likely to be cultural measures such as removing virus hosts from the proximity of mungbean crops. Report any suspicious disease symptoms in mungbeans (Figure 70) and other hosts (black gram, soybeans and navy beans) to your local agronomist or Department of Agriculture, Fisheries and Forestry Qld (DAFF)/NSW Department of Primary Industries officers. [24]

[24] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Figure 68: Silverleaf whitefly adults.

Figure 69: SLW pupa or 'redeye'.

Figure 70: Virus symptoms on mungbean.

7.6.15 Cowpea aphid, *Aphis craccivora* Koch (Hemiptera: Aphididae)

Distribution: A cosmopolitan species found throughout Australia. Heavy infestations are not uncommon.

Pest status: Moderate, widespread, and irregular.

Identification: Cowpea aphids are relatively small (up to 2.5 mm long). Adults are shiny black and nymphs are slate grey (Figure 71). The rear appendages (siphunculi and cauda) are pale with dark tips.

May be confused with: Cowpea aphids are readily distinguishable from other aphids in summer pulses by their black colouration. Brown smudge bug nymphs look superficially like aphid nymphs but they lack the aphid's siphunculi (paired protrusions either side of the central cauda at the rear of the abdomen) (Figure 72). Siphunculi are also known as 'honey tubes' or cornicles.

Host range: A polyphagous pest attacking many grain legumes, lucerne, cotton and lettuce. Mungbean are a particularly attractive host.

Life cycle: Early aphid colonisation may not be obvious but numbers can explode from flowering onwards in warm weather. Females can reproduce asexually producing >100 nymphs per female. In summer, nymphs can complete their development in 5–7 days. Severe infestations can smother stems, leaves and pods (Figure 73).

Risk period: Flowering onwards. Risk is greater in summer than spring crops.

Damage: Cowpea aphids inject toxins into the plant while feeding. Severe infestations most likely reduce mungbean vigour and yield. Aphid feeding produces honeydew, which makes harvesting difficult. Honeydew also grows sooty mould, which reduces photosynthesis.

Monitoring: The presence of ladybirds (Figure 74), hoverflies and smudge bugs are often an indication that aphids are present. Look for aphid colonies on plant stems by parting the canopy. Heavy aphid infestations will become readily visible when they spread to the upper leaves and pods.

Action level: There are no set thresholds for cowpea aphid in mungbeans.

Conservation of natural enemies: Ladybirds, predatory bugs and hoverfly larvae are key predators. Avoid early dimethoate sprays to give predators time to keep the aphids in check. [25]

[25] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Figure 71: Cowpea aphid black adults and grey nymphs.

Figure 72: Smudge bug and nymph, an aphid predator (3 mm).

Figure 73: Cowpea aphids smothering pods.

Figure 74: White collared lady bird.

7.6.16 Thrips (Thysanoptera: Thripidae): cotton seedling or cereal thrips, *Thrips tabaci* (Lindeman)

Distribution: A cosmopolitan species present throughout Australia.

Pest status: Minor, widespread, and regular.

Identification: Adults are 2 mm long and are dark and cigar-shaped and have narrow feathery wings folded along their back. Nymphs are smaller, lack wings and are pale. Thrips species can only be determined with a microscope (Figure 75).

More information

http://thebeatsheet.com.au/crops/pulses/mungbeans/seedling-thrips-in-spring-mungbean-crops/

Host range: Mungbean, navy beans, cotton and cereals.

Life cycle: Adult thrips can infest a seedling's growing point as soon as it emerges from the ground. In cracking soils, seedlings may be infested before they emerge. Nymphs feed inside vegetative terminals. Populations typically peak within 4 weeks of plant emergence.

Risk period: Spring-planted crops are at greatest risk, especially those in close proximity to maturing cereal crops. The peak risk period is seedling emergence (Figure 76).

Damage: Thrips attack the seedling's growing point and damage the embryonic leaves. However, damage is not manifested until the first trifoliate leaves open and is not evident in the unifoliate leaves. Damaged leaves can be severely distorted and discoloured. Damaged plants are stunted and they look like they have herbicide (2-4 D) damage. Vigorously growing crops quickly outgrow the symptoms, but slowly growing plants seemingly take a considerable time to recover. This is most likely due to low spring temperatures (<18°C) rather than thrips damage. In two DAFF trials, seedling thrips had no effect on yield or plant maturity (i.e. on time to flowering or harvest), despite trial seedlings displaying severe leaf distortion.

Monitoring: Open and microscopically examine the plant's growing point for thrips. Plucked growing points can also be dunked in alcohol or thrips solution to dislodge thrips.

Action level: There are no thresholds for seedling thrips and it is unlikely that this pest reduces mungbean yields except under extreme circumstances.

Cultural control: If possible, do not plant mungbeans immediately adjacent to winter cereals. Avoid spring mungbean plantings in regions where cool spring weather is likely, because low temperatures have a far greater impact on mungbean growth than seedling thrips.

Conservation of natural enemies: If a decision is made to control thrips, apply a narrow band spray over the seedlings to preserve predators such as spiders in the inter-row. [26]

Figure 75: Thrips.

Figure 76: Severe thrips damage to 1st trifoliate leaves, Oakey, Queensland.

[26] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

7.6.17 Flower thrips (Thysanoptera: Thripidae): tomato thrips (*Frankliniella schultzei* Trybom); western flower thrips (*Frankliniella occidentalis* Pergande); plague thrips (*Thrips imagines* Begnall)

Distribution: A cosmopolitan species present in all Australian states.

Pest status: Moderate, widespread and regular. However, their pest status is likely to increase given that they are vectors of the potentially devastating (for mungbean, sunflowers and other susceptible crops) *Tobacco streak virus* (TSV), recently reported in Central Queensland.

Identification: Adults thrips are 2 mm in length, cigar-shaped, with narrow feathery wings folded along their back. Nymphs are smaller, lack wings and are pale. The thrips species present can only be determined microscopically.

Host range: Flower thrips can be found in the flowers of all summer pulses, as well as in the flowers of many other crops, ornamental and weeds, including brassica weeds and *Parthenium*.

Life cycle: Thrips feed and breed within the flowers.

Risk period: Crops are at greatest risk of reproductive damage during flowering and podset. Early infestations increase the risk of TSV.

Damage: Nymphs and adults feed in growing points and inside flowers. Thrips damage can result in flower abortion and pod distortion. Deformed pods may be difficult to thresh, resulting in further yield losses (Figure 77).

Monitoring: Open and examine flowers for thrips. If flowers cannot be assessed immediately, store them in 70% alcohol to dislodge thrips and prevent thrips escaping.

Action level: Control thrips (for flower and pod damage) if, on average, there are >4–6 thrips per flower. Based on experience in other crops, spraying thrips to contain TSV is not successful, as extremely few thrips are required to effect transmission of TSV.

Cultural control: Crops that are vigorously growing can better compensate for flower abortion. Remove weeds such as *Parthenium*, which host TSV and the thrips vectoring TSV. These weeds are also a potential source of infested pollen, which can blow into mungbean crops.

Conservation of natural enemies: Pirate bugs, lacewing larvae and ladybirds prey on thrips. Some thrips species are thought to be important mite predators.[27]

[27] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Figure 77: Thrips-damaged pod.

7.6.18 Stem damaging flies (Diptera: Agromyzidae): beanfly, *Ophiomyia phaseoli* Tryon

Distribution: A major worldwide pest of legumes. In Australia, beanfly is most common in tropical and subtropical coastal and subcoastal regions.

Pest status: A major pest of navy beans in coastal regions. Less common in mungbean but occasionally inflicts severe damage. Not a pest of peanuts and very minor in soybeans.

Identification: Adults are small (3 mm long) and shiny black with clear wings (Figure 78). The larvae are cream with dark mouthparts and reach 3 mm in length. Pupae are small, brown and cylindrical with rounded ends.

May be confused with: Soybean podfly (a minor pest that attacks soybean pods).

Host range: Favourite crops are navy beans, adzuki beans and mungbean. Favoured non-crop hosts include phasey beans and pasture legumes.

Life cycle: Female flies lay their eggs in young leaves (Figure 79). Young larvae tunnel their way to the leaf mid-vein, make their way down the petiole and stem, and pupate in the lower stem (Figures 80 and 81).

Risk period: Crops are at greatest risk for 3–4 weeks from emergence, but later crops are sometimes attacked.

Damage: Larval tunneling damages the plant's vascular tissue, causing seedling death, and reduced plant vigour and petiole droop in older crops.

Monitoring: Monitor seedling crops twice weekly. Look for the distinctive pale, oviposition pin-prick windows in the leaves and for larval tunneling at the base of petioles and in the stems. Look for pupae and damaged stem tissue in the lower stems. Look also for adult flies.

Thresholds: Take action when >1 larval tunnel per plant.

Cultural control: Ensure that cropping areas are free of hosts such as phasey bean and volunteer mungbeans (and volunteer adzuki and navy beans).[28]

Figure 78: Adult beanfly (3 mm).

Figure 79: Oviposition stings of beanfly.

Figure 80: Seedlings killed by beanfly.

Figure 81: Pupae of beanfly in damaged stem.

[28] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

7.7 Key beneficials and what they do

Conserving beneficial arthropods (parasites, predators and spiders) to help control key pests is a good strategy for profitable pest management in mungbean and other summer pulses.

Some beneficials will attack anything within reach (including other beneficials); however, others have preferred prey or hosts. It is therefore important to know which beneficials attack specific pests and which life stages they attack.

For example, *Microplitis* (a parasitic wasp) will attack small *Helicoverpa* caterpillars but has no effect on large larvae, and no effect on mirids or other bugs.[29]

7.8 Sampling insects in mungbean

Correct, regular and timely crop checking is essential to:

- minimise the risk of crop damage
- detect any changes in pest populations
- determine whether pests are being held in check by beneficial insects
- maximise the chance of effective control of pests—'spray small or spray fail'

In general, mungbean are at greatest risk from budding onwards. Crops should be checked twice weekly, especially after budding.

The preferred sampling method is the beat sheet. This is the best all-round method for detecting mirids, *Helicoverpa* and podsucking bugs, which are the crop's key pests.

Visual checking in buds and terminal structures may also be needed to supplement beat sheet counts of *Helicoverpa* larvae, pod borer and thrips. Visual inspections of the canopy are required to detect *Helicoverpa* eggs and moths, as well as aphid colonies.

Other methods that have been tested include the sweep net and suction sampling.

When sampling, check first for adult mirids, bean bugs and ladybirds, because these are likely to fly away quickly.

Convert counts to beat-sheet equivalents if using a different sampling method.

7.8.1 What factors influence sampling?

Four factors influence the effectiveness of a sampling method:

1. Sampling efficiency
2. Sampling precision or variability
3. Effectiveness for a range of pests (versatility)
4. Ease of use for the operator

[29] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Sampling efficiency is defined as: the number of insects caught relative to the number actually present (the absolute number). Of greater importance generally is the precision or consistency (variability) of a sampling method.

The more consistent (i.e. the less variable) the counts achieved with a particular method, the fewer the number of samples required to make a reasonable estimate of a pest population. Obviously, the more pest species a sampling method can reliably assess, the greater use it is to consultants and growers.

7.8.2 Sampling methods and theory

Beat sheet or beat cloth

Beat-sheet sampling is the preferred sampling method for most major mungbean pests, including caterpillars, podsucking bugs and mirids. The standard sample unit at each sample site in a crop is 5 non-consecutive 1-m-long lengths of row, taken within a 20-m radius. Beat-sheet sampling is most suited for crops with a row spacing ~30 cm. Beat sheeting is now the industry-standard best sampling practice.

Beat sheets can be used at any time of day for larvae, but are most effective for podsucking bugs in the early to mid-morning (Figure 82). Beat sheeting for mirids is difficult under windy conditions because mirids blow off the sheet. When it is dewy, they stick to the sheet and to the plants being sampled.

Reducing the number of beat-sheet shakes per site greatly reduces sampling precision for that specific site. If fewer samples are taken per sampling site, then more sites must be sampled within the crop to ensure a reasonable level of accuracy. For example, you can take either 5 samples per site over 6 sites within a crop, or 1 sample per site from 30 sites. The latter will give the same overall level of accuracy for the entire crop, but it cannot be used to estimate populations at specific locations (sites) within a crop.

Figure 83 below illustrates how variable 1-m counts can be, even in a crop with a moderate mirid population. Note that within individual sites (replicates), the individual shakes varied as much as 0–4 mirids/m. Note also the variability between replicates. The average population across all sites was 2.1 individuals/m, yet there was nearly a 2-fold variation between the lowest and highest count per replicate.

Figure 82: Mungbean plants being vigorously shaken to dislodge insects onto beat sheet. Note how the sheet drapes over the next row.

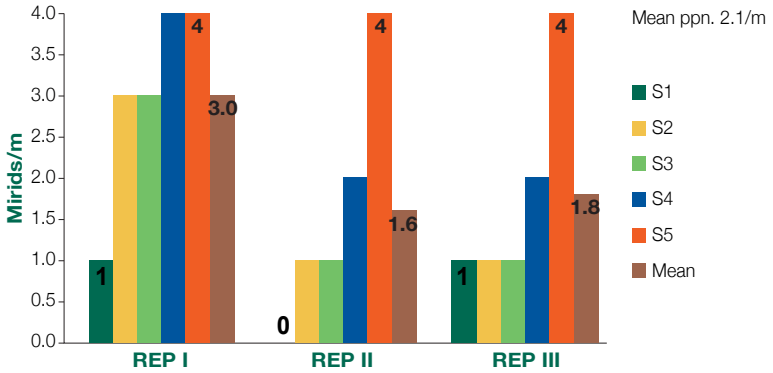


Figure 83: Variability in mirid counts within and between sites (replicates) sampled with a beat cloth.

In this instance, beat sheet size is standardised at 1.3–1.5 m wide by 1.5–2.0 m deep, the larger dimensions being for taller crops. Only plants along the central 1 m of row are sampled (shaken) with a 1-m-long stick. The extra 0.15–0.25 m on each side catches mirids sprayed out sideways when sampling, and the sheet's depth allows it to be draped over the adjacent row. This prevents mirids being flung through or escaping through this row. All plants can be sampled at once with 8–10 vigorous shakes from a 1-m shaking stick. The use of smaller beat sheets, such as small fertiliser bags, can reduce sampling efficiency by as much as 50%.

Sweep net

Sweep netting is the easiest method for sampling mirids in broadacre crops or those with narrow rows (Figure 84). Although sweep netting is quite effective for mirids, it is far less so for podsucking bugs and caterpillars. Several sweeps are taken through the upper canopy of the crop and the net is then inspected to determine the number of insects caught. The standard sample unit is 20 sweeps/20 m row, across 2 rows. However, for narrow row spacing (<50 cm), sweep across 4 rows.

Sweep netting is comparable in precision to the beat sheet but is only 33% as efficient

for sampling mirids. Only moderate sweeping speed is required when sampling mirids in mungbean, i.e. the plants do not need to be thrashed. However, heavier sweeping is more effective for caterpillars and podsucking bugs. Sweep-net sampling is only 10–25% as efficient for sampling caterpillars, but is at least as precise (consistent) as the beat sheet. For podsucking bugs, the sweep net is only 25% as efficient as the beat sheet but is at least as precise (consistent).

Mirids captured in a sweep net should be killed before tipping onto a tray and counting. The best way to kill mirids in the sweep net is to hold the net tightly above the catch and dunk the end into a jar of methylated spirits. This is less messy and toxic for the operator than spraying mirids in the net with household aerosol insect sprays.

Figure 84: Sweep netting in mungbeans. Note the long wooden handle for easier use.

Suction sampling

Suction sampling is a quick and relatively easy way to sample for mirids. The method has been trialed extensively by researchers but has had little commercial uptake. However, it may have specialised applications in other crops, e.g. in prostrate peanut cultivars. Its main drawbacks are unacceptably low sampling efficiency for pests other than mirids, a propensity to suck up flowers and bees, noisy operation, and high purchase cost (relative to a beat sheet). The standard suction-machine sample unit at each sample site (within a crop) is one 20-m-long length of row. A sampling machine commonly used by DAFF researchers is the Stihl BG75, or modern equivalent.

Visual sampling (of leaves and flowers)

Visual sampling of the canopy is the only way to check crops for moths, egg lay and aphids. Internal visual inspection (opening) of flowers and vegetative terminals is necessary to detect small *Helicoverpa*, pod borer larvae and thrips feeding within these structures.

Although visual inspection of whole plants is commonly used to assess mirid populations in cotton seedlings, it is NOT suitable for sampling mirids in mungbean.

Visual sampling is only 17% as efficient as the beat sheet for sampling mirids in mungbean, and is far too variable (inconsistent) to be considered as a viable mirid sampling method.

7.8.3 Summary of the relative merits of different sampling methods

Beat sheet sampling is industry best practice. Beat sheeting must be supplemented by visual inspections of the canopy for moths, moth and bug eggs, and aphid colonies. Open flowers and vegetative terminals to detect small (and concealed) *Helicoverpa*, pod borer larvae and thrips.

The relative efficiencies and consistency of different sampling methods are shown in Table 2. An advantage of sweep nets and suction is that they require only one individual sample per sample site, as opposed to five for the beat sheet. This makes the beat sheet more time-consuming in the field. However, when the time to assess sweep-net and suction samples post-capture (in the field or afterwards) is factored in, there is little time difference between these sampling methods.

Table 2: Relative sampling efficiency and consistency (as measured by coefficient of variation) of four sampling methods for four major pests of mungbeans

* Note that this visual sampling refers only to the inspection of whole plants, not to the inspection of flowers and buds. The values for Helicoverpa and podsucking bugs are based on data from a limited number of crops

Relative sampling efficiency (%) – mungbeans only				
Pest	**Beat Sheet**	**Sweep Net**	**Suction**	**Visual***
Mirids	100	33	43	17
Helicoverpa	100	23	34	35
Loopers	100	10	30	22
Podsucking bugs	100	23	40	43
Relative sampling consistency or variability (%) – mungbeans only				
Mirids	100	100	106	233
Helicoverpa	100	66	67	132
Loopers	100	103	104	157
Podsucking bugs	100	80	97	145
	Beat Sheet	Sweep Net	Suction	Visual

7.8.4 Converting sample totals to beat-sheet equivalents

To simplify pest-management recommendations, most pest thresholds for mungbean are expressed no. of pests per m^2 in beat sheet equivalents (BSE) (i.e. as sampled with a beat sheet). Hence, insect counts in your crop must be converted to no. of pests/m^2 in BSE.

When using a beat sheet, the conversion is simple. Divide the 'average mirid count per row metre' by the row spacing in metres (calculated by dividing counts per sample site (5 × 1 m) by 5, and averaging counts across all sample sites). For example, for 75 cm (0.75 m) row spacing, divide average counts by 0.75.

Counts from other sampling methods must also be converted to BSE. Conversion factors for different row spacing and methods are listed in Table 3.

Example calculation using Table 3: If using a beat sheet in mungbeans planted in 0.75-m spaced rows, and if on average 20 mirids are sampled per 5 × 1 m of row, divide 20 by 4 to give a standardised count of 5 mirids/m^2. If using a sweep net, also divide by 4.

Table 3: Converting mirid counts to beat sheet equivalents per m² in mungbean

For each method, divide total mirid counts per sample unit by the respective values given. Conversion factors allow for row spacing, sample unit size, and sampling efficiency

Method	Standard unit per sample site within a crop	Sampling efficiency relative to beat sheet	Conversion of counts per site to beat sheet equivalents per m² for different row spacing's.			
			25 cm (10")	50 cm (20")	75 cm (30")	100 cm (40")
Beat Coth*	5 lots of 1m of row	100%	÷ 1.25	÷ 2.5	÷ 4	÷ 5
Suction *	1 row x 20 m	40%	÷ 2	÷4	÷ 6	÷8
Sweep Net *	20 sweeps in 20 m across N rows	33%	÷ 2.6	÷ 2.6	÷ 4	÷ 5
	Number of rows per sweep		4	2	2	2

Beat sheet sampling is very difficult in broadacre crops. In such crops, the beat sheet will only sample a certain proportion of plants within each square metre. This proportion will depend on the plant population and plant height. Place the beat sheet within a previously marked square metre of crop. Count the total number of plants in this square metre, and the number of plants within sampling reach of the sheet. Repeat this at 5 sites within the crop and calculate average values. Convert counts per shake to counts/m² by dividing insect counts by the proportion of plants sampled/m² (e.g. if 50% of plants are sampled per m², divide insect counts by 0.5).

7.8.5 How many samples are required to accurately assess plants?

The more samples you take, the more accurate will be your assessment of pest activity in a crop, particularly of pests that are patchily distributed in a crop, such as podsucking bug nymphs.

There is always a compromise between accuracy and practicality. The number of samples needed to assess pest populations with a high degree of precision (e.g. ±10–20%) is usually far greater than is commercially feasible. For example, 250 individual beat sheets (5 × 50 sites) are required to sample a mirid population of 0.5/m² with ±20% accuracy (i.e. ±0.1/m²). Obviously this is impractical. The minimum numbers of samples required for 'reasonable' accuracy are shown in Table 4.

Table 4: Minimum number of samples recommended for assessing pests in mungbeans

* This is the number of sample sites; multiply by 5 to get number of individual samples. # For podsucking bugs, because GVB nymphs are notoriously patchy in distribution, more samples are desirable

Pests	Method	Sample unit	Minimum no sample sites* recommended
Mirids	Beat sheet	5 x 1m	6
	Sweep Net	20 sweeps in 20m	6
Helicoverpa, Loopers	Beat sheet**	5 x 1m	6
Podsucking bugs#	Beat sheet**	5 x 1m	6-10#
Bean podborer	Open flowers	30 flowering racemes	6
Thrips	Open flowers	25 flowers	6

The number of samples required can be further reduced if the sampler just wants to know whether a pest population is significantly above or below threshold, rather than the

precise number. This approach involves the use of a 'sequential sampling plan'. Sequential sampling plans have been developed for mirids, *Helicoverpa*, loopers and podsucking bugs in mungbeans. These plans make it easier to determine rapidly whether pests are above or below threshold, are a useful way to record insect counts, and can reduce the number of samples required.

