Crop protection concurrent session

Non-herbicide tactics to help suppress weed growth. Row orientation, spacing and variety selection as weed management tools

Greg Brooke, NSW DPI Trangie

Key words
Non-herbicide, Row orientation, Row spacing, Plant population, barley, weeds, integrated weed management.

GRDC code
UA00124

Take home message
- At Bithramere near Tamworth east-west crop row orientation in barley yielded the same as north-south sowing but reduced biomass of weeds (canola) by 30% compared with a north-south row orientation.
- At Merredin and Beverley in W.A east — west sowing gave 24% yield increase in cereals and a 37 to 54% suppression in weed biomass.
- At Trangie increasing the seed density of the barley varieties Hindmarsh and Granger improved their yield and also increased their competitiveness against weeds (oats).

The rise in herbicide resistance in Northern region cropping systems has meant that in some situations weeds are dictating more and more how farmers can farm. With multiple resistance occurring in some weed species, non herbicidal measures to control or at least help suppress weeds are of increasing necessity. For integrated weed management (IWM) systems to be effective, non-herbicide strategies are imperative.

Prior to the advent of selective in-crop herbicides and the introduction of the semi-dwarf gene, cereal cultivars were taller and by nature had more suppressive effect on weeds such as oats (Vandeleur & Gill 2004). A crops competitive effect is most highly correlated with its ability to generate a large leaf area index early in its growth stage. (Coleman, Gill & Rebetzke 2001)

Several studies have been done amongst current cereal cultivars to determine whether some varieties are inherently better at suppressing weed growth than others.

Can the inherent ability of some varieties to accumulate biomass be put to effect against weeds?

What are the trade-offs in yield vs weed suppression from high vs low harvest index varieties?

Does increasing the crop sowing rate assist with weed competition? What are the effects of increasing seeding rate on variety performance and on weed suppression?

Does row orientation make any difference to either yield or weed suppression?

It is known that as a plant type barley is more competitive than wheat and for this reason barley is usually chosen for these plant competition trials.

Row orientation - does it make a difference?

Many paddocks in our northern region were originally set up for controlled traffic tramlines 15 years ago based on practicalities such as reducing headland area by choosing row direction according to the longest run of the paddock, so that row direction varies from paddock to paddock. In irrigation
fields it is with fall of the paddock. Practicalities aside, what difference does row orientation make to crop yield and suppression of weeds?

Deliberately orienting crop rows at 90 degrees to the sunlight direction east – west (E-W) works on the principle that the crop will intercept more sunlight (photosynthetically available radiation) than will N-S sowing, giving weeds less chance to develop in the crop inter row. In winter when the sun is at a lower angle (solar plane) this shading of the inter row can confer advantages particularly in southern latitudes. Research from 2002 – 2005 conducted by Borger et al at Merredin and Beverley W.A. (latitudes S 31° to 32 °) has shown both yield advantages as well as weed suppression from east/west row orientation compared with north/south.

Merredin in Western Australia is similar in latitude to Tamworth.

Annual TOTAL solar radiation at Merredin is very similar to annual TOTAL solar radiation at some eastern state sites eg. Merredin W.A 7036MJ/m²; Trangie NSW 6864MJ/m²; Goondiwindi NSW 7172MJ/m² (source CliMate app)

Within wheat and barley crops oriented east-west, in the W.A trials weed biomass (averaged throughout all trials) was reduced by 51 and 37%, and grain yield increased by 24 and 26% (compared with crops oriented north-south) (Borger et al)

Weeds in these trials were sown wild radish (300 pod segments/m²) and annual ryegrass (“Safeguard” 200 seeds/m²)

At Bithramere near Tamworth in 2012, Matt Gardner et al established a trial with two barley varieties- Hindmarshl and Skipperl with a sown population of 44Y84/l canola as a substitute weed. Row orientation, row spacing 30 cm vs 50 cm were evaluated. A row orientation of E-W conferred a reduction in weed (canola) biomass of 39%.

Skipperl being more vigorous than Hindmarshl reduced weed (canola) biomass a further 30% and 42% over Hindmarshl for the N-S and E-W sowing.

The weed fumitory was also prolific in the N-S sowing but was reduced almost to nothing in the E-W row orientation. (Matt Gardner pers comm.)

Row orientation had no significant impact on grain yield under high weed competition. When no weeds were present, the N-S orientation had a 6% and 7% yield improvement for the 30 and 50cm row spacing treatments. (Gardner et al 2012)

Summer crop work in sorghum by Serafin, L and McMullen,G 2011 showed row orientation had no advantage in terms of yield. This is most likely because the sun is at a higher angle and also because of the relatively lower plant populations involved and the wider rows – 75cm. Importantly E–W sowing did not yield any less than did N-S sowing meaning it would be compatible with winter crop programs which deliberately oriented crop rows E-W for weed control.

Row spacing- does it make a difference?

The Bithramere2012 trial with 30 cm vs 50 cm showed no clear effects in reducing weed (canola) biomass, but the wider row spacing did incur a yield penalty of 11% in the nil weed treatment.

At Merredin W.A. two row spacings of 23 cm vs 60 cm were used and at Beverley WA two row spacings were studied at 18 cm vs 36 cm. Averaged throughout all trials, weed biomass was lower in crops with narrow row spacings (Borger et al).

Varieties – are there differences?

Most published work has concentrated on crop type eg barley vs wheat vs canola vs lupins etc and not on varieties. Recent work with barley varieties shows there is as much difference between barley varieties as there can be between crop types.
The Bithramere trial with two barley varieties showed the more vigorous barley variety Skipper(I) reduced weed (canola) biomass by 30 – 40% over Hindmarsh(I)².

Skipper(I) also out-yielded Hindmarsh(I) with both weeds present and not present and at both 30 and 50 cm row spacings.

Figure 1. Barley competition trial, Trangie 2013

Figure 1 summarises a barley competition trial conducted at Trangie in 2013 and shows the capacity of different varieties to yield both with and without weeds and the yield loss incurred by weeds (oats).

15 barley varieties were sown at 100 seeds per m² and 3 of these varieties were sown at double rate of 200 seeds per m². Row spacing was 33cm. The oat variety Yarran(I) was surface sown as a substitute weed at 50 seeds per m² and was allowed to grow right through until maturity. The yield loss attributed to weeds averaged across all varieties was 0.3t/ha.

The popular and high yielding variety Hindmarsh(I) both with and without weeds present was the highest yielding variety. Increasing the seed rate to 200 seeds/m² improved the yield of Hindmarsh(I) both with and without weeds and also gave greater suppression of weeds. This is consistent with other seeding rate trial work with Hindmarsh in variety specific agronomy package (VSAP) trial work.

The variety Granger(I) at 200 seeds/m² improved yield where weeds were present but only maintained yield where there were no weeds present.

Figure 2. Oat suppression by barley variety, competition trial, Trangie 2013
Figure 2 shows the effects of weed (oat) suppression by barley variety. Varieties such as Hindmarsh\(^1\) which are lower biomass types proved less suppressive of weeds than bulkier types such as Grange\(^1\), Fathom\(^1\), Commander\(^1\).
Increasing the seeding rate of Hindmarsh\(^1\) caused greater suppression of oat yield. Granger\(^1\) at 200 seeds per m\(^2\) gave the greatest reduction in oat yield.

**Summary**

Crop row orientation of E-W in winter cereals has given substantially greater suppression of weeds in both WA and Northern NSW trials.

Barley variety choice will impact the seed set of oats.

Increasing the seeding rate of Hindmarsh\(^1\) and Granger\(^1\) from 100 seeds to 200 seeds per m\(^2\) caused a further reduction in weed (oat) yield.

Increasing the seeding rate of ScopeCL\(^1\) did not improve yield or significantly increase suppression of oats in this trial.

**References**

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Serafin, L. and Mcmullen, G. Targeting high yields in dryland grain sorghum in northern NSW: row direction, row spacing and plant population GRDC website. 2011


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\(^1\) Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994
Taking the angst out of thresholds in the computer age - easy thresholds for pod sucking bugs

Hugh Brier (DAFF Qld)

Key words
Podsucking bugs, thresholds, soybeans, mungbeans, green vegetable bug

GRDC code
DAQ00153

Take home message
New threshold models have been developed for crushing soybeans, displacing the old ‘double the edible threshold’ rule of thumb. The new downloadable bug threshold calculator makes for the easy calculation of podsucking bug thresholds in edible and crushing soybeans, and mungbeans. Parameters the calculator will ask you for are an estimated crop yield, likely crop value, cost of control and mean seed weight (MSW). MSW are automatically calculated once you enter your soybean cultivar, but you can enter them separately if you want to. MSW are not needed for mungbean thresholds. Note that thorough and regular crop sampling is required if you are to accurately compare your bug populations to the calculated thresholds. See appendix for a mock up of the calculator as it will appear on your screen when downloaded.