A sequential sampling plan is a graph on which the cumulative number of pests (*Y*) is plotted against the cumulative number of samples taken (*X*). All plans have a cumulative 'threshold line' already plotted. For example, if the threshold is 0.5 pests/m^2, then after two sites are sampled, the cumulative threshold count is 1.0/m, after four sites 2.0/m, etc. Joining all of these points gives the (blue) threshold line (Figure 85). On either side of the threshold line are the upper and lower (green) confidence lines, which are usually set at 90%. Pest populations outside these lines are at least 90% likely to be significantly greater or lower than the cumulative threshold.

If the cumulative mirid counts are above the upper confidence line, then spray. If they are below the lower confidence lines, then spraying is not recommended. If populations start within the confidence lines, the cumulative counts should trend away from the threshold line, i.e. increasingly diverge above or below the threshold line (Figure 86).

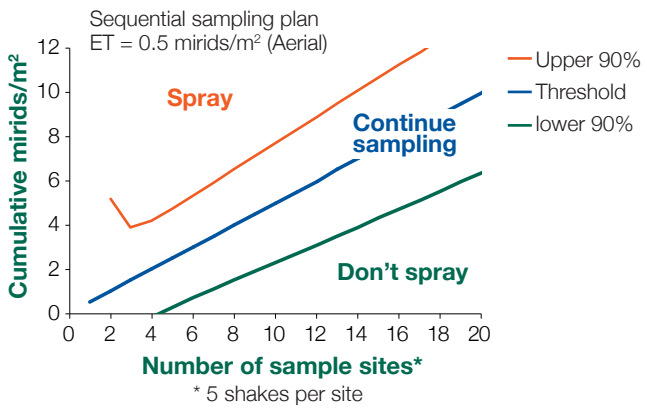


Figure 85: Sequential sampling plan for mirids in mungbean with a threshold of 0.5/m^2 (the threshold for a $700/t crop to be aerially sprayed with dimethoate at 500 mL/ha).

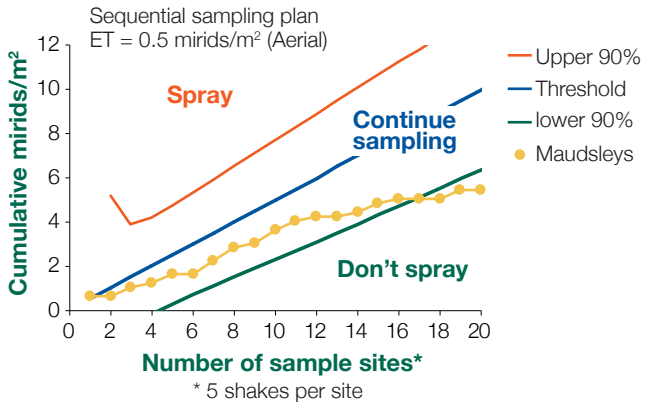


Figure 86: Note how the cumulative counts from a commercial crop trend increasingly away below the threshold. After sampling 5–6 sites in this crop, the decision not to spray could be taken with confidence, especially if the crop were inspected again in 3–4 days. (Flowering crops should be inspected on a twice-weekly sampling schedule).

The advantage of this approach is that for most pests, the trend becomes more apparent as sampling continues. If populations are not significantly different from the threshold after a reasonable number of samples are taken, a decision to spray may be held over until the crop is re-checked (within 3–4 days in flowering–podding crops), particularly where the threshold is yield-based (as for mirids). However, for podsucking bugs where the threshold is quality based, action should be taken against 'at-action-threshold' populations to prevent a downgrade of quality.

Figure 87 and 88 illustrate two further sequential sampling scenarios, one where the cumulative mirid count remains right on threshold, and one where it becomes quickly obvious that the mirid population is well over threshold.

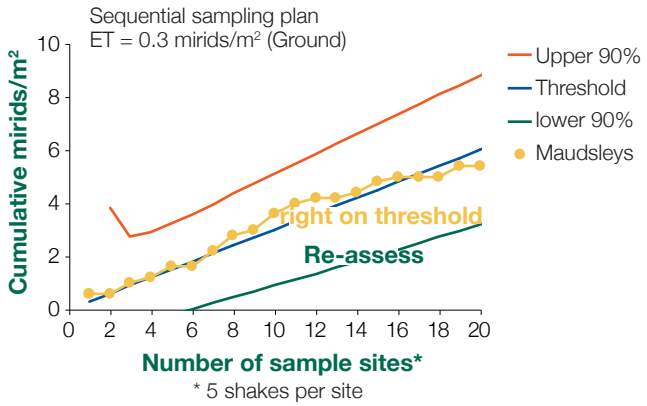


Figure 87: Sequential sampling is for mirids in mungbeans with a threshold of 0.3/m² (the threshold for a $500/t crop to be sprayed with a ground-rig with dimethoate at 500 mL/ha). Note that in this instance, the cumulative counts from the commercial crop remain right on threshold. The decision would be to re-assess in 3–4 days.

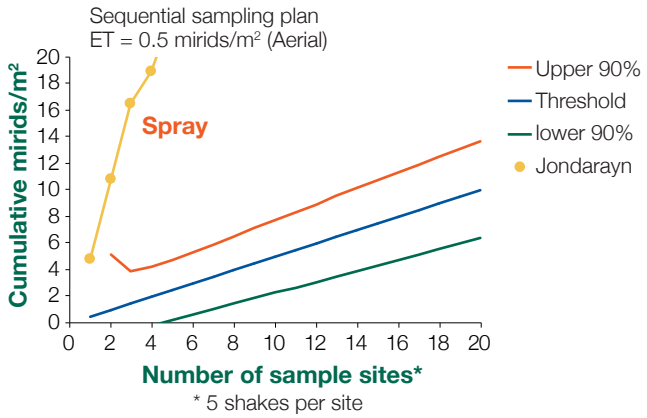


Figure 88: Data from a 0.5/m² threshold crop with a mirid population nearly 5 times threshold. Note how rapidly it climbs away above the threshold line. In this instance, a decision could be made to spray after 3–4 widely spaced sites were sampled, to ensure this population was not just confined to one part of the crop.

A sequential sampling plan for GVB is shown in Figure 89. Separate upper confidence limits are shown for GVB nymphs (red) and adults (yellow), as the nymphs are far more patchily distributed than adults. This is because GVB eggs are concentrated in rafts containing 50–100 eggs. The hatching nymphs tend to congregate around the egg-lay site and do not disperse until they are large nymphs. As a consequence, the confidence limits for GVB nymphs are much further from the cumulative threshold line than are those

for adults. For this reason, a large number of sites may need to be sampled before GVB populations can be accurately assessed, especially if, as in the case illustrated, >80% of GVB present are nymphs. In the crop in question, the true size of the GVB populations did not become obvious until 11 sites were sampled. In practice, most crops are not sampled this intensively. As a result, many above-threshold GVB populations are not detected until nymphs have reached a damaging size and have dispersed, thus increasing their chance of detection.

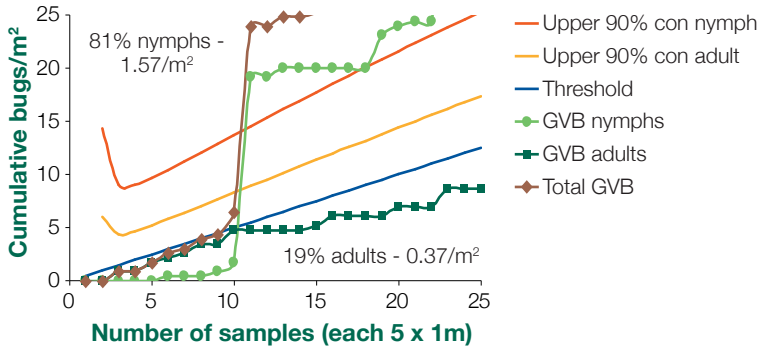


Figure 89: Sequential sampling plan for GVB in mungbeans with counts from commercial crop. Note the massive increase when a large cluster of nymphs was encountered at the 11th sample site.

Because quality-based thresholds are based on the maximum allowable percentage bug damage (usually only 2%), the number of seeds per unit area also needs to be estimated to determine the bug population that can be tolerated in a specific crop.

Because %damage = no. of damaged seeds/total no. of seeds, the smaller the crop, i.e. the fewer seeds per unit area, the greater the percentage damage from a given bug population, and the lower the threshold.

The total seeds per unit area (standardised as seeds per m^2) can be calculated in two ways.

Researcher's method:

- Determine the number of seeds per pod (assess random 10 pods, usually 10–12 in mungbean).
- Estimate the number of pods per plant (assess 10 random plants, not just the biggest ones).
- Count the number of plants per m (you may have these data after emergence).
- Calculate no. of seeds/m^2 = (seeds per pod × pods per plant × plants per m)/row spacing (m).

Experienced agronomist's method:

- Estimate the crop's potential yield (kg/ha).
- Look up the number of seeds/kg for the variety in question (planting seed records).
- Calculate no. of seeds/m^2 = (potential yield/10,000) × seeds/kg per row spacing (m)

Using a sequential sampling plan—summary

- Keep a running (cumulative) total of the number of pests per m^2 (in BSE) as you sample.

- See where the running total lies on the relevant sequential sampling chart.
- In the mirid charts, the blue line represents the cumulative mirid threshold (mirids/m^2).
- The coloured lines on either side are confidence limits, beyond which mirid numbers are significantly higher (red) or significantly lower (green) than the threshold.
- If after a reasonable number of samples, your cumulative or running total falls outside these lines, you can be 90% confident that you either have to spray, or do not have to spray.
- If your counts fall between the confidence lines, you can continue sampling until your running total is either above or below the confidence limits, or you can return in a couple of days to re-check the crop.
- The return and recheck option is most acceptable if the running total is trending below the threshold. There will be time constraints to how many samples you take, and scouts are unlikely to have time to sample more than 10 sites per crop. However, a large number of sites may be required to assess populations of GVB nymphs accurately. [30]

More information

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/09/Insect-thresholds-for-key-insects-in-sorghum-sunflower-mungbeans-What-are-they-based-on-and-when-and-how-can-they-be-modified

7.9 Economic threshold theory and practice

Economic thresholds (ETs) are one of the cornerstones of integrated pest management (IPM). They help to rationalise the use of pesticides and are one of the keys to profitable and sustainable pest management. The development of ETs requires knowledge of pests, their damage, and the crop's response to damage.

7.9.1 Threshold basics

An ET is classically defined as: the pest population causing damage equal in value to the cost of control (pesticide + application).

The ET can be considered as the 'critical' or 'break even' population. Spraying is only recommended when insect numbers exceed the ET, i.e. when the value of damage is likely to exceed the cost of control. The classical definition applies for crop–pest scenarios where yield loss is the critical factor governing spray decisions (as opposed to situations where potential quality reductions and price discounts are the critical factors).

There are sound economic and biological reasons for spraying only above-threshold pest populations. First, you are financially worse off if you spray below-threshold populations. Second, unnecessary spraying with non-selective insecticides puts crops at unnecessary risk from non-target pests, particularly *Helicoverpa*, mites and whiteflies, and can lead to yet more spraying. Third, unnecessary spraying hastens the development of pesticide resistance in *Helicoverpa* and other pests.

Economic thresholds are usually specified as the number of insects found per unit crop area (or length of row) using a specified (standard) sampling technique. In mungbean and other pulses, the recommended sampling method is the beat sheet, and thresholds are expressed as pests per m^2 (pests/m^2). If other row-based sampling methods are used,

[30] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

thresholds are expressed in terms of BSE/m^2. If the row spacing is other than 1 m, convert your pest counts per m to no. of pests/m^2 by dividing them by the row spacing in metres.

Understanding how ETs are calculated makes them easier to use, and increases confidence in using them as a key IPM tool.

7.9.2 Economic threshold types

Yield-based thresholds

Yield-based ETs are used where crop value lost as a result of pest attack is due solely to yield loss, rather than product quality. Yield-based thresholds are used in mungbean for mirids, *Helicoverpa* and loopers. Where the amount of damage per pest is known (i.e. has been quantified), the ET can be calculated using the following generic equation or model (the Norton model):

$$\text{Economic Threshold (pests/m}^2\text{)} = \frac{\ldots C \ldots}{V \times D}$$

where C = cost of control including application ($/ha)
V = crop value ($/tonne)
D = yield loss per pest (t/ha for every pest/m^2)

Spraying is only recommended when insect numbers exceed the ET, i.e. when the value of damage is likely to exceed the cost of control. How far above the ET a pest population has to be before action is taken is an individual judgment, taking into account how confident you are in your sampling, and the cost of control.

Remember that at the ET or breakeven point, you are no better off financially if you spray than if you do not spray. Although you will suffer some financial loss if below-threshold pest populations are present, you will incur even greater financial pain if you spray below-threshold populations.

Whereas the amount of damage caused per insect is relatively constant, both the value of the crop and the cost of control can vary. As a result, an ET model can accommodate fluctuations in pesticide prices and crop value. Thresholds may therefore vary widely for different pesticides. As a rule of thumb, the lower the cost of control and the higher the crop value, the lower the threshold, and *vice versa*.

Below is an example of an economic threshold calculation for Helicoverpa in mungbean, where the damage factor (D) at podding has been determined as 35 kg/ha (0.035/t) for a density of 1 larva/m^2 of crop. If a crop with an estimated value (V) of $700/t is to be aerially sprayed with indoxacarb (Steward®) (C is cost of control, including application: ~$28 + $15 = $43/ha), then:

$$\text{Economic Threshold (larvae/m}^2\text{)} = \frac{\ldots C \ldots}{V \times D} = 43/(700 \times 0.035) = 1.8 \text{ helicoverpa larvae per m}^2$$

Where crop values and spray costs vary markedly, thresholds can be easily determined and compared by referring to threshold charts specific to the pest in question.

Nominal thresholds

Where the damage factor (D) is unknown, pests are often assigned nominal or fixed thresholds, based on the knowledge of experienced consultants and researchers. Many nominal thresholds have been proved reasonably accurate; however, they fall down in situations where crop values and spray costs vary widely. An example of a nominal threshold is the old 'heli-mungbean threshold' of 1 *Helicoverpa*/m^2.

Benefit:cost ratio

A commonly quoted rule of thumb in IPM programs is the adoption of a benefit:cost ratio (BCR) of 2:1, i.e. action is only taken when the value of likely damage prevented is twice the cost of control, i.e. when pests are at twice threshold. The rationale is that for every $1 spent on spraying pests, there is a $2+ return. This rule may apply where control costs are low, e.g. for grower-applied dimethoate sprays; however, it is not appropriate where control costs are high. For example, if the cost of control was $40+/ha, it is doubtful that a grower would accept another $40+/ha of damage before they took action.

Rather than applying an arbitrary BCR to the threshold, a more realistic approach is to put an absolute limit or cap on the additional damage you are willing to carry. For example, if your preferred pesticide option costs $40/ha (chemical plus application) and you are only willing to accept another $10 of damage (remember, at the breakeven point, the cost of control = cost of damage), then your action threshold, in effect, is when the cost of control = $50/ha.

Defoliation thresholds

Defoliation thresholds are a type of yield-based threshold, but are based on studies linking percentage defoliation with yield loss. Studies have shown that vegetative crops are remarkably tolerant of attack, and can tolerate 33% defoliation with no subsequent loss of yield. However, tolerable defoliation falls to 15–20% during flowering and podding.

By factoring in the cost of control, higher defoliation levels could probably be tolerated, but in practice, if leaf feeding is severe then action might be required before defoliation reaches the threshold, since biopesticides are best targeted against relatively small larvae (ideally <7–12 mm long). However, in many cases a 50–60% kill would suffice because many of the survivors may be killed by beneficials.

Note that a new provisional threshold of 4–5 larvae/m^2 has been set for *Helicoverpa* in vegetative mungbean, based on threshold data from soybeans. The threshold is based on the propensity of *Helicoverpa* for attacking the plant's auxiliary buds, the precursors of floral buds.

The crop's growth status will have a great influence on decisions taken in these situations. The larger the crop, the lower the percentage defoliation occurring for a given number of leaf-feeding pests. As such, rapidly growing, healthy crops are at lesser risk. Smaller, drought-stressed crops also face the increased risk of terminal damage, and they are more

affected by sap-sucking pests such as aphids. Different levels of defoliation are shown in Figure 90.

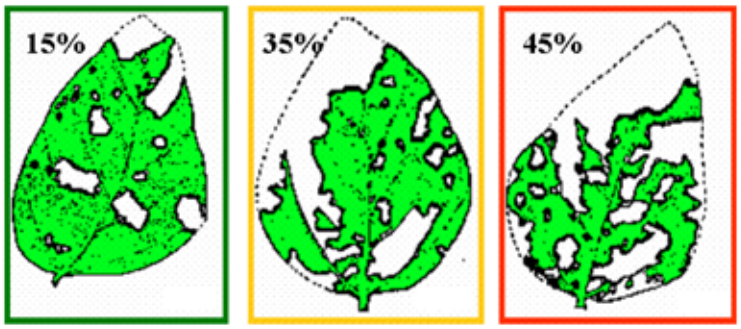


Figure 90: Defoliation ranging from 15% to 45%, as inflicted by Helicoverpa larvae. During the vegetative stage, 33% defoliation can be tolerated without yield loss, and probably close to 40–45% before spraying is economic. More than 15% defoliation can reduce yield at podding. Note how the percentage defoliation seems to be less than suggested at first observation.

Quality-based thresholds

Quality thresholds are used where reduced seed quality due to pest damage has a greater impact on crop value ($/ha) than yield loss. In such a scenario, the quality threshold is lower than the yield threshold and is the threshold that triggers pest control. For podsucking bugs in mungbean, the quality threshold is the 'governing threshold'. The reverse holds for *Helicoverpa* in mungbean, where the yield-based threshold is the governing threshold. Quality thresholds are based on a critical level of damage, which in mungbean (and other pulses) is quoted as the maximum allowable percentage seed damage.

Quality thresholds are fundamentally different to yield thresholds. Whereas slightly exceeding a yield threshold usually results in only a slight penalty, i.e. a slight increase in crop value lost ($/ha), slightly exceeding a quality threshold can dramatically reduce crop value. For example, slightly exceeding 2% seed damage in mungbeans can reduce crop value by >$100/t, or by >$200/ha in a high-yielding crop. Because the potential reduction in crop value is many times greater than the cost of pest control, action is justified before the critical threshold or level of damage is reached. Just how far the action threshold is set below the critical threshold depends on your confidence in sampling. A reasonable level for the action threshold would be 0.7 of the critical threshold.

Example:

In an 'average good sized' (2000 seeds/m^2) crop of mungbeans, >2% of seeds are damaged when GVB populations exceed 0.71 adult bugs/m^2. Thus, 0.71 GVB/m^2 is a critical pest population in edible soybeans. If GVB populations exceed this critical level of 2% damaged seeds, the bonus for edible quality is lost and crop value may be downgraded by ≥$250/ha, i.e. by many times the cost of control. If the preventative or action threshold is set at 0.7 of the ET, take action when the GVB population reaches 0.5/m^2 (=0.71 × 0.7), to ensure the critical damage level is not reached or exceeded in a 2000 seeds/m^2 crop.

Because quality thresholds are very low, thorough scouting for podsucking bugs is essential. Inadequate sampling will very likely underestimate or overestimate bug numbers.

Because quality thresholds are based on percentage seed damage, it will also be necessary

to determine the number of seeds/m^2, as well as the number of bugs/m^2. Remember that the smaller the crop (the fewer seeds/m^2), the greater the percentage damage from a given bug population, and the lower the quality threshold.

Thresholds for immature pests

For podsucking, most crop damage is caused by the large nymphs (immature stages) and adults and. For caterpillars such as *Helicoverpa*, most damage (95%) is inflicted by the final two larval instars (immature stages) but no damage is inflicted by the adults. However, the question remains: how should young larvae and nymphs be factored into threshold damage estimates?

For caterpillar pests, thresholds assume that larvae will complete their development if not controlled, thus realising their full damage potential (the D factor in threshold models). However, small larvae are often attacked by predators, killed by disease, or even blown off the crop before they reach a damaging size. For this reason, there is more leeway in decision making if the majority of caterpillars present are small, particularly if large numbers of predators are present, and naturally occurring disease is observed.

For podsucking bugs, young nymphs are far less damaging than older nymphs (1st instar nymphs do not feed at all) and are more susceptible to attack by ants and spiders. However, their true damage potential is the cumulative damage they will inflict as they progress to adulthood, plus the damage they will inflict during after reaching adulthood. This complicates bug thresholds because likely damage depends not just on the age of immature bugs, but also how close the crop is to harvest.

Multi-pest thresholds

Where several pests causing similar damage are present, it is easier to express their combined damage potential in 'standard-pest equivalents'. A common example is for podsucking bugs, where GVB is the designated 'standard bug', and other species are converted to GVB adult equivalents (GVBAEQ). This is much easier than having a separate threshold for each species, and is the only workable solution where more than one species is present.

Thresholds where multiple pests and pest stages present:

If different podsucking bug species of different ages are detected during sampling, determine the bug population's damage potential in GVBAEQ as follows:

1. Convert the counts for each bug stage (nymphs and adults) to GVBEQ by multiplying by the conversion factors listed below in point 3.
2. Total the counts for each instar (all species are now in GVBEQ).

3. Convert GVBEQ counts for each instar to GVBAEQ by multiplying by the conversion factors below. Note that conversion factors below are for 'bug detection' times ranging from 28 to 42 days before harvest.