Introduction/background
Podsucking bugs are major pests of summer pulse crops, including soybeans and mungbeans. Bugs typically infest crops from flowering onwards, but economic damage is not inflicted until the podfill stage. Crops remain at risk until very close to harvest, as bugs can still sting seeds in pods nearing harvest maturity (tan pods in soybeans and black pods in mungbeans), albeit at a reduced rate. In most cases, spray decisions will be made at early to mid podfill.

Podsucking bug thresholds are based on seed quality, and are influenced by a multitude of factors, including bug species, bug stage, yield, mean seed weight, time to harvest, and for crushing soybeans; crop value and cost of control. Many of these factors interact, making ‘on the back of an envelope’ calculations impossible. However the availability of a downloadable calculator takes the stress out of threshold calculations and enables the user to easily compare bug thresholds under a wide range of scenarios, e.g. for high and low yielding crops of different soybean cultivars.

Bug species/bug stage: Bug populations typically are low at early podding but increase exponentially as pods develop as a result of in-crop breeding. While green vegetable bug or GVB (Nezara viridula) is regarded as the key podsucking bug species, the brown bean bugs (Riptortus serripes and Melanacanthus scutellaris) are just as damaging, and the redbanded shield bug (Piezodorus oceancus) nearly (75%) as damaging and sometimes more abundant. Frequently multi bug-species populations are present containing both adults and nymphs, the nymphs progressing towards adulthood with increasing damage potential as pods mature.

Because all bug species/stages present in a crop contribute to overall bug damage, thresholds are expressed in green vegetable bug adult equivalents (GVBAEQ), and all species/stages in sample counts are converted to GVBAEQ in the threshold model. The models allow for previous nymphal damage and for a conservative level of GVB nymphal mortality of 50% of that reported by Stam et al. 1987, i.e. 31%, 16%, 3% and 0.5% in the 1st, 2nd, 3rd and 4th instar nymphs respectively. Mortality of 5th instar nymphs and adults is assumed to be negligible. In practice, adult bug counts alone will often determine if spraying is required. There is a more advanced option in the calculator to enter counts
for each bug instar (I-V or 1<sup>st</sup> to 5<sup>th</sup>) separately or, for people not confident of correctly identifying all nymph stages, to combine counts of 1<sup>st</sup> and 2<sup>nd</sup> and also 3<sup>rd</sup> and 4<sup>th</sup> instars. Note the more advanced option gives a more accurate calculation. Note also that 5<sup>th</sup> instars are instantly recognizable by the presence of wing buds.

**Seed quality**: Podsucking bug thresholds are based on seed damage (shrivelling, distortion and discolouration) inflicted over an extended period of time, up to 42 days in soybeans and 35 days in mungbeans. The major impact of this damage is reduced seed quality. While bug damage can also reduce yield, yield thresholds for podsucking bugs are markedly higher than the quality thresholds, which consequently are the ruling thresholds.

**Threshold guidelines for edible soybeans and mungbeans**: Podsucking bug thresholds are determined by percent seed damage bonuses or penalties set by industry. Soybeans destined for the culinary or edible human consumption market (grades CS06/7) are allowed up to 3% seed damage after which, the edible bonus of typically $50-$100+ per tonne is lost, and the product reverts to crushing (non-edible) status. For most except very low yielding crops (<1t/ha), the edible bonus is many times greater than the cost of control, increasing in magnitude as yields increase (Fig.1).

![Graph showing relationship between cost of control and potential edible bonuses ($/ha) in edible soybeans. Note that the bonus per hectare (ha) = bonus per tonne ($/t) x yield (t)](image)

Spraying is therefore recommended well before the critical 3% damage level is reached, typically for bug populations predicted to give 2% seed damage, i.e. roughly 70% of 3%. For example for a 3t/ha crop, even a $50/t penalty equates to a loss of $150/ha, as opposed to the cost of podsucking bug control at typically only $15-$18/ha. Action is taken for populations predicted to give 2% damage level to give growers a safety margin as even a slight transgression of the 3% damage level results in an immediate and substantial reduction in crop value. Podsucking bug thresholds in mungbeans follow the same model, but the critical level of damage is only 2%, and the resultant action threshold is based on only 1.4% damage, i.e. 70% of 2%. Note that neither crop value nor the ‘cost of control’ are required in the threshold models for edible soybeans and mungbeans.

**Impact of yield on thresholds**: Podsucking bug thresholds for both soybeans and mungbeans are based on % seed damage. Crop size/yield must therefore be allowed in any threshold calculations, as a given bug population will inflict less damage in percentage terms in a high yielding crop with more seeds, than in a low yielding crop with fewer seeds. Consequently thresholds increase proportionally
as yields increase, i.e. the bug threshold for a 4t/ha soybean crop is twice that for a 2t/ha crop (Fig. 2), and similarly for mungbeans – see comparison between 1t/ha and 2t/ha crops (Fig. 3).

**Figure 2.** Relationship between yield and 2% action and 3% damage thresholds for edible soybeans. Thresholds expressed in green vegetable adult equivalents per square metre (GVBAEQ/m²).

**Figure 3.** Relationship between yield and 1.4% action and 2% damage thresholds for mungbeans. Thresholds expressed in green vegetable adult equivalents per square metre (GVBAEQ/m²).

**Seed size and thresholds:** Seed size as measured by mean seed weight (MSW) is another key threshold factor in soybeans for which MSW can vary from 7 to 27 g per 100 seeds (14,300 to 3,700 seeds/kg) for cultivars Oakey (a Nato variety) and Bunya respectively. Data from field trials shows an inverse power relationship (y=ax⁻²) between the rate of damage (y) and seed size (x). In other words, each bug damages relatively fewer seeds in large seeded varieties (e.g. Bunya) than in small seeded varieties (e.g. Oakey). As a result, one might expect higher thresholds in large seeded
cultivars. However a countering factor is that for a given yield, small seeded cultivars have more seeds. The net result when both factors are included in the model is that thresholds are higher in small seeded than in large seeded soybean cultivars (Fig. 4). Seed size is not an issue in mungbeans as differences in seed size (mean seed weight or MSW) are minor compared to soybeans.

In summary, action thresholds for edible soybeans and mungbeans are set for bug populations predicted to damage 2% and 1.4% of seeds respectively. Estimate the potential yield of your crop and know the seed size (mean seed weight or MSW) of your soybean cultivars, although the on-line model will do this for you – just enter the variety’s name. If you are not confident in estimating yields, use the following formulae; (provided in the on-line calculator – see Appendix Fig. A):

Yield (t/ha) = seeds per pod x pods per plant x plants per metre x MSW x 0.0001/row spacing in metres, where MSW = g per 100 seeds.

![EDIBLE Soybean Bug Thresholds for Different Cultivars](image)

Figure 4. Relationship between yield and 2% action thresholds for edible soybeans ranging in mean seed weight (MSW) from 7.5 to 27.5 g per 100 seeds. Thresholds expressed in green vegetable adult equivalents per square metre (GVBAEQ/m²).

Thresholds for crushing soybeans: Crushing soybeans (grade CS08) are usually older cultivars with a dark seed hilum. In contrast to edible soybeans, the new bug thresholds for crushing soybeans are much more complicated, as they are affected by the cost of control and crop value, as well as yield and mean seed weight. The seed-quality penalty guidelines are also quite different. As with edible soybeans, there are no penalties for up to 3% seed damage. However for every additional 1% damage above 3% and up to 6%, there is a 1% reduction in crop value ($/t) and for every 1% damage above 6% up to 9%, there is a 2% reduction in crop value. For ≥ 10% seed damage, there is a total rejection of harvested seed.

Thresholds are determined by calculating the cost of potential penalties ($ per tonne x yield [t/ha]), comparing these to the cost of control ($/ha), and calculating the number of bugs to give threshold damage for the yield, crop value and MSW of the crop in question. The resultant models (bug threshold versus yield) are not linear as for edible soybeans, but are curvilinear. (Fig. 5 and Fig. 6.)
The models show that (a) the higher the yield, the higher the threshold (Figs. 5-7), (b) the higher the cost of control, the higher the threshold (Fig. 5), (c) the higher the crop value, the lower the threshold (Fig. 6), and the lower the mean seed weight, the higher the threshold (Fig. 7).