Bug species	Genus	Conversion to GVBEQ
Green vegetable bug	Nezara	1.00
Large brown bean bug	Riptortus	1.00
Small brown bean bug	Melanacanthus	1.00
Redbanded shield bug	Piezodorus	0.75
Brown shield bug	Dictyotus	0.20

Days to Harvest	I	II	III	IV	V	Adult
28	0.25	0.39	0.64	0.84	0.96	1.00
35	0.31	0.44	0.68	0.86	0.97	1.00
42	0.35	0.47	0.71	0.88	0.97	1.00

4. Total the GVBAEQ for all instars to determine the bug population's overall damage potential. For example, if on average, one 2nd instar larva, two 3rd instar larvae and 0.5 adult are present at 35 days prior to harvest, then the overall damage potential of that population = (0.44 × 1) + (0.68 × 2) + (0.5 × 1) = 2.3 GVBAEQ.

DAFF is currently developing and trialing a computer model that will more easily accomplish the above steps.

Increasing pest populations

Where pest numbers are obviously increasing (as evidenced by increasing counts over time), the timing of preventative action (e.g. spraying) depends on the type of threshold. For podsucking bugs, action should be taken before the critical quality threshold is reached, to avoid a sudden and major downgrading of crop value. In most crops, podsucking bug populations invariably increase as the crop pods progresses from podset to late podfill. [31]

[31] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

7.10 Mungbean thresholds

Economic thresholds for pests in mungbean are presented in Table 5.

Table 5: Summary of mungbean economic thresholds

Pest	Crop stage	Threshold	Comments
Seedling thrips	Seedling	None	Spring mungbeans only Mostly not worth spraying for
Bean fly	Seedling	1 larval tunnel per plant	May need respray in 7 days Look for stings on leaves
Helicoverpa ⊙	Vegetative	provisionally 4-5/m^2	New threshold based on published soybean data
Loopers♦	Vegetative	33% defoliation	Refer to defoliation Figure 7. 10
Mirids	Budding, Flowering, Podding	0.3-0.5/m^2 for dimethoate	Values are for ground & aerially sprayed crops respectively.
Bean podborer✪	Budding, Flowering, Podding	Provisional new threshold of 5-9/m^2 larvae in flowers, or 0.7-1.3/m^2 larvae on beat sheet	Based on provisional new threshold model based on recent field data
Thrips	Budding, Flowering	4-6 per flower	Open and inspect flowers. Report any TSV-like symptoms (see Module 4)
Helicoverpa ✖	Budding-Podding	**0.9-3.0/m^2** depending on pesticide used & mungbean prices✠	**Based on new threshold model** developed by GRDC/ DAFF IPM project
Spodoptera	Budding-Podding	3/m^2	A nominal threshold. Less damaging than helicoverpa
Loopers♦	Budding-Podding	3.0/m^2	A nominal threshold. Plants likely to compensate for moderate early damage
Podsucking bugs#	early to late Podding	0.25-1.0 /m^2	Thresholds vary according to crop size (seeds/m^2) ##. Sample thoroughly as patchy distribution of nymphs

Note: Thresholds are based on beat sheet sampling and are expressed in pests per m^2

⊙ Provisional new threshold extrapolated from soybean trials.

♦ Loopers are mainly leaf feeders in soybeans, but they will attack mungbean flowers and small pods.

✖ Inspect flowers and terminals for small Helicoverpa larvae.

✪ Refer below for new provisional bean pod borer threshold table.

Expressed in green vegetable bug adult equivalents (GVBAEQ). Convert counts of other bug species and nymphs to GVBAEQ. One brown bean bug = 1GVB. One redbanded shield bug = 0.75 GVB.

Refer below for podsucking bug threshold table. [32]

[32] H Brier, G Cumming (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

7.11 Detailed threshold information for key pests

7.11.1 *Helicoverpa* thresholds:

Table 6: Economic thresholds for Helicoverpa in mungbeans at late podfill

Thresholds are based on damage of 35 kg/ha per larva/m². (Data are from 2006–07 and assume near 100% control)

Cost of control # = Value of damage ($/ha)	Thresholds# for Helicoverpa (larvae/m²) at Mungbean Crop Values listed below ($/t):					
	$500	$600	$700	$800	$900	$1000
$ 20	1.1	1.0	0.8	0.7	0.6	0.6
$ 25	1.4	1.2	1.0	0.9	0.8	0.7
$ 30	1.7	1.4	1.2	1.1	1.0	0.9
$ 35	2.0	1.7	1.4	1.3	1.1	1.0
$ 40	2.3	1.9	1.6	1.4	1.3	1.1
$ 45	2.6	2.1	1.8	1.6	1.4	1.3
$ 50	2.9	2.4	2.0	1.8	1.6	1.4
$ 55	3.1	2.6	2.2	2.0	1.7	1.6
$ 60	3.4	2.9	2.4	2.1	1.9	1.7
$ 65	3.7	3.1	2.7	2.3	2.1	1.9

In Table 6, cross-reference the cost of control (pesticide plus application) against the likely crop value. In the first highlighted example, where the cost of control = $40/ha and crop value =$700/t, the ET =1.6 larvae/m² (circled in red).

In the blue highlighted example, you are prepared to accept an extra $10/ha damage, in effect increasing the cost of acceptable damage to $50/h and raising the action threshold to 2.0 larvae/m². The BCR in this scenario is 1.25:1 (50/40 = 1.25). If you decided to accept an extra $20 damage, the action threshold would be 2. 4 larvae/m² (circled in purple), and the BCR would be 1.5:1.

7.11.2 Mirid thresholds

Table 7: Mirid thresholds for mungbeans based on a rate of damage of 60 kg/ha per mirid/m²

This rate of damage holds over a wide range of growing conditions. Green and brown mirid counts can be totaled; they are equally damaging

Cost of Control# = value of damage ($/ha)	Mirid Thresholds# (Adults + Nymphs/m²) at Mungbean Crop Values listed below:					
	$400/t	$500/t	$600/t	$700/t	$800/t	$900/t
$ 10	0.42	0.33	0.28	0.24	0.21	0.19
$ 15	0.63	0.50	0.42	0.36	0.31	0.28
$ 20	0.83	0.67	0.56	0.48	0.42	0.37
$ 25	1.04	0.83	0.69	0.60	0.52	0.46
$ 30	1.25	1.00	0.83	0.71	0.63	0.56
$ 35	1.46	1.17	0.97	0.83	0.73	0.65
$ 40	1.67	1.33	1.11	0.95	0.83	0.74

In Table 7, cross-reference the cost of control (pesticide plus application) against the likely crop value. In the first highlighted example, where the cost of control = $10/ha and crop value =$700/t, the ET = 0.24 mirids/m². This scenario approximates dimethoate applied by

the grower with a ground-rig. In this situation, a BC ratio of 2:1 could be easily considered (in the interests of IPM) because it means carrying only another $10 of damage. This in effect doubles the tolerable damage to $20/ha and raises the threshold to 0.48 mirids/m^2.

Coincidently in a $700/t crop, this population (0.48/m^2) is the break-even threshold for aerially applied dimethoate (cost of chemical + application) = $20/ha. In this scenario, most people are unlikely to accept a BC ratio of 2:1, i.e. a doubling of the tolerable damage to $40/ha and the mirid threshold to 0.96/m^2. For an aerially sprayed crop (potentially worth $700/t), accepting an additional $10 of damage would raise the threshold to 0.71 mirids/m^2. Because it is substantially more expensive than dimethoate, mirid thresholds for Steward® (indoxacarb) are substantially higher than for dimethoate (~2–3 times higher). For this reason, Steward® is best reserved for use against *Helicoverpa*.

7.11.3 Bean pod borer—new thresholds

Table 8: Provisional thresholds for bean pod borer: (a) as found in flowering raceme0.9er m^2 and (b) as sampled with a beat sheet

(a) Larvae found in RACEMES per square metre

Cost of Control	Crop value				
	$400	$500	$600	$700	$800
$20	6.3	5.0	4	4	3.1
$25	7.8	6.3	5	4	3.9
$30	9.4	7.5	6	5	4.7
$35	10.9	8.8	7	6	5.5
$40	12.5	10.0	8	7	6.3
$45	14.1	11.3	9	8	7.0
$50	15.6	12.5	10.4	8.9	7.8

(b) Larvae per square metre on BEAT SHEET

Cost of Control	Crop value				
	$400	$500	$600	$700	$800
$20	0.9	0.7	0.6	0.5	0.4
$25	1.1	0.9	0.7	0.6	0.5
$30	1.3	1.0	0.9	0.7	0.6
$35	1.5	1.2	1.0	0.9	0.8
$40	1.7	1.4	1.1	1.0	0.9
$45	1.9	1.6	1.3	1.1	1.0
$50	2.2	1.7	1.4	1.2	1.1

Note in Table 8 that the beat sheet threshold is only one-seventh of the 'found in racemes' threshold (cross-match the threshold for a $600/t crop and a $35/ha cost of control for both sampling methods). This is because the beat sheet detects only one-seventh of the larvae actually present. Inspect buds and flowers thoroughly to detect small larvae

To calculate the number of pod borers per m^2, divide the number of BPB detected in racemes by the number of racemes sampled (at least 30), and multiply by the number of racemes per m^2. No. of racemes per m^2 = racemes per row metre/row spacing in metres. Alternatively, racemes per square metre = racemes per plant x plants per row metre/row spacing (m).

7.11.4 Podsucking bug thresholds

The ET and action threshold for podsucking bugs are presented in Figure 91. The action threshold is set at 70% of the ET to ensure the critical level of damage is not accidentally exceeded. Also included are the yield thresholds for podsucking bugs. In most crops (i.e. the size range denoted by the double-ended green arrow), the quality action threshold is lower than the yield threshold, and hence is the governing threshold. However, in very large crops (> 3000 seeds/m^2) with a high mungbean value ($900/t), the yield threshold is lower than the quality threshold.

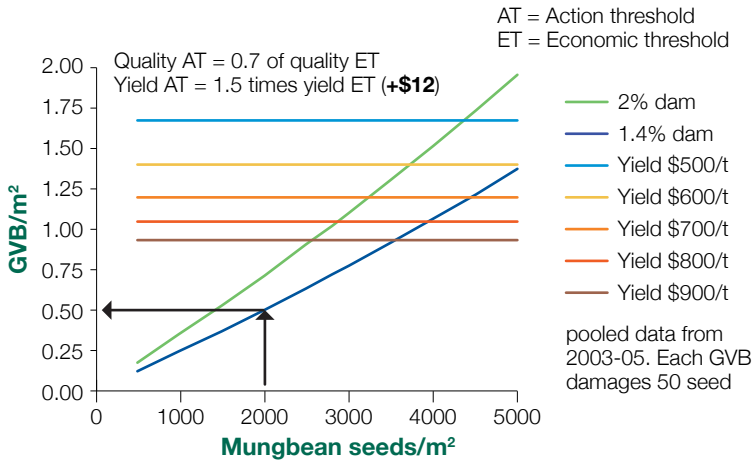


Figure 91: Economic and action thresholds for podsucking bugs in podding mungbean. Quality thresholds are based on green vegetable bug adult equivalents (GVBAEQ)/m² required to inflict 2% seed damage. This is the critical level of damage that triggers a price downgrading of ≥$100/t.

Table 9: Economic and action thresholds for podsucking bugs in podding mungbeans, based on green vegetable bug adult equivalents (GVBAEQ)

Note that action is taken at 0.7 of the critical threshold

GVBAEQ to damage N% seeds		
Crop size Seeds/m²	Critical level 2% damage	Action threshold 1.4% damage
500	0.17	0.12
1000	0.34	0.24
1500	0.52	0.36
2000	0.71	0.50
2500	0.90	0.63
3000	1.10	0.77
3500	1.30	0.91
4000	1.52	1.06

In Table 9 above and the preceding Figure, the critical threshold for a 2000 seeds/m² crop is 0.71 GVBAEQ/m². However, if the action threshold is set at 0.7 of the critical threshold, the action threshold in this 2000 seeds/m² crop is 0.5 GVBAEQ/m².

SECTION 8

Nematode control

More information

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/08/Root-lesion-nematodes-cereal-variety-and-rotational-crop-impacts-on-yield-and-nematode-populations

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Latest-nematode-summer-and-winter-crop-rotation-results

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/09/Levels-of-tolerance-and-resistance-of-summer-crops-to-rootlesion-nematodes-rotational-crop-performance-and-profits

http://journals.fcla.edu/nemamedi/article/view/63529

8.1 Background

Root-lesion nematodes (RLN; *Pratylenchus* spp.) are microscopic, worm-like animals that extract nutrients from plants, causing yield loss (Figure 1).

Pratylenchus migrate freely between roots and soil, if the soil is moist. The life cycle begins when juvenile and adult nematodes invade the new crop roots, and feed and multiply as they move through the root.

Individual eggs are laid within the root, from which juvenile nematodes hatch, grow to adults and lay eggs. There may be 3–5 cycles within the plant host each season (Figure 2). As plants and soil dry out, RLN enter a state of anhydrobiosis and can survive high soil temperatures and desiccation.

There are no set rules for the type of soil preferred by RLN. They are found throughout the northern grain region, in soil types ranging from heavy clays to sandy soils.

Intensive cropping of susceptible species, particularly wheat, will lead to an increase in RLN levels. Crop rotation with resistant crop species is the key to reducing RLN and the damage caused by this pest.

Mungbean is resistant to *P. neglectus* and susceptible to *P. thornei*. Mungbean is an excellent host crop for several types of plant parasitic nematodes. The major nematodes that affect mungbean are root-knot nematodes (*Meloidogyne* spp.) and RLN (*P. thornei*).[1]

[1] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

More information

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

https://www.grdc.com.au/~/media/B4063ED6F63C4A968B3D7601E9E3FA38.pdf

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

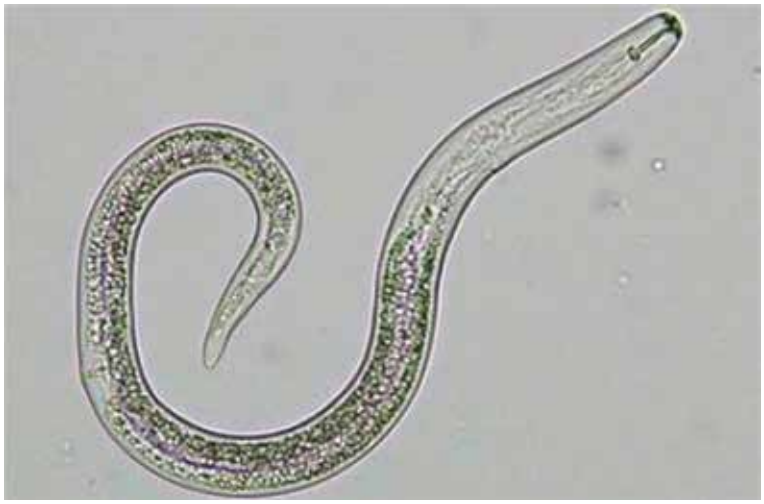


Figure 1: Microscope image of a root-lesion nematode. Notice the syringe-like 'stylet' at the head end, which is used for extracting nutrients from the plant root. This nematode is <1 mm long. (Photo: Sean Kelly, Department of Agriculture and Food, Western Australia, http://soilquality.org.au/factsheets/root-lesion-nematode-in-queensland)

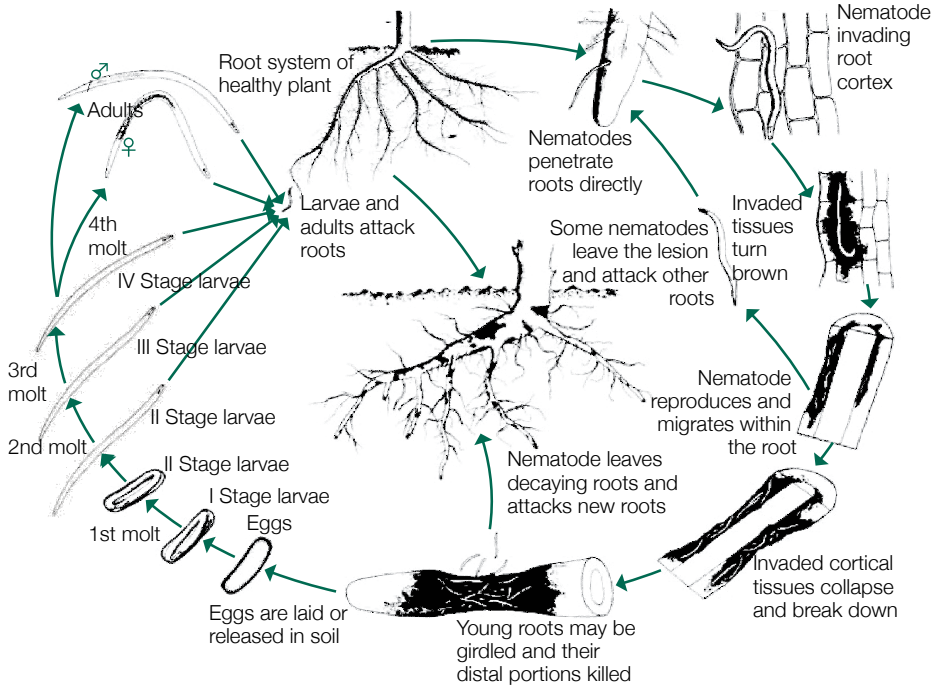


Figure 2: Life cycle of root-lesion nematode. (Source: Plant Parasitic Nematodes Fact Sheet 2009, GRDC, http://www.grdc.com.au/uploads/documents/GRDC_NematodesFS_North_4pp.pdf)

8.2 Root-knot nematodes

The impact from root-knot nematode (*Meloidogyne* spp.) can be particularly severe, and complete crop losses have been experienced in sandier soils in the Mackay area following sugarcane.

8.2.1 Symptoms

Patchy areas of poor growth and stunting may indicate the presence of root-knot

nematodes. The characteristic symptom of plants infected by root-knot nematode is the presence of root galls (Figure 3). Galls are internal swellings, variable in size, and unlike *Rhizobium* nodules, they cannot be rubbed off. Seedlings can be killed outright and survivors may be stunted and produce less grain. Additionally, grain on stunted plants is harder to harvest.

8.2.2 Biology

Root-knot nematodes have a wide host range including many weeds (such as nut grass), other pulses (although soybeans and peanuts appear to be tolerant) and horticultural crops (such as tomatoes). Nematode numbers can build up very rapidly, particularly in soils low in organic matter (such as those with high sand content).

Figure 3: Characteristic galling of roots on plants infected with root-knot nematodes.

8.2.3 Management

After a susceptible crop is harvested, nematode numbers in the soil decline quickly, and a clean (i.e. no weeds) 6-month fallow coupled with cultivation will reduce numbers significantly. Practice farm hygiene to minimise the movement of contaminated soil on machinery and other equipment, and in overland water flow.[2]

8.3 Root-lesion nematodes

Root-lesion nematodes (*P. thornei*) can reduce the yield of mungbean, and large populations will remain in the soil causing a major issue in the cropping system.

[2] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

8.3.1 Symptoms

It is extremely difficult to detect damage from RLN on mungbean; however, roots may develop small spots (up to 2 mm long) or black striping. The most reliable way to detect RLN is to have soil samples tested in a laboratory. Mungbean varieties may lose yield (intolerance) when *P. thornei* is present, because of damaged, ineffective root-systems.

8.3.2 Biology

Mungbean varieties are susceptible to infection by the RLN *P. thornei* but are resistant to *P. neglectus*. When a susceptible crop is grown, *P. thornei* will build up to high levels and populations will persist in the soil to infect other susceptible crops such as wheat and chickpeas. Resistant crops such as sorghum and sunflowers do not allow RLN reproduction, and populations of the nematodes will not increase. RLN are found a wide variety of soil types.

8.3.3 Management

Numbers of RLN do not reduce quickly in the absence of a host crop (or weeds), so growing resistant and/or tolerant crop species or non-host crops is a major part of management. Successful management relies on the identification of the RLN to species level. For example, when *P. neglectus* is present, mungbean is a suitable crop to grow because they will keep populations at low levels. The impact of cane-lesion nematodes (*Pratylenchus zeae*) on mungbean has not been investigated.[3]

8.3.4 *Pratylenchus thornei*

Although both species of RLN are of concern to grain-growers in the northern grains region, more crops and varieties are vulnerable to *P. thornei*.

Pratylenchus thornei is widespread in the northern grains region, with surveys conducted by Department of Agriculture, Fisheries and Forestry Queensland (DAFF) and New South Wales Department of Primary Industries (NSW DPI) showing *P. thornei* presence in ~50–70% of paddocks, frequently at high levels (Figure 4). More than 2,000 individuals/kg soil were found in ~20–30% of paddocks.

Yield losses in wheat of up to 50% are not uncommon when intolerant wheat varieties are grown in paddocks infested with *P. thornei*. Yield losses in chickpeas of up to 20% have also been measured in DAFF trials.[4]

[3] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[4] J Thompson, K Owen, T Clewett, J Sheedy, R Reen (2009) Management of root-lesion nematodes in the northern grain region. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/crop-diseases/root-lesion-nematode

More information

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Summer-crop-decisions-and-root-lesion-nematodes#sthash.TECof4mR.pdf

https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Managing-root-lesion-nematodes-how-important-are-crop-and-variety-choice

JP Thompson (2010) Occurrence of root-lesion nematodes (*Pratylenchus thornei* and *P. neglectus*) and stunt nematode (*Merlinius brevidens*) in the northern grain region of Australia. *Australasian Plant Pathology* 39.

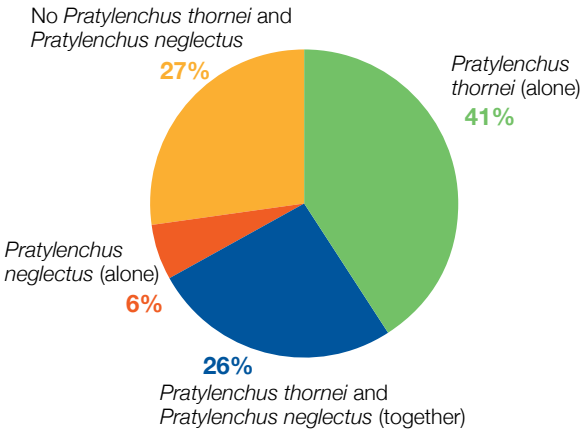


Figure 4: Results of a root-lesion nematode survey of nearly 800 farms in the northern grain region. (Source: Management of root-lesion nematodes in the northern grain region, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/crop-diseases/root-lesion-nematode*)*

8.3.5 Other nematodes in the northern grain region

The stunt nematode (*Merlinius brevidens*) is widely distributed in the northern region (found in about three-quarters of fields). It feeds on the outside of plant roots (an ectoparasite) and it is thought to be less damaging than RLN. In 2007, large populations were identified in winter cereals in northern NSW, and research is under way into the interaction of these nematodes with fungi in causing root disease.

In lighter textured soils, stubby-root nematode (*Paratrichodorus* sp.) and root-knot nematodes (*Meloidogyne* spp.) have been found on cereals and grain legumes. Other RLN species occurring away from traditional wheat areas are *P. zeae* on maize and sugarcane, and *P. brachyurus* on peanuts.

There have been isolated reports of cereal cyst nematode (*Heterodera avenae*) from near Tamworth and Dubbo in NSW, on lighter textured soils and friable clay soils. [5]

8.4 Symptoms and detection

Root-lesion nematodes are microscopic and cannot be seen with the naked eye in the soil or in plants. The most reliable way to confirm the presence of RLN is to test farm soil. Nematodes are extracted from the soil for identification and determination of their population size. Look out for tell-tale signs of nematode infection in the roots and symptoms in the plant shoots, and if seen, submit soil and root samples for nematode assessment.

Aboveground symptoms of RLN attack on all crops can include:

- poor establishment
- stunting
- yellowing of lower leaves
- poor tillering

[5] J Thompson, K Owen, T Clewett, J Sheedy, R Reen (2009) Management of root-lesion nematodes in the northern grain region. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/crop-diseases/root-lesion-nematode

Symptoms can be confused with nutrient deficiency and may be exacerbated by a lack of nutrients. Infected plants may wilt prematurely in dry periods and at the end of the season.

When roots are damaged by RLN, the plants become less efficient at taking up water and nutrients and tolerating stresses such as drought or nutrient deficiencies. Affected plants may partly recover if the rate of new root growth exceeds the rate at which RLN damage the roots. However, recovery will depend on the extent of root damage, the growing conditions, and whether sufficient fertiliser is applied.

An examination of washed plant roots may provide some information, but symptoms can be difficult to see and roots may be difficult to remove from heavy clay soils. Primary and secondary roots may show a general browning and discoloration.

The root cortex (or outer root layer) is damaged and may disintegrate. Diagnosis is best confirmed with laboratory testing of soil and/or plants for the presence and population densities of the two species. [6]

8.5 Management

No nematicides are currently registered for use in mungbean or cereal crops in the northern grain region. Nematicides offer only partial control of RLN in the northern grain region, because of poor penetration into the soil (RLN are often found deep in the soil profile). [7]

Rotations and variety choice are key to the successful reduction of RLN populations in the soil. Only non-host crops or resistant varieties will minimise the build-up of RLN. Tolerant crops will suffer less damage, but if these varieties are susceptible, RLN numbers can still increase.

Different species of RLN can be hosted on different crops; therefore, it is important to identify which species is/are present. Testing services are available around Australia and growers are advised to contact their local department of agriculture.

More information

http://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS111/Rotate-to-reduce-nematode-risk

Regular testing has shown that there are crop varieties with tolerance to *P. thornei*. It is recommended that varieties be chosen to minimise crop loss. In cases of heavy infestation with *P. thornei*, non-affected crops such as sorghum (grain and forage), cotton, millets (but not white french millet), panicum, sunflowers, lablab, pigeon peas, canary seed, durum wheat and linseed can be grown in rotation.

For *P. neglectus*, faba beans, mungbean, black gram, soybeans, cowpeas, lablab, triticale, and linseed can be grown.

[6] GRDC (2009) Root lesion nematode dominates in the north. Northern Region. Plant Parasitic Nematodes Fact Sheet, GRDC, http://www.grdc.com.au/uploads/documents/GRDC_NematodesFS_North_4pp.pdf

[7] J Thompson, K Owen, T Clewett, J Sheedy, R Reen (2009) Management of root-lesion nematodes in the northern grain region. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/crop-diseases/root-lesion-nematode

Testing for RLN

PreDicta B is a DNA-based soil analysis service that is delivered by accredited agronomists and can detect *P. neglectus*, *P. thornei* and cereal cyst nematode. Contact your local agronomist, or to locate your nearest supplier, email your contact details and location to predictab@saugov.sa.gov.au. Crown Analytical Services in Moree are the agents for the northern region (phone 0437 996 678 or email: crownanalytical@bigpond.com).

8.5.1 Resistance *versus* tolerance

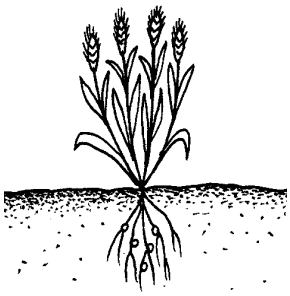
Resistance: nematode multiplication

- Resistant crops do not allow RLN to reproduce and increase in number in their roots.
- Susceptible crops allow RLN to reproduce so that their numbers increase. Moderately susceptible crops allow increases in nematode populations but at a slower rate.

Tolerance: crop response

- Tolerant varieties or crops yield well when sown in fields containing large populations of nematodes.
- Intolerant varieties or crops yield poorly when sown in fields containing large populations of nematodes (Figure 5).

Resistant and tolerant



Resistant and intolerant

Susceptible and tolerant

Susceptible and intolerant

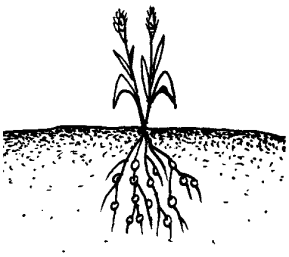


Figure 5: Variety ratings for nematodes. (Source: Southern and Western Plant Parasitic Nematodes Fact Sheet 2009, GRDC, http://www.grdc.com.au/uploads/documents/GRDC_NematodesFS_SthWst_6pp.pdf)

Variety ratings for nematodes

Varieties are rated according to their tolerance or intolerance and their susceptibility or resistance to nematodes. The mechanisms of resistance and tolerance are different and need to be treated as such.

- Intolerance means the crop yields poorly when attacked.
- Susceptibility means nematode numbers increase during the cropping season.
- Tolerance and intolerance ratings indicate the effect nematodes will have on the yield of the current crop.
- Resistance/susceptibility ratings indicate the effect the crop variety will have on reproduction of the nematodes, and hence the possible effect on the next crop via the nematode population remaining in the soil to infect the next crop.

Pictured are four combinations of ratings for nematodes. Tolerance/intolerance = the effect on the yield of the current crop, Resistance/susceptibility = the effect on building nematode numbers and the carryover to next year's crop.

Paddock hygiene

A paddock that is free of parasitic nematodes is a valuable asset. RLN appears to be spread in soil moved by surface water, vehicles and farm machinery. Good hygiene, by removing adherent soil from farm machinery, should be adopted to avoid infesting clean paddocks. Avoid contamination by ensuring that farm machinery entering the paddock is

free of soil from other paddocks. It is essential to clean machinery with a pressure hose away from uninfested paddocks.

8.6 Damage caused by pest

Numbers of RLN build up steadily under susceptible crops (Figure 6), causing a decrease in yields over several years. Yield losses >50% can occur in some wheat varieties and up to 20% in some chickpea varieties. The amount of damage caused will depend on:

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

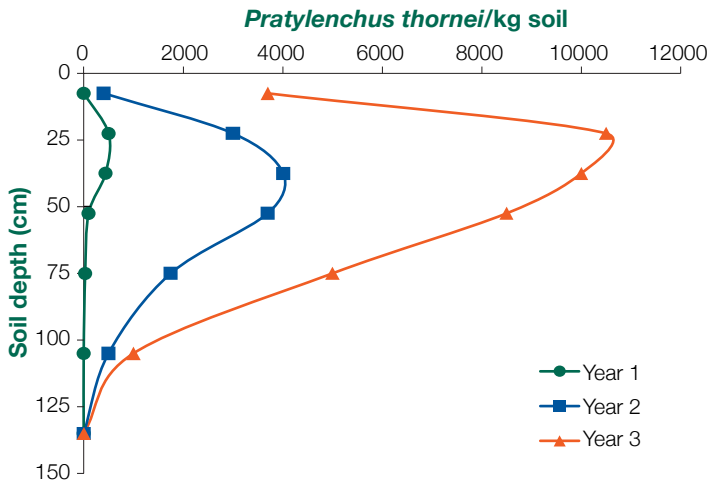


Figure 6: Numbers of root-lesion nematode (Pratylenchus thornei) during 3 years of continuous wheat at Wellcamp, Queensland. Populations increased from low levels to levels that would reduce yields of intolerant crops. The graphs show numbers in the soil sampled before sowing wheat each year. (Source: Management of root-lesion nematodes in the northern grain region, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/crop-diseases/root-lesion-nematode)

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http://www.appsnet.org/publications/Darwin_Presentations/Thursday%20Presentations_Aud/Mal%20Ryley%20[Compatibility%20Mode].pdf

http://grdc.com.au/GRDC-Report-PulseDiseaseCosts

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2008/07/HALO-BLIGHT-IN-MUNGBEAN-PATHOGEN-HOSTS-INFECTION-CROP-IMPACT-MANAGEMENT-AND-FUTURE-GENETICS-AND-BREEDING-OPTIONS

https://www.grdc.com.au/uploads/documents/2010ASGCEditedPapersPDF/Ryley_FoliarPathogens_edited_paper.pdf

SECTION 9

Diseases

Various management practices are used to reduce the impact of mungbean diseases. The aims of integrated pest management (IPM) are:

- reduction of inoculum (agronomic practices, e.g. rotations, residue management, volunteer destruction)
- exclusion of causal agent (seed source, quarantine)
- protection of host (resistance, pesticides) [1]

Some varietal resistance is available to protect mungbean crops against diseases such as tan spot, halo blight and powdery mildew (see Table 1). Several other diseases may occur in mungbean depending on conditions or inoculum levels.

9.1 Varietal disease resistance

Jade-AU(ᴅ) has the best available combined suite of resistance to powdery mildew, tan spot and halo blight.

Powdery mildew

Jade-AU(ᴅ) is moderately susceptible (MS) to powdery mildew. Although it has greater resistance than Crystal(ᴅ) and mildew is slower to develop, the disease can still be economically damaging if it occurs prior to or at flowering.

Tan spot and halo blight

Jade-AU(ᴅ) is moderately susceptible (MS) to these diseases; tan spot field resistance is slightly better than in Crystal(ᴅ) (Table 1). Both diseases are caused by bacteria, and as such, foliar fungicide sprays are of no benefit. There are no effective in-crop management options.

[1] M Ryley, J Tatnell (2010) Management of the major foliar diseases of mungbeans and peanuts in Australia. Department of Employment, Economic Development and Innovation, Queensland, http://www.appsnet.org/publications/Darwin_Presentations/Thursday%20Presentations_Aud/Mal%20Ryley%20[Compatibility%20Mode].pdf

Table 1: Disease resistance of Australian mungbean varieties (source: The National Mungbean Improvement Program)

S, Susceptible; MS, moderately susceptible; MR, moderately resistance; R, resistant. Score: 1, no disease; 9, dead

	Powdery mildew			Tan spot			Halo blight		
		Score			Score			Score	
Variety	Rating	Average	Range	Rating	Average	Range	Rating	Average	Range
Large-seeded shiny green mungbean									
Jade-AU(Þ	MS	4.1	1.7–5.3	MS	3.1	2.0–4.0	MS	5.0	4.5–5.3
Berken	VS	6.2	5.0–7.5	S	5.9	4.3–8.0	S	6.3	5.0–8.0
Crystal(Þ	S	5.3	3.3–7.0	MS	4.0	2.7–5.3	MS	4.8	4.0–5.3
Small-seeded shiny green mungbean									
Green Diamond(Þ	MS	4.5	3.0–7.5	S	5.1	3.7–6.7	S	6.9	6.0–7.7
Dull-seeded green mungbean									
Satin II(Þ	S	5.1	3.7–7.0	MS	3.9	2.7–5.0	MS	5.0	3.7–6.3

9.2 Mungbean disease summary

The major diseases and disorders affecting mungbean in New South Wales and Queensland are:

- tan spot (caused by the bacterium *Curtobacterium flaccumfaciens* pv. *flaccumfaciens*)
- halo blight (caused by the bacterium *Pseudomonas savastanoi* pv. *phaseolicola*)
- powdery mildew (caused by the fungus *Podosphaera fusca*)
- charcoal rot (caused by the fungus *Macrophomina phaseolina*)
- other diseases and disorders such as Fusarium root rot (caused by *Fusarium* sp.), puffy pod (most likely cause an abiotic factor), and gummy (or frothy) pod (suspected causal agent *Gluconobacter* spp.)
- root-lesion nematodes (RLN; *Pratylenchus thornei*)
- *Tobacco streak virus* (Central Queensland only, 2010)

Not all diseases will be seen in mungbean crops in a region every year. The distribution, incidence and severity of a mungbean disease depends on the interaction between the pathogen, the host and the environment (including weather and soil conditions, and agronomic practices), and vectors in the case of viruses. [2]

Table 2 summarises the management options for halo blight, tan spot, powdery mildew and charcoal rot. The focus should always be on integrated disease management—do not rely on one method alone. [3]

[2] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[3] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Table 2: Relative impact of different management options on important mungbean diseases

The number of ticks assigned to each management option × disease combination is an assessment of the relative impact of that management option on the specific disease

Management option	Halo blight and tan spot	Powdery mildew	Charcoal rot
Rotation	✓	×	✓✓✓
Residues	✓	×	✓
Volunteers, alternative hosts	✓✓	✓✓	✓✓
Clean seed	✓✓✓	×	×
Quarantine	✓✓	×	×
Hygiene	✓✓	×	×
Resistance, tolerance	✓✓✓✓	✓✓✓✓	×
Fungicides	×	✓✓✓	×

9.3 Key criteria and considerations in management

9.3.1 Steps in disease risk assessment

1. Identify factors that determine risk.

- Pathogen: exotic *v.* endemic; biotypes (races), pathogenicity, survival and transmission; is it amenable to chemical management?
- Host: host range; varietal reactions; vulnerability; does susceptibility change with growth stage?
- Environment: weather dependency; interactions with nutrition, herbicides, other diseases and agronomic factors (e.g. planting depth, row spacing, no-tillage, soil conditions).
- Risk management: access to components of management plan; ease of implementing plan; how many options; cost of implementation.

2. Assess risk levels of the factors.

- Pathogen: level of inoculum; pathogen-infected seed; aggressiveness of isolate; weed hosts prevalent in paddock or nearby; paddock history.
- Host: how susceptible; nutritional status; frost susceptibility; herbicide susceptibility.
- Environment: length of season; likelihood of rain, drought, waterlogging, irrigation; availability of spray gear; paddock characteristics; herbicide history.
- Risk management: not yet considered; plan being developed; plan in place?

3. What risk level is acceptable?

- High: grower is prepared to accept substantial yield loss because potential returns are high and financial situation sound; crop failure will not impact on rotation or other components of farming system.
- Low: grower needs cash flow and cannot afford to spend much or lose the crop; failure seriously affects farming system. [4]

[4] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

9.3.2 Reduction of inoculum

Paddock selection

Selection of the most appropriate paddock for growing mungbean requires consideration of previous crops, the history of diseases on mungbean, other crops and weeds in the paddock, and the herbicide history. Other legume crops such as cowpeas, navy beans and soybeans are known hosts of the important bacterial pathogens of mungbean, and crops such as sorghum, sunflowers and maize and many weeds are important hosts of charcoal rot. Sulfonylurea (Group B), triazine (Group C), or Group I (e.g. Lontrel™, a.i. clopyralid; Tordon™ 75-D, picloram + 2,4-D) herbicides applied in the last 12 months can cause direct damage or favour the development of some diseases (particularly charcoal rot) in herbicide-weakened plants. The presence of these herbicide residues in soil may cause crop damage, making in-field disease diagnosis difficult.

Control of volunteers and alternative hosts

As outlined above, many weeds and crops are hosts of some mungbean diseases, so management of these potential hosts and of mungbean volunteers is essential, through herbicides or other practices. In Central Queensland, *Parthenium* in vacant land and roadsides is the major non-crop host of *Tobacco streak virus*.

Stubble management

There is evidence that many stubble-borne diseases are increasing in importance under minimum-till or no-till practices. Consequently, there may be a role for strategic stubble management when there is a risk of high levels of inoculum carrying over to the next crop. [5]

9.3.3 Exclusion of the pathogen

Seed quality and treatment

The bacteria that cause tan spot and halo blight are highly seed-borne, and this can lead to problems of crops sown with infected seed. Growers should not keep planting seed from crops that have displayed symptoms of these bacterial diseases. Use seed in bags with the Australian Mungbean Association (AMA) logo, because this seed is sourced from crops that have been inspected and found to be practically free of the major bacterial diseases. Currently, there are no permitted or registered chemical treatments for the control of bacterial and fungal pathogens on mungbean seed.

Hygiene

Many mungbean pathogens can be spread by soil (e.g. the charcoal rot pathogen *Macrophomina phaseolina* and RLN) or infected crop residues (e.g. pathogens causing halo blight and tan spot). Contaminated machinery, vehicles, other equipment and boots can introduce pathogens onto farms and between paddocks on a farm, so they must be thoroughly cleaned before entering the farm or paddock. Where possible, overland water flow should be managed to reduce the risk from contaminated soil and residues. [6]

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[5] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[6] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

9.3.4 Protection of the host

Varietal selection

Resistance to the tan spot, halo blight and powdery mildew pathogens has been a major consideration in the mungbean breeding programs conducted initially by CSIRO and later by the Department of Agriculture, Fisheries and Forestry, Queensland (DAFF), based at Hermitage Research Station. Considerable progress has been made in the release of new varieties with improved disease resistance.

The disease reactions of individual varieties may vary from location to location and from season to season depending on the disease pressure. Weather conditions have a marked effect on both the host (e.g. stress) and the pathogen (e.g. survival, multiplication and spread).

Fungicides

The only mungbean disease that can be managed by pesticides currently is powdery mildew. No pesticides are registered for the management of either the bacterial diseases tan spot and halo blight, or seed-borne diseases. [7]

9.3.5 Regular crop monitoring

More information

https://www.grdc.com.au/uploads/documents/2010ASGCEditedPapersPDF/Ryley_FoliarPathogens_edited_paper.pdf

Regular monitoring is necessary for the early detection of powdery mildew. Pre-flowering infection by this disease can cause significant yield losses, but early application of sulfur can reduce losses. Crop monitoring should include a range of locations in the paddock, preferably following a 'V' or 'W' pattern. Inspections should occur every 7 days after the initial inspection, because mungbean crops mature very quickly.

Unfortunately, if tan spot, halo blight or other diseases are present within a crop, then little can be done to minimise their impact that season. [8]

9.4 Bacterial leaf diseases

The bacterial diseases tan spot and halo blight are two of the most important diseases of mungbean in Australia, and can lead to widespread and serious yield losses. Heavily infected crops may suffer yield reductions in the order of 25–50%, and occasional cases of total crop failure occur under severe disease pressure.

The causal bacteria of both diseases survive from season to season mainly on, or in, infected seed, but they can also carry over on weeds such as bellvine, cowvine and morning glory, and volunteer plants of mungbean and other hosts such as soybeans and navy beans. Infected crop residues (leaves and pods) can also harbour the bacteria, but survival on such residues is limited. [9]

[7] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[8] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[9] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

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

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. 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(b)).

Other hosts include cowpeas, and weeds such as cowvine and bellvine. Control of both mungbean volunteers and weeds should be a high priority. [10]

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

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 (Figure 1).

[10] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

Dark-green, water-soaked areas develop on stems and circular water-soaked spots form on pods. [11]

Seedlings

Symptoms are visible on seedlings at the 1st or 2nd trifoliate leaf stage and are usually the result of seed-borne inoculum. Infected seedlings have small, dark, water-soaked lesions surrounded by a wide yellow-green halo (usually much larger than the lesion) on the leaflets. The halo is caused by a toxin (phaseotoxin) produced by the bacterium. Seedlings infected with Psp often survive and are the major source of inoculum for later infection in the crop.

Vegetative stage

Lesions on expanding leaflets have characteristics similar to those on leaflets of infected seedlings. On older, fully expanded leaflets, the lesions are darker, with halos that are less pronounced than those on younger leaflets (Figure 2). The lesions often coalesce to form large necrotic regions (Figure 3). The surfaces of lesions on the underside of leaflets are often shiny, due to the presence of bacterial cells (Figures 4 and 5).

Podding stage

Circular, brown or red water-soaked lesions occur on pods. As the pods mature, the bacteria cells of Psp ooze from the lesions, forming a crusty drop (Figure 6). Usually, seeds directly below the lesions are internally infected, and those that come into contact with this ooze or with infected plant tissue during harvesting can be surface-contaminated. Infected seeds can be shriveled or discoloured, although many appear normal. [12]

Figure 1: Halo symptoms on young leaf.

[11] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[12] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Figure 2: Halo symptoms on older leaf.

Figure 3: Lesions on upper leaflet surface.

Figure 4: Lesions on lower surface of same leaflet.