**Figure 5.** Impact of 'cost of control' and yield on crushing soybean thresholds with a MSW of 20g/100 seeds and crop value = $500/t.

**Figure 6.** Impact of crop value and yield on crushing soybean thresholds with a MSW of 20g/100 seeds and cost of control = $20/ha.
The threshold, soybeans. Therefore, there is a downloadable calculator. For example a 1% penalty in a 5t/ha crop values at $800/t equates to $40/ha. If likely control costs were $15/ha, it would be worthwhile acting preemptively to ensure the 3% damage level was not exceeded.

**Soybean threshold summary:** Clearly the old ‘double the edible threshold’ rule of thumb for crushing soybeans does not hold in the majority of cases, and a more accurate threshold calculator is required. Given the 4-way interaction of cost of control, crop value, yield and mean seed weight in crushing soybean thresholds, the only way to determine bug thresholds is with the new downloadable threshold calculator. The calculator also takes the angst of calculating the damage potential of mixed bug species/bug stage populations in both edible and crushing soybeans. Because some cultivars can be marketed as either edible or crushing beans, the calculator calculates both threshold types. See appendix for a mock up of the calculator as it will appear when downloaded.

**The elephant in the room – bug sampling:** While the calculator can calculate pod sucking bug thresholds more accurately than ever before, the weak link in the system remains sampling. This is because bug populations, especially of young nymphs, can be notoriously patchy. Inadequate sampling can therefore result in a significant over or under estimation of bugs actually present. As a
rule of thumb, aim to sample 5 widely-separated sites throughout a crop, with at least 4 x 1 m samples per site. Using a GPS while sampling, may give you a more accurate record of bug population variability on your property.

However on the grower’s side is the fact that young nymphs inflict very little damage (1st instars cause no damage) and that the thresholds are based on damage inflicted over a lengthy period of time (up to 42 days in soybeans). The models also allow for previous nymph damage where larger nymphs are detected. Remember that economic damage only occurs from podfill onwards, and spraying for podsucking bugs is not recommended before this crop stage. Another reason for not spraying too early is that the SP’s (e.g. detemethrin) are ineffective against bug eggs, and it is better to let these hatch before spraying. The final reason is that delaying (currently non-selective) bug sprays for as long as possible reduces the risk of flaring other pests, especially silverleaf whitefly and mites in soybeans.

One frequently asked question regarding the pre-emptive bug threshold approach for mungbeans and edible and high-yielding crushing soybeans is “What happens if the population never reaches the critical penalty-invoking damage levels equating to 2% damage in mungbeans and 3% damage in soybeans”? The answer is that, unless crops are terminally drought stressed, podsucking bug populations invariably increase as crops mature, due largely to in-crop breeding, but also because older (later instar) nymphs are more likely to be encountered while sampling. This is because they disperse from their early-instar clusters and their distribution becomes less patchy.

Acknowledgements

Jozef Wessels for technical assistance in numerous podsucking bug threshold trails, both in the field and processing hundreds of damage samples; Tonia Grundy for formatting the models for on-line use; GRDC for funding a series of Pulse IPM projects that generated the data used in the models; Yash Chuan for assisting with formulae used in the models; and the then Queensland DPI (now DAFF) for making available field trial technical support and resources at the Kingaroy Research station.

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Expanded conversion table for all nymph stages

Use this version only if you are confident that you can correctly identify all nymphal stages of each of the four pod sucking bug species:

Please ensure required values (*) are completed

### Crop*
- Select crop
- metres

### Row spacing*
- metres

### Days to harvest maturity*
- days

### Predicted yield*
- t/ha

### Cost of control including application
- $/t

WARNING: Check 'Days to Harvest' is MORE than the Withholding Period for the insecticide you intend to spray with

\[ \text{Predicted yield (t/ha)} = \text{seeds per pod} \times \text{pods per plant} \times \text{plants per metre} \times \text{MSW} \times 0.0001/\text{row spacing in metres} \]

### SOYBEANS ONLY

<table>
<thead>
<tr>
<th>Variety</th>
<th>Mean seed weight (MSW)</th>
<th>Calculated values:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select variety</td>
<td>grams/100 seeds</td>
<td>seeds/kg</td>
</tr>
</tbody>
</table>

### OR*

- number seeds
- seeds/kg

### Bug growth stage:

<table>
<thead>
<tr>
<th>Instar</th>
<th>Green vegetable bug (GVB)</th>
<th>Brown bean bugs (BSB)</th>
<th>Redbanded shield bug (RBSB)</th>
<th>Brown shield bug (BSB)</th>
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</thead>
</table>