Figure 5: Psp cells oozing from lesions on underside of leaves.

Figure 6: Psp cells oozing from lesions on pods.

Conditions favouring development

Cool (18°–23°C), wet weather favours infection, with symptoms appearing 7–10 days after infection. Wind, rain, and movement of people and machinery from infected crops spread the disease. [13]

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 soybeans and navy beans, as well as host weed species cowvine, bellvine and morning glory (Table 3). [14]

[13] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[14] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

Table 3: List of alternative hosts for halo blight and tan spot

✓✓✓, Recorded in Australia in the field; ✓✓, recorded overseas in the field; ✓, Recorded as a host after inoculation; –, not recorded as a host

Host		Disease	
Botanical name	**Common name**	**Tan spot**	**Halo blight**
Cajanus cajan	Pigeon pea	-	✓✓✓
Centrosema sp.	Centro, Butterfly pea	-	✓✓
Desmodium spp.	Desmodium	-	✓✓
Dolichos spp.		-	✓✓
Glycine max	Soybean	✓	✓✓
Ipomoea diamantinensis	Cowvine	✓	-
Ipomoea plebeia	Bellvine	✓	-
Lablab purpureus	Hyacinth bean	✓	✓✓
Macroptilium aptropurpureum	Siratro	-	✓✓
Neonotonia wightii	Glycine	-	✓✓
Phaseolus acutifolius	Tepary bean	-	✓✓
Phaseolus cocconeus	Runner bean	✓	✓
Phaseolus lunatus	Lima bean	✓	✓✓
Phaseolus vulgaris	French or navy bean	✓	✓✓✓
Pisum sativum	Pea	✓	✓✓
Pueraria lobata	Kudzu bean	✓	✓✓
Vigna angularis	Adzuki bean	✓✓✓	✓✓
Vigna mungo	Black gram	✓✓✓	✓✓✓
Vigna radiata	Mung bean	✓✓✓	✓✓✓
Vigna unguiculata	Cowpea	✓✓✓	✓✓✓

9.4.3 Biology

Survival and spread

The cells of both bacterial pathogens can survive on or in infected plant residues (leaves, pods and perhaps stems for Cff), on or in infected seeds, and on volunteer mungbeans and alternative hosts. Work in Australia and overseas suggests that these pathogens are unlikely to survive in infected stubble from one season to the next, but under some conditions, e.g. dry winters, stubble could act as source a source of inoculum.

A range of legume crops and pastures, and weeds, including *Vigna unguiculata* (cowpeas), *Vigna angularis* (adzuki beans), *Phaseolus vulgaris* (navy beans, green beans), and *Ipomoea* species are known hosts of one or both of these pathogens in Australia or overseas (Table 3).

The most important mode of survival of the tan spot and halo blight pathogens is in or on seed. For both, external seed contamination results from infected plant residues contacting seed during harvesting, whereas internal contamination results from infection of green pods. It is possible that internal infection by Cff results from systemic infection inside infected plants.

The cells of both bacterial pathogens are spread in water droplets, whether from rain or irrigation. Wind-blown droplets containing the cells can cause rapid spread within a crop.

Infection and development

The cells of Psp invade plant tissue via wounds and natural openings (e.g. leaf stomata) when free moisture occurs. The pathogen can survive and grow on the surface of plants even when there are no obvious symptoms of halo blight infection. Symptoms appear 7–10 days after infection when environmental conditions are favourable. Halo blight is generally considered a cool-temperature disease, with temperatures of 18°–23°C reported as optimal for development.

The cells of Cff enter plants through hydathodes (specialised cells around the leaflet margin that secrete water droplets) and wounds in aboveground parts. Cff is not as easily spread in rain or through contact with wet foliage as Psp, and it may infect tissues in the absence of rain. The appearance of symptoms is often rapid following hailstorms, when temperatures are >30°C, and when the crop becomes moisture-stressed. Evidence suggests that the pathogen is systemic within infected plants, that is, the bacterial cells move from the site of infection throughout the plant.

Both diseases can develop rapidly in plants under the right conditions, partly because bacterial cells undergo 'binary division', that is, a single cell divides into two then these two cells divide into two, etc. This exponential increase in cell numbers over a short period can result in millions of cells being produced from one cell over a short period. [15]

9.4.4 Management

The risk of a tan spot and/or halo blight epidemic occurring in a crop can be minimised by the management practices outlined below.

Crop rotation

Growing a non-host crop for 2 years or more will provide sufficient time for residue decomposition and help to reduce the number of volunteers present during each succeeding season. Incorporation of stubble will also assist this process. Alternative summer crops that are not hosts of the two bacterial pathogens include sorghum, maize, millets and sunflowers.

Selecting resistant varieties

Consider using a variety with some resistance to the two diseases. DAFF, NSW Department of Primary Industries and Grains Research and Development Corporation are supporting the mungbean breeding program in Australia. Varieties with higher levels of resistance to the tan spot and halo blight pathogens than the current commercial varieties are being released as they become available.

Sourcing low-risk planting seed

Diseased seed is the main cause of initial infection within the crop—only one infected seed per 10,000 is enough to initiate an epidemic under conducive weather conditions. The pathogens have been shown to survive in infected seed for more than 20 years. Avoid using planting seed from a mungbean crop that has been visibly affected with tan spot and/

[15] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

or halo blight, and avoid using planting seed of unknown disease status, i.e. a crop that has not been inspected regularly for tan spot and halo blight during the previous growing season. Seed that has been inspected as part of the AMA program has the best assurance that it is not infected; note, however, that there is no guarantee implied or given that it is absolutely free.

Control host weeds and volunteers that provide a source of disease inoculum

Weeds such as cowvine, bellvine and morning glory (all *Ipomoea* spp.), *Desmodium*, phasey beans (*Macroptilium lathyroides*) and *Centrosema*, which are hosts of one or both diseases, should be killed, preferably with a residual pre-emergent herbicide. Volunteer mungbean plants must be controlled year-round.

Hygiene

Avoid cultivation when the stand is too tall to allow machinery to pass through without wounding the foliage. People and animals can spread the pathogen and also wound plants. Do not allow contract machinery on your farm unless it has been thoroughly cleaned of mungbean residue. Do not move machinery from an infected paddock to a clean paddock without thorough cleaning.

Chemicals

There are no registered seed dressings or foliar sprays for the control of bacterial diseases of mungbean. [16]

9.5 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, first appearing in circular patches and later spreading over the surface of leaves, stems and pods (Figure 7). Late infections may cause leaf drop. [17]

On some varieties, e.g. Green Diamond(), a diffuse red-brown discoloration often develops on the leaf surface at the sites of powdery mildew colonies (Figure 8). Colonies usually turn grey as they age. [18]

[16] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[17] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[18] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Figure 7: Powdery mildew on cv. Berken.

Figure 8: Powdery mildew on cv. Green Diamond(b).

Conditions favouring development

Favoured by cool (22°–26°C), dry growing conditions. The disease is more critical if it infects plants before they flower or when crops are under moisture stress. The fungus survives on alternative hosts and it is spread by wind.

9.5.1 Biology

Survival and spread

In the northern region, *P. fusca* can survive from season to season only on a living host. It does not survive in residues or seed. Its only confirmed hosts apart from mungbean are phasey beans and several members of the Asteraceae family. Powdery mildew pathogens that infect other field and horticultural crops such as sunflowers, barley, grapes, cucurbits and tomatoes are not *P. fusca*. For some of these powdery mildews, the spores that develop in the powdery growth are capable of travelling many hundreds of kilometres in the wind; it is therefore likely that spores of *P. fusca* also can spread long distances.

Infection and development

Infection can occur at any stage of plant growth, when airborne spores land on the plant surface and germinate and the fungal strands grow across the surface. The fungus sends feeding structures (haustoria) into the cells of the epidermal layer, and chains of spores develop from the fungal strands, resulting in the white, powdery growth on infected plant

tissues. Disease development is favoured by cool (22°–26°C), dry weather and it is often more prevalent during autumn in late-planted crops. [19]

More information

https://www.grdc.com.au/uploads/documents/2010ASGCEditedPapersPDF/Ryley_FoliarPathogens_edited_paper.pdf

9.5.2 Management

Select varieties with higher levels of resistance. Several fungicides are currently registered for use as management options under permit: tebuconazole (PER13979), sulfur fungicides (PER13605) and carbendazim (PER13609). These fungicides act as protectants only, so they must be applied early in disease development to be effective. Minimise leaf burn from the sulfur by applying in the late afternoon or at night. Use with high water volumes and ensure thorough coverage. [20]

The fungus that causes powdery mildew of mungbean, *Podosphaera fusca*, was previously called *Sphaerotheca fuliginea* and is sometimes referred to in publications as *Podosphaera xanthii* or *Erysiphe polygoni*. The taxonomy of this fungus and closely related species is in a state of flux; however, *P. fusca* is thought to have a wide host range, particularly other legumes.

Yield losses of up to 40% have been demonstrated in Australia (DAFF) and overseas (Quebral and Lantican 1969; AVRDC 1984) when powdery mildew has been well established before flowering.

1. Use resistant varieties at times of medium to high risk. If planting at times of high risk, particularly in late summer, use varieties with the highest levels of resistance to powdery mildew.
2. Use fungicides if powdery mildew is present before flowering. Large yield responses (up to 30%) are achievable from the timely and correct application of fungicide, even under low-yielding, water-limited conditions.

The level of yield loss experienced in a crop is influenced by:

- resistance of the variety
- stage of plant development when powdery mildew appears
- effectiveness of fungicide application

Evidence from trials suggests that yield losses can be expected when the disease is established before flowering.

Critical factors in achieving a profitable response to sulfur and carbendazim sprays include:

- In pre-flowering crops, sulfur and carbendazim should be applied at the first sign of disease on the lower leaves.
- A repeat application of sulfur 10–14 days after the first spray can provide extended control and a further increase in yield.
- Application of sulfur after flowering is unlikely to result in a significant yield increase.

[19] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[20] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

- Sulfur and carbendazim act as a protectant barrier over the surface of the plant, so good application techniques and spray coverage are critical.
- Minimise leaf burn from sulfur by applying the fungicide in the late afternoon or at night.

Tank-mixing sulfur with any product that contains xylene as a solvent should be avoided; xylene can react with the sulfur causing heat and flocculation of the sulfur, blocking nozzles and filters. [21]

9.6 Charcoal rot (*Macrophomina phaseolina*)

Charcoal rot is a fungal disease of great concern because 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 (Figure 9), 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. [22]

Small, black microsclerotia in the affected tissue give the tissue a charcoal appearance. Seeds from charcoal rot-affected crops are often pinched and smaller than normal. [23]

Figure 9: Ash-grey coloured stem of plant infected with charcoal rot.

Conditions favouring development

Charcoal rot appears to be very seasonally dependent; however, there is limited information on the conditions favouring its development.

[21] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[22] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[23] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

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 podfill.

9.6.1 Biology

Survival and spread

The fungus has a very large host range, including most summer crops (particularly sorghum, maize and sunflowers) and many weeds, and can survive in infected residues and in the soil for many years as small, dark, fungal bodies (microsclerotia) (Figure 10). The pathogen can survive in the roots of symptomless weeds. *Macrophomina phaseolina* is likely to be in most soils at varying levels, depending on cropping history and other factors, but can be spread in soil and infested residues. [24]

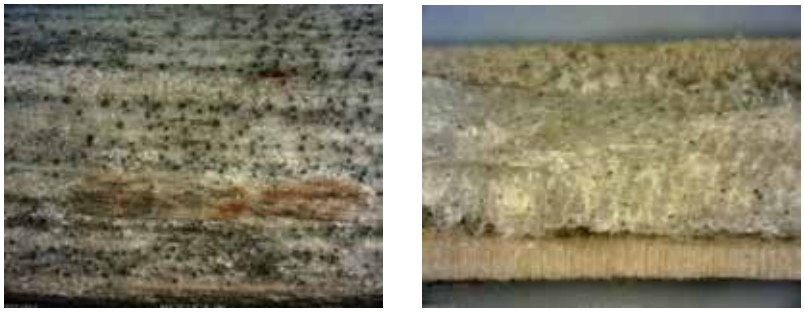

Figure 10: Microsclerotia of M. phaseolina. Left: on exterior of stem; right: in interior of stem.

Infection and development

Modes of infection of stems and seeds appear to be different. Stem infection results when microsclerotia in the soil are stimulated to germinate by exudates from roots of young mungbean plants. The fungus remains dormant in the roots until a combination of flowering and heat and/or moisture stress induces rapid colonisation of the roots and lower stem. This rapid invasion, together with the release of toxins by the fungus, causes rapid, premature death. On the other hand, infection of seeds results from microsclerotia in soil peds that are splashed onto developing pods during rain. Often, there are no external signs on charcoal-rot-infected seeds.

The pathogen can also produce flask-shaped fruiting bodies (pycnidia) on infected stems, but the infection role of the spores produced in these fruiting bodies is unknown. [25]

9.6.2 Management

Charcoal rot is seed-borne. It has a wide host range and can remain in the soil for many years. Rotation seems to affect the likelihood of infection with the disease, particularly prevalent following sorghum and cotton. Avoid paddocks where charcoal rot has been a problem within the past 4–5 years.

[24] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[25] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Movement of soil and plant debris can spread the fungus; therefore, hygiene is important.

Planting into good soil moisture and maintaining good growing conditions can help to minimise the level of occurrence. [26]

Charcoal rot is very common in mungbean, but little can be done to minimise the impact of this disease in the field. In mungbean, the major financial effect of charcoal rot is on sprouting-quality seed, where detection of the pathogen leads to downgrading of the quality of the seed line, and its rejection as Sprouting grade seed. One infected seed in a batch of sprouting seed is enough cause the spoilage, because the high temperatures generated during the sprouting process are ideal for growth of the fungus. [27]

There are few options for the management of charcoal rot in mungbean. No sources of resistance to root and stem infection or to seed infection have been identified. Fungicides are not a cost-effective option for controlling seed-borne infection, because one infected seed alone can contaminate a batch of sprouts.

Rotation with non-host crops is generally not effective, due the longevity of the microsclerotia and the wide host range of the pathogen. The following management options may reduce charcoal rot levels:

- Avoid paddocks where charcoal rot has been a problem within the past 4–5 years.
- There is evidence in other crops that levels of charcoal rot infection can increase under minimal-till or no-till because the microsclerotia can survive longer in infected residues than in the soil. Strategic cultivation may reduce the levels of *M. phaseolina* in the soil.
- Many summer and winter weeds are hosts of the charcoal rot pathogen; therefore, their management can reduce the carryover of the pathogen from one season to the next.
- If crops that appear to be suitable for a sprouting market are desiccated, harvest as soon as possible following application of the desiccant. Because *M. phaseolina* is a rapid coloniser of dying plant tissue, delayed harvesting following desiccation can lead to an increased risk of infected seed. [28]

9.7 Pod disorders

9.7.1 Puffy pod

Symptoms

The pods appear enlarged (puffy), often blotchy and soft (Figure 11). Pods are swollen, soft and slow to mature and may have black blotches on the surface (Figure 12). Affected pods do not produce mature seeds; more commonly, they become infected by secondary rots (Figure 13). Growing points are often stunted and no flowers are produced from the deformed buds.

[26] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[27] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[28] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Conditions favouring development

Puffy pod occurs intermittently, and despite extensive research, the cause of the disorder remains unknown. Biotic agents such as pathogenic fungi, bacteria, viruses and phytoplasma have been discounted, and so the cause appears to be abiotic, perhaps stress-related.

Management

The affected pods are amongst the last to develop, usually on the second or subsequent flower flushes. Healthy and affected pods can appear on the same raceme, but once affected, all flowers and pods on a raceme are also afflicted with the disorder. [29]

If the level of puffy pod in a crop is significant, do not wait for affected pods to mature. Desiccate with a herbicide, and ensure a suitable drum speed and airflow to eject unthreshed puffy pods out behind the header. [30]

Figure 11: Puffy pod disorder. Normal pod (left) v. puffy pod.

Figure 12: Puffy pod. Black blotches on affected pods.

[29] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[30] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

Figure 13: Seeds in puffy pods are red-brown, dull green or dark green, and when mixed with normal seeds reduce the visual appearance of the sample, resulting in significant downgrading.

9.7.2 Gummy pod (*Gluconobacter* spp.)

Gummy pod (also called frothy pod) occurs because of a bacterial infection that is a secondary process following an over-production of sugar by the flower nectaries in the plant. A species of the bacterium *Gluconobacter*, which is a natural inhabitant of the flowers and extra-floral nectaries, has been identified as the cause of disorder.[31]

Symptoms

Symptoms appear as pods, stems and pod stalks coated with a sticky foam and gum (Figure 14). The sticky, white froth oozes from the flowers and from nectaries near the point of attachment of the pods with the stalks (extra-floral nectaries), ultimately causing a soft, wet rot of the flowers, stalks and stems. In extreme cases, this may lead to stems collapsing and pods dropping.

Conditions favouring development

Excess heat and/or moisture stress appears to trigger this condition, which is often found in crops but is of little consequence until ideal conditions prevail. Uneven flowering as a result of insect damage 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 by rapidly drying the affected plant parts.[32]

[31] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[32] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

Figure 14: Gummy (frothy) pod symptoms on mungbean.

9.8 Minor diseases and disorders

Several other fungal, bacterial, viral and phytoplasma diseases affect mungbeans in Australia. The effects of these are generally minor. Details of other mungbean diseases and disorders are included in the Topcrop publication 'Mungbean and soybean disorders: The ute guide'. [33]

9.8.1 Legume little leaf/witches' broom/big bud

This disease is caused by a phytoplasma (extremely small bacteria), with infection resulting in the production of multiple short shoots bearing small, distorted leaves (Figure 15).

Symptoms

Infected plants appear to have small, cupped leaves; they are ill-thrifty and very erect. The flowers appear distorted with green petals and often pods are not produced or are empty. If pods develop they are usually shorter, small and thin and curved upwards, and seeds fail to develop or turn brown.

Conditions favouring development

The phytoplasma is spread by leafhoppers. The incidence of infected plants is usually extremely low, but if weather and other conditions have favoured high vector numbers, patches of infected plants may be evident. Dry seasons often promote migration of leafhoppers into crops.

The phytoplasma can survive in weeds, so infected plants are commonly found near the edges of paddocks.

Management

No control measures are warranted. [34] Occurrence is usually minor, but monitoring of leafhopper numbers is recommended. [35]

[33] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[34] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[35] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

Figure 15: Distorted leaves and pods due to phytoplasma.

9.9 Fusarium wilt and base rot

Fusarium wilt occurs in low-lying areas of paddocks that have been waterlogged or experienced prolonged periods of high soil moisture (Figure 16).

Affected plants are wilted and they die prematurely (Figure 17). There is usually a black lesion at the stem base, and the roots are rotted (Figure 18). The internal tissues in the affected stem bases turn dark brown (Figure 19). Although the species *Fusarium oxysporum* has been isolated from infected plants, its biology is unknown. Paddocks prone to waterlogging should be avoided. [36]

Figure 16: Fusarium wilt affected patch.

[36] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Figure 17: Plant affected by Fusarium wilt.

Figure 18: Suspected Fusarium root rot basal stem lesion.

Figure 19: Internal discoloration.

9.10 Sunburn

Only the underside of the leaves is affected by sunburn (Figure 20). There is a light-brown–gold discoloration of the veins and interveinal tissue, which is not obvious on the corresponding upper surface. It is unlikely that any yield loss results from sunburn.[37]

Figure 20: Sunburn on underside of leaflet.

9.11 *Tobacco streak virus* (TSV)

In 2006, TSV was identified as the cause of a severe dieback in sunflower crops in the Central Highlands region of Queensland, and since then has been found in mungbean crops in that region.

To date, the disease caused by TSV is restricted to susceptible crops in the Central Highlands and has not been found outside this region.

9.11.1 Symptoms

Infected mungbean plants are usually stunted and wilted, with dead (necrotic) stems and tips (Figures 21 and 22). Yellowing of leaves followed by spreading necrosis is common,

[37] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

sometimes with necrotic line patterns. Plants that are infected early have the worst symptoms and often die prematurely.

The major weed hosts of TSV show no symptoms.[38]

Figure 21: TSV-infected mungbean plants. Left: stem necrosis; right: leaf necrosis.

Figure 22: TSV-infected mungbean plants. Left: pod necrosis; right: terminal necrosis.

9.11.2 Survival and spread

TSV can survive only in living host plants and in the seed of some of its hosts. TSV has a wide host range, which includes about 20 weed species and several crop species in the Central Highlands region. Crop hosts include sunflowers, mungbean, soybeans, cotton and chickpeas (rare), and the major weed hosts are *Parthenium* (Figure 23) and crownbeard.

Research to date indicates that although TSV can be transmitted at high rates in seed of *Parthenium*, it is not seed-borne in mungbean or sunflowers.

The virus is transmitted in infected pollen (particularly that of *Parthenium*, which produces copious amounts of pollen), which is moved by wind or thrips (e.g. tomato and onion thrips). Long-distance spread can occur if machinery contaminated with infected *Parthenium* seed is moved from Central Queensland to other cropping areas.[39]

[38] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[39] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Figure 23: Flowering Parthenium weed is the major weed host of TSV but shows no symptoms.
Figure 24:

9.11.3 Infection and development

Infection of plants occurs when TSV-infected pollen enters the wounds made by feeding thrips. Virus particles in the pollen are released into the plant, where they rapidly multiply and travel throughout the plant.

TSV disease is favoured by climatic conditions that enable large populations of thrips to develop and large amounts of infective pollen to be produced by host plants such as *Parthenium*. These conditions generally occur during warmer, wetter months and they are highly dependent on rainfall and weed growth patterns.

The life cycle of thrips is shorter during summer, which results in large populations, and weed numbers can increase rapidly follow intermittent rain. If large populations of thrips are present at the same time as large numbers of flowering weed hosts (e.g. *Parthenium*), the combined effect can be high TSV transmission rates and a high threat to susceptible crops Figure 24). [40]

[40] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

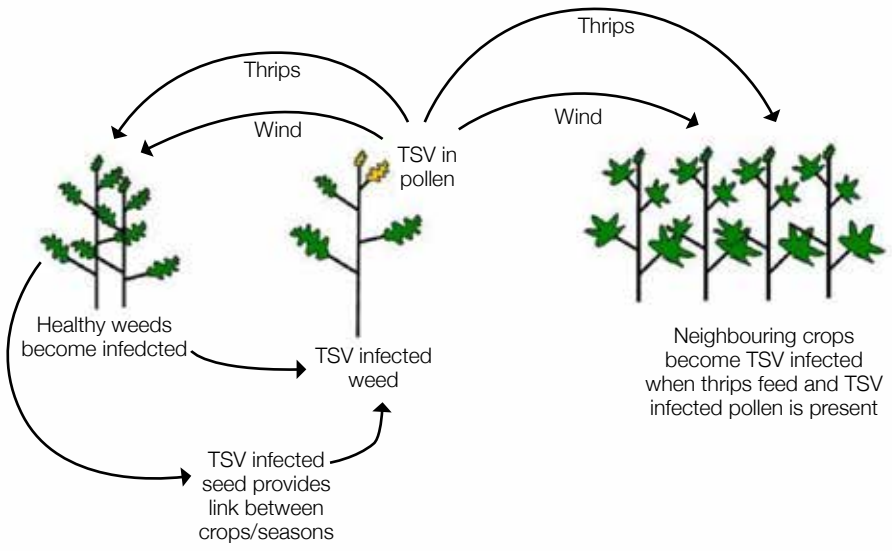

Figure 25: Disease cycle of TSV. Transmission into mungbeans occurs only when thrips and TSV-infected pollen are present.

9.11.4 Management

Paddock selection

Identify and avoid high-risk paddocks that have a history of TSV, or are next to areas with high populations of *Parthenium* or other weed hosts. Planting upwind of high-risk areas may help reduce the level of TSV transmission into the crop.

Some evidence suggests that mungbean crops planted into marginal soil moisture are more susceptible to severe TSV symptoms.

Hygiene

Ensure that machinery (particularly harvesters) that has been in TSV-infected crops of mungbean or other hosts is thoroughly cleaned of *Parthenium* seed and trash before it is moved to other paddocks, farms or regions.

Parthenium and other weed hosts in or near the crop should be controlled with a herbicide or other method as soon as they are found. Volunteer plants of mungbean and other known host plants of TSV should also be controlled.

Resistance/tolerance

Although different levels of tolerance to TSV have been identified in sunflower hybrids, all current mungbean varieties appear to be highly susceptible.

Thrips management

It is unlikely that in-crop thrips management using insecticides will provide effective control of TSV transmission, because thrips can enter the crop soon after spraying. In addition, insecticide applications may disrupt IPM strategies. [41]

[41] M Ryley, G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

December 2014

SECTION 10

Plant growth regulators and canopy management

Not applicable for this crop.

SECTION 11

Desiccation

Mungbean has an indeterminate flowering habit. This means that it does not have a defined flowering period and, consequently, can have flowers, green pods and black pods present on the plant at the same time. This growth habit makes the harvesting decision very difficult.

The ideal stage is when a majority of pods are physiologically mature, and 90% of the pods have turned either yellow or black. At this point, the crop has reached maximum maturity and it is at optimum yield and quality. The crop should be considered ready for either desiccant application, or direct harvest.

Desiccation is the process whereby a chemical defoliant is applied to the crop to increase yield and quality. The effect of the desiccant is to defoliate green leaf from the plant and dry the tips of the stem (flowering terminals). This minimises problems associated with green leaf or stem interfering with the threshing action, and/or staining the beans.

When desiccating mungbean, it is important to use a robust rate of desiccant and to allow sufficient time for the crop to dry down before commencing harvest. [1]

The following factors should also be taken into account.

More information

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/09/Effective-Desiccation-of-Mungbean-Vigna-radiata

11.11.1 Yield potential and plant vigour

Large, well-grown crops that are healthy at harvest time should normally be desiccated. Large, healthy crops require a higher rate of glyphosate than is normally the case.

Low-yielding crops are often small in stature and they have relatively small amounts of leaf and stem. In these situations, it may not be economical to use a desiccant.

11.11.2 Variety

Jade-AU(b) and Crystal(b) are much more likely to require a desiccant because they have the ability to remain green and healthy, even when there is a dry finish to the season.

11.11.3 Water quality and pH

Poorer results may occur with water containing suspended clay or organic matter (e.g. from dams, streams and irrigation channels) or which has high levels of calcium, magnesium or bicarbonate ions.

Water pH should be neutral to slightly acid.

[1] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

11.11.4 Spray application

Use a nozzle and pressure range to generate a medium spray quality with sufficient total water volume to ensure good canopy penetration and coverage. It is recommended to use 80 – 100L when applied by ground rig.

Check the label at APVMA.

11.11.5 Timing of harvest after desiccation

Rate of dry-down of the crop and timing of harvest will depend on:

- choice of desiccant
- rate used
- temperature conditions

Many growers harvest too soon after desiccation. The following recommendations are provided as a guide only (Table 1).

Table 1: Time to maximum desiccation

Product	Rate (L/ha)	Time to max. desiccation	Withholding period
Reglone® (diquat)	2.0–3.0	5–6 days	0 days
Glyphosate	Various	7–12 days	7 days

More information

www.apvma.gov.au

11.11.6 Weather

If rainfall is likely around harvest time, diquat will generally enable the harvesting operations to be commenced sooner than glyphosate. Regrowth can occur as early as 10 days after spraying with diquat.

11.11.7 Uneven application of desiccants

Care during application should be taken to avoid striping during aerial application of both Reglone and glyphosate. While it does minimise gumming problems in the header, seed staining is still a significant problem and negates the main reason for using a desiccant.

Caution is required when using ground rigs in broadacre (solid) plantings of mungbean because of the risk of shattering losses. Studies in Central Queensland have recorded grain losses of ~100 kg/ha in such situations.

11.11.8 Misconceptions

Some misconceptions exist around the following issues as they relate to desiccation:

1. Pod dry-down. Desiccation with either treatment does not cause pods to dry down. At the 90% yellow–black stage, the seed moisture content will already be in the range 7–13%, and below the accepted receival standards.
2. Sample quality. Desiccation will not reduce the quality of the sample, provided it is done on time. Research has shown that desiccation improves both quality and yield.
3. Timing of harvest. Harvest often commences too soon after desiccation. Maximum dry-down of leaf moisture can take as long as 5–6 days with Reglone® and 7–17 days with glyphosate.[2]

[2] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

SECTION 12

Harvest

Well before harvest, marketing plans need to have been developed and practices put in place to ensure that a quality product is grown, harvested, delivered, stored and then marketed (Figure 1). [1]

Figure 1: Mungbean pods. (Photo: GRDC)

More information

http://www.mungbean.org.au/pdf/Desiccation%20of%20Mungbeans%20-%20as%20an%20Aid%20to%20Harvest.pdf

12.1 Staining of seed coat

'Sap' from the mungbean plant can form a film over the seeds during harvest. This sticky coating on the seed then attracts dust, which is unavoidable during the harvest operation. The net effect is the loss of the glossy lustre of the mungbean sample.

This staining of the seed coat is regarded as the single most important issue affecting mungbean quality and net returns to growers (with potential losses of $100–300/t).

Lower quality beans are also more difficult and slower to market overseas.

Plant sap also combines with dirt and dust to form a build-up of gum, and can cause blockages inside the header. Growers understand the problems this causes at harvest, but may not appreciate the major impact it also has on bean quality and, ultimately, the overall level of mungbean profitability.

[1] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

To minimise the level of seed staining, desiccation must be carried out as effectively as possible (see GrowNotes Mungbean Section 11. Desiccation).

Other management practices also affect the level of seed staining.[2]

12.1.1 Harvesting non-desiccated crops

The decision not to use a desiccant is warranted only in situations where the crop has dried down naturally because of terminal drought stress.

The variety Satin II(b) will often dry down evenly, and is less prone to staining damage because of its naturally dull seed coat.

12.1.2 Header set-up

Header set-up to avoid over-threshing is very important even in desiccated crops. This will minimise the impact of any residual moisture within the leaves and stems on seed staining.

Plants should come off the back of the straw-walkers largely intact with minimal crushing of the stems. Examination of the plant material on the walkers is the best guide of whether the crop is being over-threshed.

To assess how effective these strategies have been in minimising seed staining, compare a hand-threshed sample with a sample taken from the header box. Always assess gloss, or lustre, in full daylight against a white background.[3]

The preferred moisture content for delivery to the packing sheds is in the range 12–14%. Maximum moisture for beans held in storage is 12%.

A high proportion of high-moisture beans (~14%) in the sample can lead to browning and discoloration of those beans when held in storage or during shipment to export destinations. This browning of the seed coat usually occurs after delivery to the packing shed, normally a month or more after harvest.

Classification of deliveries may be delayed on suspect lines with a significant proportion of high-moisture beans in the sample. These suspect lines may be put into short-term storage until the extent of the problem is evident.[4]

12.2 Modifications and harvest aids

Early harvesting can solve many problems associated with losses, because the pods are less prone to shattering and dropping. The crop is also easier to gather because it stands more erect, allowing the harvester front to operate at a greater height, reducing the soil, rock and sticks entering the harvester.

[2] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[3] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[4] DAFF (2012) Nutrition, irrigation and harvesting. Department of Agriculture, Fisheries and Forestry Queensland, https://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/mungbeans/nutrition,-irrigation-and-harvesting

Early harvesting also means fewer summer weeds to clog the harvester. Early harvesting also plays a role in disease control and crop establishment in the following crop. Early-harvested grain is of better quality in terms of colour, weathering and disease status.

A straw chopper may be of value to chop the stubble and spread it uniformly. Crop lifters are not usually required unless the crop is badly lodged. Set the finger-tine reel to force the mungbean material down onto the front. Moving the broad-elevator auger forward can improve the feeding of light mungbean material.

Vibration due to cutter-bar action, plant-on-plant and reel-on-crop impact, and poor removal of cut material by the auger can cause shattering and grain loss.

Grain loss can be reduced by harvesting in high humidity and/or at night if necessary, to minimise pod shattering. Avoid reaping in extreme heat.

Finger reels are less aggressive than bat reels and cause fewer pod losses.

Double-acting cutter bars reduce cutter-bar vibration losses. Four-finger guards with open second fingers also reduce vibrations.

A lupin breaker is a cheap and simple device that can increase harvesting capacity to reduce grain loss. A small, serrated plate attaches to the front spiral and creates an aggressive, positive feed action to clear the cut material from the front of the knife.

Other options are available to improve pulse harvesting as follows. Cost–benefit should be assessed for products. A small area of pulses may not justify the cost of some of these modifications. [5]

12.2.1 Aussie-Air

Aussie-Air directs a blast of air through the reel fingers, and is suitable for both heavy and light crops.

The manufacturer claims an extra 15 hp (~11 kW) is required to drive an Aussie-Air but there is also less power requirement because of wider concave clearances. The actual power requirement should be no more than for a heavy cereal crop.

12.2.2 Harvestaire

This device replaces the reel with a manifold that directs a blast of air into the front.

The manifold causes some interference with the incoming crop. Correct orientation of the air blast is very important. An optional secondary fan to increase the air blast can be worthwhile. The extra device is more effective in light crops.

12.2.3 Vibra-mat

This vinyl mat vibrates with the knife, stops bunching at the knife of open-front headers and

[5] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

helps the table auger to clear the cut materials (Figure 2); its chief advantage is that it is very cheap. It is more effective in light crops.

It is important to match groundspeed to table-auger capacity and crop density; too slow and the plants will not have enough momentum to carry to the front, too fast and the cut crop will not be cleared from behind the knife.

12.2.4 Extension fingers

Plastic extension fingers (~30 cm long), which fit over existing fingers, can save significant losses at the knife, for little financial outlay. Pods that would have fallen in front of the knife are caught on the fingers and pushed into the comb by the incoming crop (Figure 3).

12.2.5 Extended fronts

Extended fronts are now available for some headers and reduce losses at the knife by increasing the distance between the knife and auger to a maximum of 760 mm. This helps to stop losses from material bunching in front of the auger, where pods can fall over the knife and be lost.

12.2.6 Platform sweeps

Platform sweeps are used in conjunction with extended fronts. They consist of fingers that rake material towards the auger to help eliminate bunching. They can also be used on conventional fronts.

12.2.7 Draper fronts

Draper fronts such as MacDon® and Honeybee® have large clearances behind the knife and carry the crop to the elevator. The front can also be used for cereals without modification.

Figure 2: Harvestaire front combined with extension fingers and a blue vibra-mat. (Photo: G. Cumming, Pulse Australia)

Figure 3: Plastic extension fingers fitted to a Draper front. (Photo: G. Cumming, Pulse Australia)

12.3 Grain losses at harvest

Harvest losses in commercial mungbean crops can often exceed 30%, and this is one of the key management issues affecting the overall profitability of a mungbean crop.

Header losses average 34% across all of the 23 commercial spring-planted mungbean crops monitored through the APSRU-TOPCROP project in 1998, and in one individual case were in excess of 50%. These estimates closely agree with previous header evaluations conducted in Central Queensland during the 1985–87 seasons, where harvest losses averaged 30% of harvestable yield losses of (losses of ~230 kg/ha) (Table 1).

Table 1: Mungbean harvest losses (Central Queensland) (kg/ha)

Crop	Yield	Total loss	Front loss	Uncut los	Windrow
Spring 1985	775	174	120	30	23
Summer 1986	900	251	200	33	23
Spring 1986	890	282	179	70	39
Summer 1987	850	290	189	101	-

Of the overall losses, 88% occurred as either:

- front losses comprising detached pods or shattered pods, due to the shaking motion as plants are being cut (67%); or
- uncut losses comprising lodged or uncut pods remaining attached to the stubble (21%).

Header fronts need to be set and maintained at a height below 25% of total crop height to minimise stubble losses in mungbeans.

Most header operators were not aware of the magnitude of the losses. Virtually all of these harvest losses occur at the front of the header, mostly as whole pods. During cutting, plant stems are deflected laterally due to the knife's sideways motion, and forwards due to the cutter bar's forward movement.

These deflections are transmitted to upper branches and pods, and the vibration is often sufficient to dislodge pods and throw them in front of the cutter bar. Under dry conditions, seed can also be lost through shattering of pods.

These losses can be substantially reduced by using:

- double-cut knife guards
- extension fingers
- reduced ground speeds of 6–7 km/h
- air fronts
- vibra-mat

There is a dramatic increase in front losses once crops reach the critical 90% black pod stage (Figure 4). Crops under terminal drought stress can dry down rapidly in summer, with crops progressing from 60% to 90% black pod in as little as 4 days in extreme cases.

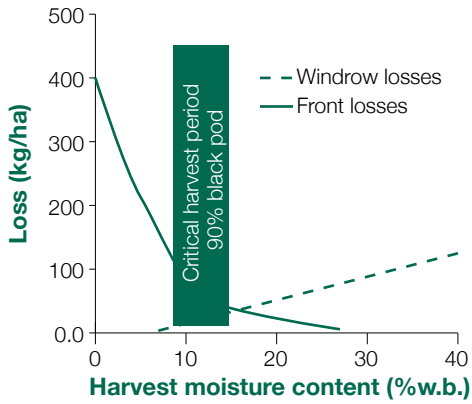

Figure 4: Impact of moisture at harvest on losses.

Both studies highlight the need for careful planning in terms of:

- in-crop management that promotes even maturity
- timing of harvest operations
- header set-up and operation

12.3.1 Harvest loss assessment

An estimate of losses occurring at the header front can be calculated on the basis of: 2 seeds/m^2 = 1 kg/ha. This is for large-seeded types (Crystal(), Berken, Emerald(), Satin II()) with 15,000–20,000 seeds/kg (Table 2).

Table 2: Header front losses

	Losses at header front (kg/ha)	
Average seeds/0.1m^2	Large seed varieties (Berken, Delta, Emerald, White Gold)	Small seed varieties (Green Diamond, Celera)
5	25	18
10	50	36
15	75	54
20	100	72
25	125	90
30	150	108

12.3.2 Assessing grain-harvest losses

Grain can be lost from several places during harvest and each loss needs to be assessed so that corrective action can be taken. Grain can be lost before harvest (due to pod shedding; 'A' in Figure 5), at the harvester front (due to the front type or setup; 'B'), and in the thrashing system of the machine (due to drum, concave and sieve settings; 'C').

To determine harvest losses:

- Harvest a typical area without stopping the machine, then stop and allow the machine to clear itself of material.
- Back the harvester about 10m and shut down the machine.
- Sample grain losses in each of the following three areas:
- pre-harvest (that is in the standing crop in front of the harvester, 'A'),
- front (in the cut crop in front of the harvester, 'B'), and
- machine (in the cut crop behind the harvester including trash, 'C').
- Sampling is best done using a quadrat with an area of 0.1 m^2.
- Count the number of seeds lying within each of 10 quadrats in each of the three locations.
- Average the 10 samples in each area.[6]

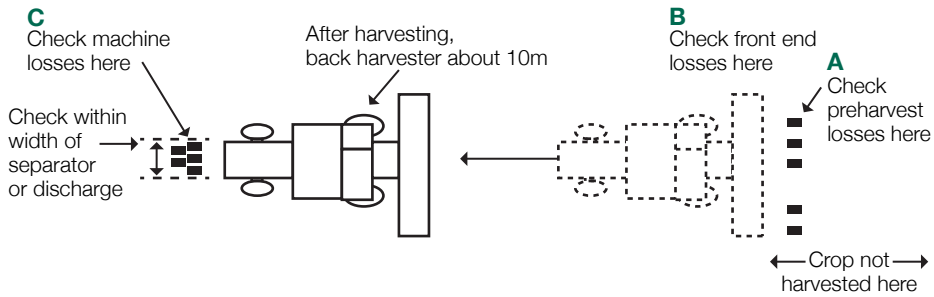

Figure 5: Sampling places for estimating pre-harvest (A), front (B) and machine (C) losses.

12.4 Mechanical damage—cracked grain

A common practice, particularly among new growers, is to delay harvest until the plants begin to die off and all pods are mature. Although this strategy would appear to maximise yields and simplifies the harvest operation, any benefits from delaying the harvest are usually well and trul offset by:

- the risk of weather damage
- cracking over-dry grain
- grain losses from shattering during harvest

12.4.1 Cracking and mechanical damage

Mungbean seed is easily damaged during harvest, with the risk of damage increasing significantly as the seed dries out. Two types of mechanical damage can occur to the beans.

[6] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Split or badly chipped grains

These cracked grains represent 5–20% of the harvested crop, and are readily apparent in the sample. They can usually be removed during cleaning and grading, where they are segregated and sold as stockfeed at a fraction of the price received for processing beans.

The following estimates have been provided by the grading sheds as a guide to acceptable levels of cracked grain:

- below 6%, good
- 6–8%, average
- >10%, serious problem

Rotary headers produced 30% less splits than conventional headers in a Department of Agriculture, Fisheries and Forestry Queensland survey of commercial mungbean crops in Central Queensland. The experience of harvest contractors and farmers tends to support this.

Some of the more experienced operators of rotary headers have the level of cracked grain down to ~1–2% of yield. This usually involves some slight modification to existing equipment, for example, use of worn, unplated rasp bars on the rotor. Chrome-plated rasp bars in particular should be avoided because they develop a sharp edge and are particularly abrasive.

Hairline cracks in the seed coat

These are not easy to detect visually, but can result in an unacceptably high level of oversoaks (grain that imbibes after submerging in water at 32°C for 1 h) and downgrading in quality from sprouting to processing grades, i.e. a $200–$300/t drop in price.

This type of damage cannot be graded out of the sample, and in many instances is just as serious as cracked grain.[7]

12.5 Estimating yield in mungbeans

An estimate of yield can be obtained, based on a count of:

- plants per m^2
- number of pods per plant (Table 3)

Only count mature, black or yellow pods if the crop is ready to harvest. Disregard green pods, or pods stunted by insect damage.

The calculation assumes an average of 10 seeds per pod (which is consistent, at 10 or 11 seeds per pod); seed weight varies from variety to variety. This estimate can be adjusted up or down by 20% based on seed size; for small seed reduce the estimate by 20%, and for large seed increase the yield by 20%.

[7] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Table 3: Impact of number of pods per plant on yield

Population plants per square metre	Pods per plant			
	5	10	15	20
10	250	500	750	1000
15	375	750	1125	1500
20	500	1000	1500	2000
25	625	1250	1875	2500
30	750	1500	2250	3000

12.6 Grain moisture

The ideal grain moisture level for delivery to the grading plants is 13%. Samples >14% can either be rejected, or accepted at the owners risk and put into aerators.

Handling the grain during the cleaning and grading process will further assist in the drying process, and should ideally be carried out before the sample drops to <12% moisture. Over-dry beans (<12%) are very easily damaged by cracking and chipping.

The maximum moisture content for the long-term storage of the finished graded product is 12%.

The accepted industry standard for the calibration of the Marconi moisture metre is presented in Table 4.

This is a scale developed specifically for mungbean by Agritech Services (Toowoomba), using the following protocol:

- Finely grind on a hand grinder.
- Use air temperature at the testing location, and not the grain temperature.
- Do at least 3 or 4 samples to arrive at a representative figure.
- As a guide, samples under 19 on the black should be around the ideal moisture content for harvesting.

Use of the standard wheat scale will give a low reading, usually 0.5–1% lower than the actual moisture content. [8]

[8] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Table 4: Marconi moisture meter calibration for mungbean moisture percentage

	Air temperature °C			
Dial reading	20	25	30	35
0	11.1	10.6	10.1	9.6
1	11.2	10.7	10.2	9.7
2	11.3	10.8	10.3	9.8
3	11.4	10.9	10.4	9.9
4	11.5	11.0	10.5	10.0
5	11.6	11.1	10.6	10.1
6	11.7	11.2	10.7	10.2
7	11.8	11.3	10.8	10.3
8	11.9	11.4	10.9	10.4
9	12.0	11.5	11.0	10.5
10	12.2	11.7	11.2	10.7
11	12.3	11.8	11.3	10.8
12	12.4	11.9	11.4	10.9
13	12.5	12.0	11.5	11.0
14	12.6	12.1	11.6	11.1
15	12.7	12.2	11.7	11.2
16	12.8	12.3	11.8	11.3
17	12.9	12.4	11.9	11.4
18	13.0	12.5	12.0	11.5
19	13.1	12.6	12.1	11.6
20	13.2	12.7	12.2	11.7
21	13.3	12.8	12.3	11.8
22	13.4	12.9	12.4	11.9
23	13.5	13.0	12.5	12.0
24	13.6	13.1	12.6	12.1
25	13.7	13.2	12.7	12.2
26	13.9	13.4	12.9	12.4
27	14.0	13.5	13.0	12.5
28	14.1	13.6	12.1	12.6
29	14.3	13.0	13.3	12.8
30	14.5	14.0	13.5	13.0

SECTION 13

Storage

Growers contemplating medium to long-term storage (3–6 months) need to be aware that mungbean continue to age, and that quality deteriorates over time.

Mungbean will darken in storage, with the rate of seed coat darkening being accelerated by:

- high seed moisture content
- high temperatures
- high relative humidity
- condition of the seed at harvest

Seed subject to field weathering prior to harvest will deteriorate a lot quicker in storage, even when stored under 'acceptable' conditions of temperature and relative humidity.

High relative humidity and high temperatures result in rapid deterioration in grain colour.

To maintain bright green colour and minimise darkening of seed, any grain stored at ≥12% moisture content will require cooling.

Growers should avoid even short to medium-term storage of weather-damaged grain.

Pulse grain placed in storage with high germination and vigour will remain viable for at least 3 years if the moisture content of the grain does not exceed 11% and grain temperatures remain cool. Storage life of pulses is determined by moisture content, temperature, insects and diseases. [1]

13.1 Moisture

Pulses harvested at ≥14% moisture must be dried before going into storage, to preserve seed germination and viability. As a rule, every 1% rise in moisture content above 11% will reduce the storage life of pulse seed by one-third (Figure 1). [2]

13.2 Temperature

High temperatures in storage will cause deterioration in grain viability. Temperatures of stored pulse grain should not exceed an average of 25°C, with preferable average

[1] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[2] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

temperature <20°C. In general, each 4°C rise in average stored temperature will halve the storage life of the grain (Figure 1).

Silo temperatures can be reduced by painting the silo white; dark-coloured silos will absorb more heat.

Grain in large silos (>75 t) will remain cooler because grain is a poor conductor of heat. External day and night temperature fluctuations rarely reach 15 cm beyond the silo wall. Small silos (<20 t), and field bins will have larger temperature fluctuations and can cause deterioration in grain quality.[3]

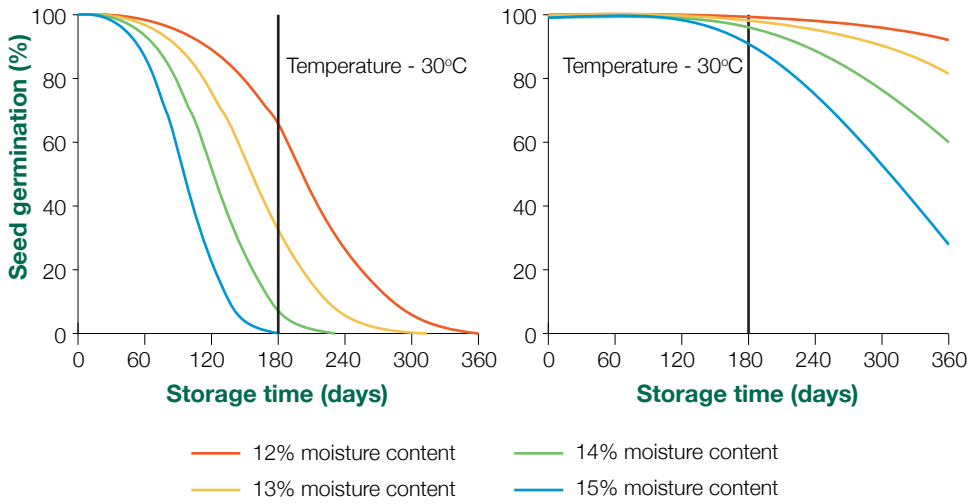

Figure 1: Effect of grain temperature and moisture content on germination of wheat seed. Left: storage at 30°C; right: storage at 20°C.

13.3 Principles of grain storage

Store only grain that is dry and clean. With a moisture meter, accurately check the moisture content of all grain entering storage. Moisture content of grain during harvest can change during the day and evening. Aerate as the silo is filled and during the storage period. This maintains the grain at low temperatures and uniform moisture conditions.[4] Inspect grain in storage at least once per month. Sample grain from the top and bottom of a silo, visually checking for quality and sieving for insects pests. Keep storage records. When insects are detected, fumigate grain in a sealable storage.

13.3.1 Cooling grain and aeration

Aeration cooling of grain has several advantages:

- Germination percentage is maintained longer.
- Moist grain can be stored briefly under constant aeration.
- Moisture migration and hot spots are reduced.
- Insect breeding is slowed or stopped.

[3] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[4] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

- Mould growth is slowed.
- Darkening of the seed coat is slower.

Aeration is a valuable when storing pulses in a silo. Aeration allows grain to be harvested earlier and at higher moisture levels and assists with grain quality. Aerated silos are fitted with fans that push air through the grain to cool the grain, and help to equalise moisture content and temperature throughout the silo. Ensure the aerated silo has a waterproofed vent to allow easy air movement out from the silo top. This venting lid needs to be replaced with a sealing lid when the silo is put under fumigation.

Aeration fans should run through a set schedule for the first 8–10 days. This is 'continuous' fan run-time (24-h) for ~3 days, then 9–12 h/day of cooler night-time air for the next 5–7 days. This pushes cooling fronts through the full grain depth. Finally, fan run-time for the longer term storage is ~100 h/month of the best available ambient air. Automatic aeration controllers are available, and these do a more reliable job of selecting fan run times by continuously monitoring ambient air temperature and humidity. Cooling achieved during storage depends on the moisture content of the grain and the humidity and temperature of the incoming air. Correctly controlled aeration can reduce grain temperature to ≤20°C. Aeration alone does not guarantee insect-free grain, but when combined with good storage hygiene, it will significantly reduce storage pest problems.

13.3.2 Prevent moisture migration

As a rule, the only time a silo should be 'sealed' is during the fumigation period of 1–2 weeks. To maintain grain quality and prevent moisture migration, store grain in a well-managed, aerated silo. In a sealed silo, there is no venting and therefore no escape for moisture that may condense in the silo headspace. This top area of the silo is at high risk from moulds and insect colonisation if the silo is left sealed for extended periods.

Water entering through structural damage to a storage will increase grain moisture content, leading to moulds and increased insect damage.[5]

13.3.3 Drying grain

Continuous-flow or batch dryers provide reliable drying, although they can reduce quality if run at too high a temperature. Do not exceed 45°C when using heat to dry pulse grains. Check the specifications or talk to the manufacturer about safe conditions for drying pulses.

High-capacity aeration systems can also be used to dry grain, and are ideally suited for drying grain harvested at 14–18% moisture content. This process requires a larger capacity fan to move high volumes of air through the grain at a faster rate than required for cooling only.

More information

For general information on handling, drying and cooling see the Agridry Rimik Pty Ltd website.

[5] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

13.4 Insect pests in storage

Bruchids are considered the major insect pest of stored mungbean, except in cases where mungbean are loaded into storages containing residues of cereal grain already infested with:

- rust-red flour beetle *(Tribolium castaneum)*
- lesser grain borer *(Rhyzopertha dominica)*
- saw-toothed grain beetle *(Oryzaephilus surinamensis)*

Where a prior infestation exists in the storage structure, it can develop and spread to mungbean.

The key to control is to ensure that all handling equipment and storages are cleaned of old cereal grain before they are used to handle pulse crops. Good hygiene combined with aeration cooling will reduce the frequency of infestations.

If insects are found in stored mungbean, the only registered treatment is phosphine fumigation. Adult insects are usually the first to die when using phosphine. However, immature stages of the insects, and resistant strains that are being found more frequently, can only be controlled by phosphine in a sealed, gas-tight storage. Phosphine is very toxic to people as well as insects, so do not handle treated grain before completion of the 7–10-day exposure period and 1-day fan-venting period to remove the gas.

No insecticide sprays are currently registered for use on pulses. Markets are particularly sensitive to insecticide residues, so any detection of residues on mungbean could result in loss of a market, not just rejection of a contaminated delivery. Residual sprays should not be used on pulse storages and handling equipment. Use diatomaceous earth (DE) products such as Dryacide® as a structural treatment to storage.

13.4.1 Bruchids in stored mungbean

Bruchids are a serious insect pest of stored grain-legume seed and pose a major threat to the Australian mungbean industry. They are widespread in storage and processing facilities in the northern grain region and are a serious concern to the whole industry.

Although crops may be infested in the field, infestations are often too low to detect at harvest. Bruchids are usually not detected until seed has been stored for some time (e.g. >2–3 months.) Bruchids breed rapidly in storage and if bulk or bag stocks are not carefully inspected every month, the grain can be destroyed.

Growers need to exercise reasonable care when buying planting seed of mungbean, cowpeas, or lablab. Cowpeas and mungbean seed, in particular, are highly prone to infestation with bruchids. No protectant insecticides are registered for use on mungbean seed in Australia.

The only registered treatment for mungbean seed is fumigation with phosphine.[6]

[6] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

13.4.2 Insect description and life cycle

Adult bruchids are a grey–brown-coloured beetle with a tear-shaped body (i.e. taper towards the head) about 3 mm long and 2 mm wide. They do not have the elongated snout of true weevils, which infest cereal grains. They are strong fliers and can easily climb vertical surfaces.

Adult beetles fly reasonable distances and may infest grain in the field prior to harvest (e.g. by entering insect-damaged or weather-damaged pods); however, infestation more commonly occurs during storage, from previously infested grain.

The beetles do not actually feed on the grain, but mate and then lay their eggs, which are cemented on the surface of the seed. The eggs are small and white and, despite being only 0.6 mm long, are readily visible. Eggs hatch within a few days, and the emerging larvae, which look like short, cream-coloured maggots, then burrow into the seed and commence feeding and are rarely seen.

After a few weeks, new adult beetles emerge from the damaged grain through characteristic circular holes (Figures 2 and 3). Because their life cycle is quite short (3–4 weeks from egg to egg at 30°C), the bruchid population can 'explode' to cause substantial damage in a short space of time.[7]

Figure 2: Adult bruchid, emergence hole and eggs.

[7] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Figure 3: Bruchid adults emerging from grains and eggs laid on surface of grains.

13.5 Farm hygiene

Hygiene is the most cost-effective method of managing the bruchid problem.

Beetles emerging from infested seeds fly readily to other stocks of grain legumes stored on the farm, and to legume crops ripening in the field. Growers can minimise the chances of this happening by regular cleaning of all residues of grain legumes from planting equipment, shed floors, augers and empty trucks, storages and headers after harvest.

Farm hygiene is essential in reducing next season's infestation of grain legume seed.

13.6 Aeration

A combination of aeration and good hygiene should provide an acceptable level of control of bruchids in bulk stored mungbean. Aeration of stored grain with cool air will significantly slow development, and restrict the amount of insect damage.

The bruchid population increases rapidly at high temperatures (>30°C), but development in each stage of the life cycle slows as the temperature drops. Insect activity and development ceases altogether at temperatures <20°C.

To achieve a satisfactory level of control using aeration during the summer months, several conditions must be met:

- The number of insects entering the storage must be low, so hygiene standards must be good.

- Surface heating of silos by the sun should be reduced by using a white or reflective coating on the outside of the silo.
- An efficient switching mechanism (controller) should be used to select automatically the most favourable ambient air to cool the grain. Aeration systems that switch on and off manually or by time clocks are less effective and may lead to mistakes and grain damage.[8]

13.7 Fumigation

Phosphine is the only fumigant currently registered for use in pulses.

Once mungbean are infested, the only solution is to fumigate with phosphine. Once the fumigation is completed, return the storage to aeration cooling management.

More information

For fumigation product information, hazardous substance database and protective equipment see the Dräger website.

Successful fumigation requires a sealed storage area.

To be effective, fumigation should only be carry out in a storage designed to be sealed gas-tight (Figure 4). A concentration of over 300 ppm must be maintained over a period of 7–10 days to achieve a total kill. Although fumigation in unsealed silos may kill some adult beetles, it is often ineffective on larvae, pupae and egg stages, which quickly emerge from the seed after a poor fumigation to continue their life cycle.

13.7.1 Controlling insects in storage

Provided the correct methods and gas-tight storages are used, fumigation will penetrate the grain and destroy all stages of insects—adults, eggs, larvae and pupae—at the time of fumigation.

More information

http://storedgrain.com.au/grain-storage-bruchids-in-mungmungbean-and-other-pulse-crops-dpif-note/

http://storedgrain.com.au/storing-pulses/

http://storedgrain.com.au/stored-grain-pests-identification-the-back-pocket-guide-2011/

Effective fumigation with phosphine needs a minimum concentration of 200 ppm to be maintained for at least 10 days where the grain temperature is 15°–25°C. An unsealed silo will not hold this concentration.

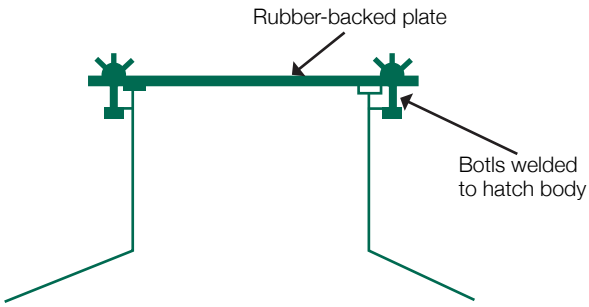

Figure 4: Gas-tight storage design.

[8] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

SECTION 14

Environmental issues

More information

http://www.moreprofitperdrop.com.au/wp-content/uploads/2013/10/WATERpak-4_6-Irrigated-Mungbens-best-practice.pdf

http://www.queenslandcountrylife.com.au/news/agriculture/cropping/general-news/baralaba-mungbeans-bounce-back/2686252.aspx

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Summer-crop-options-for-the-central-west-mungbeans-soybeans

http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/summer-crop-production-guide

Mungbean is regarded as chilling-sensitive, with a critical temperature of 15°C below which the growth rate is significantly retarded. Below this temperature both cell structure and function are impaired.

When planted during the preferred spring and summer seasons, the crop will be finished and harvested prior to the first frost.

However, particularly late-planted summer mungbean may still be in the field when the first frost occurs. This will kill the plant and result in poor grain quality from any immature grain present at the time.

14.1 Waterlogging

Mungbean is sensitive to excessive waterlogging, and the importance of good layout and drainage cannot be over-emphasised. Waterlogging events of >5 days can cause root nodules to die back, with subsequent nitrogen-deficiency problems in the crop. [1]

[1] DAFF (2012) Nutrition, irrigation and harvesting. Department of Agriculture, Fisheries and Forestry Queensland, https://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/mungbeans/nutrition,-irrigation-and-harvesting

SECTION 15

Marketing

Australia is a relatively small supplier compared with the main exporters of mungbean, China and Burma. The small size of the industry means prices are largely dictated by the demand from the world market, and the supply from the harvest in China (September–November) and Burma (January–May), both of which may fluctuate between seasons.

The main uses for mungbean are as a green vegetable, bean sprout (Figure 1), in cake manufacture, bean flour and livestock feed. The grain is graded, cleaned, bagged and packed into shipping containers. Fumigation may be necessary to prevent insect contamination, and drying or aeration (if delivery moisture is above standard). Mungbean grading losses can account for 8–20% of the crop yield.

Figure 1: Sprouted mungbean. (Photo: GRDC)

More information

http://www.mungbean.org.au/pdf/Marketing%20Your%20Mungbean.pdf

Marketing in the mungbean industry is quite intensive, with seed parcels traded on an individual basis, typically in 25-kg bags.

Forward selling is limited and hectare contracts are the main option available for marketing.[1]

15.1 Grades

Mungbean buyers focus on visual appearance, with a bright, even green colour, varietal purity and size being critical. As a result, such prices are usually determined by the final graded quality, as opposed to an agreement prior to grading.

The export standards are quite stringent, with processing plants required to be registered and maintaining Australian Quarantine and Inspection Service (AQIS) standards, which focus on a high level of hygiene.

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%), charcoal rot, size and oversoaks.
2. Cooking—classified on appearance, size, range and purity.
3. Processing—classified on appearance, size, range and purity.

Approximately 80% of Australian mungbean production currently falls into the Processing market. Growers should budget on prices for this grade as a guide. Only very small proportions of the crop make 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 mungbean being harvested in the sample
- contamination from animals such as birds and rodents
- weed seed contamination[2]

15.2 Unique marketing system

Mungbean have strict hygiene requirements, because >95% of Australian production is used for human consumption. They are often sold with no further processing or heat treatment.

Bacterial contamination with *Salmonella* and *E. coli* at any stage of growing, harvesting,

[1] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[2] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

More information

http://www.mungbean.org.au/pdf/MungbeanGrowerDeclaration.pdf

http://www.mungbean.org.au/pdf/Aus%20Mungbean%20Code%20of%20Practice.pdf

handling or storage of the crop can result in serious food poisoning and possible human mortality.

Under AQIS regulations, all mungbean destined for export must be cleaned and packaged at a Registered Mungbean Processing Establishment and handled in accordance with the Industry Code of Hygienic Practice. This is an enforceable, inspectable and auditable process designed to maintain the integrity of the health regulations relating to the product.

All harvesting and handling equipment used on-farm and during transport to the Registered Processing Establishment also falls under the Code of Hygienic Practice. Copies of this Code are available from all Australian Mungbean Association (AMA) Registered Processing Establishments and on the AMA website. [3]

Confidence in the mungbean industry and its unique marketing system will most likely be realised if there is an understanding of the fundamental requirements of the mungbean consumer and the marketing system required to best meet these needs. These fundamentals include:

- Consumers purchase mungbean as a vegetable. They are one of the most popular vegetables of the Asian culture, whereas in Australia they are considered grain crop.
- The marketing of mungbean to overseas countries is not unlike marketing a vegetable crop in Australia. The buyer places emphasis on product familiarity, product appearance and quality. These markets also tend to be highly volatile, reflecting changes in supply and demand.
- What can appear as a good sample to the Australian farmer may be unacceptable to some buyers, creating further confusion for the grower.

Mungbean are handled and traded differently from most other pulses and coarse grains (Figure 2). They are not traded in bulk shipments like wheat, sorghum, barley or chickpeas.

[3] Australian Mungbean Association, http://www.mungbean.org.au

More information

http://www.mungbean.org.au/grainqualitystandards.html

http://www.mungbean.org.au/pdf/Marketing%20Your%20Mungbean.pdf

http://www.mungbean.org.au/pdf/Mungbean%20QSEED%20Seed%20Production%20Scheme.pdf

Figure 2: Mungbean is handled and traded differently from other broadacre crops.

Pre-plant surveys conducted by both NSW Department of Primary Industries (NSW DPI) and CSIRO clearly demonstrate that many growers believe they will achieve Sprouting grade, and are disappointed and frustrated when they do not achieve this grade level.

Only 20% of the total Australian crop eventually meets the strict quality criteria for the Premium Cooking and Sprouting trade. The remaining 80% fall into the Processing grade. Growers need to budget on achieving Processing grade. This represents a price difference from sprouting of $150–350/t to growers.

Crop management therefore should be aimed at maximising yield. If weather conditions suit this management strategy, it will provide the best opportunity to achieve the higher priced cooking or sprouting grades.

Depending on the supply and which buyers are active at any given time, major price fluctuations can occur. This is no different from most vegetable markets.

Confusion exists over how prices and returns are quoted to growers. The different grading plants use a range of methods to quote growers on price. Therefore, it is important to understand the quote so that accurate comparisons can be made.

Several contracting and marketing options are available from a number of buyers. Growers should do their initial market research prior to planting.[4]

[4] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

15.3 Background

Mungbean is a relatively new crop to Australia. Although the crop was grown in small areas during the 1950s and 1960s, production levels did not began to increase until 1978. Over the past two decades, mungbean production has steadily increased to 40,000–60,000 t/year on a regular basis, of which 95% is exported.

Although these tonnages are small compared with other summer crops grown in Australia, the need for a summer legume in rotations has seen a greater emphasis not only on agronomy and breeding, but also on processing and marketing. Mungbean is processed, marketed and shipped in a way that differs from most grains being produced.

Mungbean is not a commodity traded on the futures market or shipped in bulk. It is a product that is graded, bagged and shipped in containers. It is spot-marketed to individual resellers overseas and is treated more as a horticultural product than grain.[5]

15.4 Classification system

This system was implemented to aid sale by description, rather than the previous system of sale by sample (which was extremely slow). It does not operate under single-desk marketing like wheat and sorghum. Processors and exporters all spot-market individually.

Growers generally do not understand the criteria used to classify mungbean. Great emphasis is placed on appearance such as colour, lustre and levels of wrinkled mungbean. These criteria are different from those of other grain crops, and growers subsequently are challenged with making a qualitative assessment of their own sample.

As with any grain, classification is unpopular but necessary. Over the past 10 years, the AMA has developed both receival standards and quality classifications to assist growers, processors and exporters to understand the various market requirements, and to try to standardise and introduce direction to the mungbean industry (Table 1). This did not occur before the organisation formed, and it has helped to reduce the reliance on mungbean being sold on individual samples. That was a very slow process whereby a small sample was dispatched to the potential buyer overseas prior to confirmation of the sale. Knowledge of mungbean classification is important because in-crop management has a substantial effect on the final quality.[6]

[5] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[6] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

Table 1: Mungbean grades and varieties that meet the criteria

Mungbean grades	Varieties that meet criteria	Test required
Sprouting	Berken Emerald(b) Regur Satin II(b) White Gold™	Appearance Size range Purity, moisture Germination Oversoaks Charcoal rot Microbiological Physical sprout test
Cooking	Berken Crystal(b) Emerald(b) Regur Satin II(b) White Gold™	Appearance Purity Moisture Size range
Premium and No. 1 Grade	Celera(b) Green Diamond(b)	Appearance Purity Moisture Size range
No. 1 Processing	Berken Crystal(b) Emerald(b) White Gold™	Appearance Purity Moisture Size range
Processing (all varieties)	Berken Celera(b) Crystal(b) Emerald(b) Green Diamond(b) Regur Satin II(b) White Gold™	Appearance Purity Moisture
Manufacturing	All varieties	Purity Moisture

More information

http://ausgrain.com.au/Back%20Issues/185jfgrn09/38_Mungbean.pdf

http://www.mungbean.org.au/grainqualitystandards.html

15.4.1 Appearance

Appearance is based on a visual assessment against the standard or base sample at time of testing. Appearance is determined by:

- uniformity of colour
- shades of colour
- insect damage
- lustre
- brightness of colour
- condition of skin coat
- other characteristics that affect appearance

When classifying a sample on appearance, it is compared with a standard or base sample set by the AMA annually, following a set procedure to ensure uniformity from one year to the next. All registered sheds and AMA-approved seed-testing laboratories are issued with these samples. Currently, two independent laboratories are approved by the AMA to test mungbean and issue an AMA grading.

These are:

- SGS Agritech Laboratories, Toowoomba, Qld ((02) 6792-4588)
- Futari Grain Technology Services, Narrabri, NSW ((07) 4633-0599)

Cooking, Sprouting, and No. 1 Processing classifications must have bright seed with no discoloration, staining, dust or wrinkled mungbean.

Mungbean that fail to meet this standard are classified as 'Processing grade' or 'No grade' or 'Sale by Sample'. Approximately 85% of the mungbean harvested fall into the Processing grade. Growers need to understand that it is difficult to obtain Sprouting quality, and that it generally represents <10% of all mungbean produced. Growers should consider aiming for Cooking or No. 1 Processing rather than Sprouting because of the high risks involved with growing the Berken variety.

Processing mungbean are described as Poor, Average and Good; this is done to optimise returns to the grower. For example, a line of good Processing quality not quite good enough to make Cooking quality will still achieve a premium over a line of poor Processing quality with a high level of discoloration and wrinkle. A $100/t price differential can occur between different quality mungbean within the broad classification of Processing grade.

Mungbean can deteriorate in quality especially if the overall moisture level is high, or individual mungbean are high in moisture. This is an important consideration when mungbean are freshly harvested. The mungbean at harvest can be an even green colour with a few wrinkled seeds, but in time, these seeds can deteriorate quite dramatically, turning brown in the process. This can lead to substantial claims being made against exporters and processors.

If the mungbean fail to make Processing, they will be reduced to Manufacturing or Sale by Sample (Figure 3).

All mungbean should be classified in direct sunlight on a white plate.[7]

15.4.2 Purity

The purity requirements of mungbean classifications are:

- Manufacturing: 99%, 0.5% other seeds, max. soil content 0.1%
- Processing: 99%, 0.5% other seeds, max. soil content 0.1%
- No. 1 Processing: 99%, 0.5% other seeds, max. soil content 0.1%
- Cooking: 99%, 0.3% other seeds, max. soil content 0.1%
- Sprouting: 99%, 0.3% other seeds, max. soil content 0.1%

Soil has major market implications. If the line contains soil at above the maximum content allowable, it will have to be sold on a 'Sale by Sample' basis.

Some weed seed can be very difficult to grade out, especially in the small-seeded varieties (i.e. bellvine, cowvine). This can have major implications in the marketing of the line. It

[7] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

will have to be sold on sample and at a discount. Prohibited weeds are not allowed in stockfeed gradings, so gradings containing weeds such as castor oil will have to be dumped. This also applies to stockfeed gradings with excessive levels of any weed seed or soil or high moisture (mould).

Cereal seeds such as sorghum and wheat in mungbean will exclude the line from the US market.

15.4.3 Size range

For Sprouting, Cooking and No. 1 Processing grades, 98% of seeds must be within a 2-mm size range based on slotted sieves, and in this range, 75% must be within 0.8 mm.

The size range is especially important with Cooking and Sprouting mungbean. In Cooking mungbean, size is important mainly because of appearance and to a lesser extent cooking times. In Sprouting mungbean, it is essential, because the sprouts will grow at different rates if uneven.

15.4.4 Moisture

For all grades, maximum moisture for export is 12%. High individual mungbean or overall moisture can cause downgrading. Gradings will imbibe moisture from green material at a faster rate than whole mungbean. Gradings may at times have higher moisture content than the cleaned mungbean and thus may need to be dumped or dried.

15.4.5 Oversoaks

This applies to Sprouting mungbean only. Oversoaks are defined as the percentage of mungbean grain that imbibe after submerging in water at 32°C for 1 h (max. 10% allowable).

15.4.6 Germination

Germination applies to Sprouting mungbean only. The germination must be a minimum of 90% excluding hard seeds.

15.4.7 Charcoal rot

Charcoal rot applies to Sprouting mungbean only. There is nil tolerance—tested at 28°C for 4 days.

15.4.8 Microbiological indicators

This applies to Sprouting mungbean only, unless otherwise requested; nil tolerance—tested for *E. coli*, coliform, and *Salmonella*.

15.4.9 Chemical residues

The Australian Department of Agriculture, Fisheries and Forestry conducts The National Residue Survey (NRS), in which random samples are taken from export commodities and tested for chemical residues.

The NRS currently tests for residues of agricultural and veterinary chemicals and environmental contaminants in 11 meat products, honey, egg, three fish products, 14 grains, pulses and oilseeds, and five horticultural products.

An annual report is published indicating the number of samples taken and the compliance rate (%) of these samples with Australian registration and Maximum Residue Limits (MRLs).

In addition to this, importing countries are increasing their level of testing and some buyers may ask for specific chemical testing of mungbean prior to importation.

It is important that growers complete their 'Grower Declaration Form' honestly, even if off-label practices have been required. [8]

Figure 3: Left: Mild Processing quality; right: Manufacturing quality.

15.5 Price and marketing

More information

http://www.mungbean.org.au/pdf/Marketing%20Your%20Mungbean.pdf

http://www.mungbean.org.au/grainqualitystandards.html

Mungbean are not an easy crop to market. In comparison to other grains, a lack of contract options has been available to the exporters and in turn the growers, and any contracts that are available require the exporter or processor to carry all the risk. This has left the industry open to criticism, mainly from new growers to the industry. However, a range of contracts is available to growers, and checking the marketing options available prior to planting is strongly recommended.

Mungbean are purchased on a clean-weight basis in bags, with the grower generally standing the cost of grading and bagging (~$80–85/t). These charges are generally deducted from the grower's payment. [9]

15.5.1 Difficulties in marketing

Mungbean are not traded on futures markets, rather, they are spot-marketed in relatively small shipments (in general 1–10 containers of 22 t each).

[8] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

[9] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

The harvest time of the major competitors (China and Burma) occurs when the Australian crop is planted, so market information prior to planting for the growers, processors and exporters is limited.

The size and quality of the crop in these countries dictates world prices:

- China's harvest, September or November
- Burma's harvest, January or May

Marketers are unable to estimate what tonnage of a particular quality will be produced, and growers are not prepared to book firm tonnage and quality.

All mungbean has to be graded, bagged and exported in containers. The average production has ranged from 40,000 to 60,000 tonne, all of which is cleaned and bagged at ~4–6 t/h through the grading sheds.

Because of the slow rate of processing through the sheds, purchasing the total crop at harvest is not possible. Over the cleaning period, the market can and does change, quality could deteriorate and, because exporters are not paid in full until delivery, cash flow would be affected.

Even if the crop could be processed at a faster rate, the market could not handle the tonnage in one go. Most overseas buyers have very small premises, and they then distribute the mungbean into their market, sometimes as little as a few bags at a time. Remember that mungbean is a 'vegetable' commodity in world markets. [10]

15.5.2 Factors affecting price

Australia is, by world standards, a small player in mungbean. China is still the biggest exporter of mungbean in the world. Myanmar has produced up to 150 kt (rough estimate) and their quality has improved substantially. Geographically, both of these countries are better positioned to supply our Asian markets and speak the native tongue. Years of large production in these countries can severely affect price.

Mungbean are used as a fresh vegetable in Asian markets; thus, the price is influenced by price and availability of other vegetables.

Taiwan is a market where mungbean soup is used as a cooling food in hot summers. This means the weather has to be hot to increase demand.

Wet summers in the Philippines increase demand for processing mungbean for use as a vegetable.

Sri Lanka has emerged as a large user of Australian mungbean over recent years.

Quality

The factors affecting quality are mainly climate, agronomy and management. Quality is the largest single factor affecting price. Although climate cannot be controlled, management

[10] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

issues such as sap staining due to premature harvesting, soil or weeds in the sample can result in a substantial loss of income. For example, a reduction in quality from Cooking to Average Processing as a result of sap staining may result in a price difference of up to $70/t. In some years, the difference could be as high as $200/t.

Choice of variety is also important; for example, Berken is more susceptible to weathering than Emerald(1)

Price can also vary within a grade depending on quality. A grower may receive $450/t for Processing, whereas the neighbour may receive $550/t, but this is quite often the difference between Poor and Good Processing. To market mungbean in another way would be detrimental to the price received for the better quality Processing mungbean.

The economies of the various countries and the strength or weakness of their currency can influence the price they can afford to pay. Mungbean are generally sold into developing countries where the price will be compared with the fresh vegetable market and thus fluctuate weekly or even a daily basis. [11]

15.6 Overseas markets

Approximately 95% of mungbean produced in Australia is exported. Only a small amount of sprouting mungbean is sold on the domestic market. Our position in the market has improved over the last few years.

Improved classification adherence to quality standards, hygiene practices, and being able to offer large quantities in single lines has helped to establish Australia as an emerging force in the world mungbean market.

Continuity of supply over recent years has improved because of improved grower confidence and expansion of the industry into 'new areas', although continuity remains one of the major problems. Australian mungbean are liked (preferred) overseas for the consistency of quality over large lines. Buyers also like the consistency of our grading system.

Philippines and Sri Lanka

The Philippines and Sri Lanka import a large percentage of the processing mungbean produced in Australia. Quality requirements have increased over the past few years. This market is prepared to pay more for good quality, but insists on discounting for poor quality.

Demand in the Philippines increases if there is a wet summer and vegetables are in short supply, because mungbean are used as a replacement.

Taiwan

Taiwan is a price-driven market, where imports are predominantly cooking mungbean and some processing mungbean. Market share has increased for Burma through improved

[11] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

quality. Demand increases during hot summers because the mungbean are used to make soup, which is considered a cooling food.

India

India is a price buyer and enters the market only when the domestic crop fails to meet demand. India purchases Celera(), Regur and poor-quality Processing mungbean.

USA/Canada

The USA is a producer in its own right but is still a net importer of mainly sprouting mungbean. Exporters must be aware of the nil tolerance to cereal grains when sending product into USA.

This is also a premium market for Celera(), Regur and Cooking mungbean.

Malaysia

Malaysia purchases low-quality Cooking mungbean along with a range of processing-quality mungbean, depending on the market segment. The quantity shipped into Malaysia annually is highly dependent on pricing levels because of its close proximity to Myanmar.

Japan

Japan imports Sprouting mungbean mainly from China and to a lesser extent Thailand. It imports only a few hundred tonne per annum from Australia.

Europe and the United Kingdom

These markets are still recovering from *Salmonella* outbreaks in the United Kingdom and Sweden, which was linked to Australian mungbean. The Code of Hygienic Practice introduced by AQIS is helping to repair Australia's reputation. Sprouting mungbean are mainly exported to these markets.

The United Kingdom has good demand for Celera() Regur and some Cooking mungbean from the Indian population.

Indonesia

Indonesia was emerging as an outlet for poor-quality mungbean but political and economic problems in recent years have resulted in them being less active in the market place.

Australian domestic

Domestic use is ~3000 t Sprouting mungbean and Cooking mungbean. Approximately 80% are sprouted. [12]

15.7 Intake and processing

Mungbean must be processed for export by a registered mungbean plant that processes and packs mungbean in accordance with the *Code of Hygienic Practices* for pulses and

[12] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

legumes. This code insures that the plants are in good condition and that good hygiene practices are adhered to.

Grading, bagging and containerising of the mungbean crop takes time, especially when the crop is ~50,000 t. The situation has improved over the past few years, and will continue to improve as the processing plants build on existing infrastructure. Grading involves more than just screening out split grain or admixture cleaning. Mungbean have to be sized and gravity-graded as well as screened, which makes it difficult to estimate grading losses visually.

15.7.1 Intake

Prior arrangements have to be made for delivery because of storage problems at the peak of the season.

Upon delivery, all mungbean are tested for moisture, purity (other seeds, soil, etc.), hygiene and mould, and given a preliminary classification if deemed Cooking or potential Sprouting mungbean. If Processing, they will be classified and stored ready for grading.

Cooking mungbean will have the final classification after grading to ensure no deterioration is occurring.

Sprouting mungbean will have a charcoal rot and oversoaks test prior to grading. If they fail, they will become cooking-quality mungbean; if they pass they will be graded and be subjected to the remaining tests.

15.7.2 Processing

Prior to cleaning, each grower's mungbean are issued a line and lot number for identification from the grower to the end user. Each bag is branded with this number along with the registration number of the processing plant. This provides an auditable trail back to the plant and in turn back to the grower in case of hygiene or residue problems. A Grower Declaration Form must be supplied with all mungbean delivered.

During grading, the mungbean are sized to specifications, and all splits chips and waste is removed. A small loss is also incurred over the gravity tables, referred to as rejects. The rejects are mungbean that are lighter than the rest of the sample because of insect damage, weathering, or mechanical damage. Losses can vary between 8% and 30% depending on the sample, but average losses range between 12% and 18%.

The mungbean are then bagged (mainly in 25- or 30-kg bags) and palletised until sold. Upon sale of the mungbean, and when shipping instructions have been received, they are packed into 21.5–22-m containers and shipped. [13v]

More information

http://www.mungbean.org.au/pdf/MungbeanGrowerDeclaration.pdf

http://www.mungbean.org.au/pdf/Mungbean%20QSEED%20Seed%20Production%20Scheme.pdf

[13] G Cumming *et al.* (2014) Northern Mungbean—Best Management Practices Training Course. Pulse Australia Ltd.

15.8 Grain 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). 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 their role, refer to the GTA website.

Always refer to your marketing agent or contract arrangement for specific delivery requirements. [14]

More information

Australian Mungbean Association.

Australian Oilseeds Federation.

Pulse Australia.

15.9 Opportunities for Australia in mungbean development

Australia can develop its mungbean industry more efficiently and effectively as a part of an international research effort in collaboration with other national programs. Such international collaboration is already being done by Australian industries and Australian Centre of International Agricultural Research (ACIAR) to develop chickpea in conjunction with International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and lentil with International Center for Agricultural Research in the Dry Areas (ICARDA). It is highly cost-effective.

Extensive studies of the costs–benefits of international agricultural crop research and development show that it has a median rate of return of 58%, and rates of return to horticultural research are among the highest, averaging 67% (DFID 2005).

The mungbean breeding program in India, for instance, involves many universities and government institutions working in the All India Coordinated Pulse Improvement Program, including Punjab Agricultural University, with an entire department of 15–20 scientists working together on mungbean and other pulse crops. There are opportunities for synergies with the expertise that Australia has already built up in areas such as mungbean breeding, plant pathology, and crop modelling. [15]

More information

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

http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-102/Mungbean-show-mainstay-potential

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/175911/East-dryland-mungbean-12-13.pdf

[14] N Moore, L Serafin, L Jenkins (2014) Summer crop production guide. NSW DPI Management Guide, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

[15] W Easdown, ML Chadha (2010) International collaboration to develop the Australian Mungbean Industry. 1st Australian Summer Grains Conference, http://www.grdc.com.au/uploads/documents/2010ASGCEditedPapersPDF/Easdown_InternationalCollaboration_edited_paper.pdf

SECTION 16

Current research

Soon to be populated.

SECTION 17

Key contacts

James Clark - Chair

Hunter Valley grower James brings extensive knowledge and experience in dryland and irrigated farming systems to the Northern Panel. He has been a member of the panel since 2005 and chairman since 2008. James says the panel's role is to capture and invest in growers' priorities and empower them to adopt new production gain opportunities. He strongly believes the grains industry needs to continue building RD&E capacity to ensure growers remain competitive.

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Loretta Serafin - Deputy Chair

Loretta has more than 12 years' experience as an agronomist in north-west NSW and currently works with the NSW DPI in Tamworth. She is a technical specialist for northern farming systems and provides expertise and support to growers, industry and agronomists in the production of summer crops. She has a passion for helping growers improve farm efficiency and sees her role as a conduit between advisers, growers and the GRDC to ensure that growers' needs are being met.

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John Sheppard

John, a panel member since 2006, has a wealth of practical farming experience and brings a wheat breeder's perspective to the panel. He views the panel as an opportunity for growers and professionals to work together to shape the future of the industry, and develop best management practices, as well as new varieties and products. He is particularly interested in genotype-by-environment interaction and the preservation of genetic resources.

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Jack Williamson

Jack, a private agricultural consultant, runs a broadacre commodity production farm in Goondiwindi. Previous roles as a territory sales manager for Nufarm and as a commercial agronomist for McGregor Gourlay Agricultural Services have given Jack extensive farming systems knowledge, and diverse crop management and field work experience. Jack is a member of the Northern Grower Alliance (NGA) local consultative committe and Crop Consultants Australia, and was previously president of the MacIntyre Valley Cotton Field Day Committee.

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Julianne Dixon

Jules is manager of AMPS Research and a passionate agronomy consultant, communicator and industry advocate. Her role involves the development and expansion of self-funded, privatised research, development and extension. Her experience in project management and strategic development extends across all facets of an integrated grains business. She has an established network in eastern Australia and Western Australia, including researchers, leading growers, agronomy consultants and commercial industry.

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Keith Harris

Keith has served on the Northern Panel since 2011 and brings more than 30 years' experience in property management. Keith, based on the Liverpool Plains, NSW, consults to Romani Pastoral Company on the management of its historic holdings 'Windy Station' and 'Warrah', near Quirindi. He sees the main aim of the panel as representing growers and conducting research that provides growers with the tools they need to maximise property performance and minimise risk.

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Kelly Becker

Based at Theodore, Queensland, Kelly is a certified mungbean and chickpea agronomist and also advises growers on wheat, corn and sorghum crop production. She has been involved with variety trials on a commercial basis and industry farm practice trials as an agronomist. She strives to be proactive within the industry and aims to assist growers to improve farming operations by ensuring that they are up to date with new practices and technology.

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Penny Heuston

Penny brings extensive experience to her second term on the Northern Panel. She is committed to maximising the profitability of grain production in a low-rainfall environment through increased productivity and good risk management practices. She was principal in a farm advisory business in centralwest NSW and worked with growers across north-west NSW before joining Delta Agribusiness, where her main focus is the Warren, Nyngan, Tottenham and Gilgandra areas.

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Rob Taylor

Rob is a grain grower at Macalister on Queensland's Darling Downs and farms 2300 hectares of maize, sorghum, wheat, barley and chickpeas on the Jimbour Plain. Rob is currently chair of the Agrifood Skills Initiative for the Western Downs Regional Council area. Rob views his role on the panel as taking information and feedback from growers, advisers and researchers to the GRDC to ensure research is targeted.

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Will Martel

Central NSW grower Will has served on the Northern Panel since 2011. Previously he worked in a Quirindi grain trading company and with Brisbane-based Resource Consulting Services (RCS) where he benchmarked more than 400 growers across Australia on their performance, focusing on whole-farm profitability rather than individual enterprise gross margins. His main role on the panel is identifying investment areas that will enable growers to remain economic and environmentally sustainable.

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Dr Stephen Thomas - GRDC Executive Manager Commercial

Before joining the GRDC Steve held a senior position with the NSW Department of Primary Industries at Orange. In early 2009 he was appointed executive manager practices at the GRDC and in 2011 was appointed executive manager research programs. Currently Steve holds the position of executive manager commercial. He sees the GRDC's role is to interact with growers regularly to determine their needs and focus on the big picture across entire farming systems.

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Sharon O'Keeffe - GRDC Northern Regional Manager

Sharon is the Northern Regional Manager for the Grains Research Development Corporation (GRDC), based in Boggabri NSW. Sharon's role is to identify and oversee regional research, development and extension (RD&E) needs, manage the regional delivery of information and promote the GRDC's products and services. Her role strengthens links between GRDC panels, researchers, industry, advisors and growers. Sharon holds a Masters in Agriculture and a Bachelor of Rural Science (hons).

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David Lord - Panel Support Officer

David operates agricultural consultancy Lord Ag Consulting. For the past four years he has worked as a project officer for Independent Consultants Australia Network (ICAN), which has given him a good understanding of the issues growers are facing in the northern grains region. David's new role is Northern Panel and Regional Grower Services support officer.

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SECTION 18

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