### Counts (average per metre row)

<table>
<thead>
<tr>
<th>Instar I</th>
<th>Instar II</th>
<th>Instar III</th>
<th>Instar IV</th>
<th>Instar V</th>
<th>Adults</th>
<th>Total AEQ/m</th>
<th>GBVAEQ/m² re. days to harvest</th>
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</thead>
</table>

### Total GVBAEQ for all species

<table>
<thead>
<tr>
<th>Edible Soybean/Mungbean Threshold</th>
<th>per m² GVBAEQ/m²</th>
<th>Total GVBAEQ for all species</th>
<th>per m² Crushing Soybean Threshold</th>
<th>Are you above threshold?</th>
<th>Are you above threshold?</th>
</tr>
</thead>
</table>

### Total GVBAEQ for all species

For more information on identification of bug species, including beneficial (predatory) bugs, see the Good Bug Bad Bug book.

**Figure 8.** On-Line Calculator for podsucking bug thresholds in soybeans and mungbeans (example only – colour scheme may differ in actual calculator)
Transform™ is a new systemic insecticide with a novel mode of action (Group 4C) for controlling sap-feeding (sucking) insects. Transform is now registered in the broadacre crops canola, cereals and soybeans for the control of aphids and other pests. Aphids feeding on maturing canola distort new growth in leaves, flowers and pods and their honeydew excretions encourage the growth of sooty mould. Aphids transmit viral diseases, such as Barley Yellow Dwarf Virus in wheat and barley, leaving the crop unable to yield to its potential.

**Transform Insecticide:**
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- Is effective against insects which are resistant to other insecticides
- Is an effective rotational partner with other chemistries
- Is soft on beneficial insects (i.e. it is IPM compatible) and predatory mites
- Has a favourable ecotoxicology profile and is not persistent in the environment
- Can be applied by ground-rig in a minimum of 50 L/ha of water. Can be aerially sprayed in a minimum of 30 L/ha of water
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  - 2 x 1 L Part B: 120 g/L spinosad. Controls lesser grain borer including multi resistant strains.
- The combined pack will treat 250 tonnes of grain
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- Should Conserve On-Farm be applied twice to a parcel of grain, it is possible that grain MRL violations will occur, endangering overseas trade.
- The product will only be used to treat grain grown by the purchaser and stored on the property on which it was grown. A reseller programme has been put in place to ensure growers are trained on its correct usage.

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6. Regular content updates.

Improved understanding of thresholds – armyworm in barley and aphids in canola

Melina Miles, Adam Quade, Richard Lloyd and Paul Grundy, Queensland Department of Agriculture, Fisheries and Forestry

Key words
Barley, canola, IPM, insect pests, armyworm, aphids, pest management

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Take home message
The 2013 season demonstrated that the presence of armyworm in above threshold densities did not necessarily result in head lopping and associated crop losses. Increased sampling effort resulted in significant savings in insecticide and application. The beatsheet provides the best overall estimate of armyworm larvae, but the inclusion of soil inspections when sampling for armyworm provides a clearer picture of larval densities and risk to the crop. Predicting the likelihood of damaging head lopping is not possible based on larval density and size alone. The additional factors driving this behaviour are unclear.

Removing late terminal growth on canola racemes (simulated aphid damage) did not result in a reduction in yield at 10, 50 or 100% of racemes treated. The need for aphid management needs to be considered in the context of crop growth and yield potential. Improved knowledge of canola physiology in different regions will be useful in making these assessments.

Armyworm in barley – what we learnt in 2013
Thresholds for armyworm were derived in the 1980s and 1990s, and have not been revisited since then. The origin of the estimate of damage that we currently base the economic threshold on is unknown. The calculation of potential loss, and consequently the economic threshold is as follows:

1. armyworm damage is estimated to be 7 heads lopped per day per large larva (= 70 kg/ha at 1 larva/m²) (based on the estimate of 1 lost head per m² = a loss of 10 kg/ha).
2. If a large armyworm larva is active for 7 days, then this is a potential loss of 0.5 t/ha.
3. Using these estimates, the economic threshold for armyworm, with variation in grain price, would be as per Table 1.

Table 1. Estimates of economic threshold for armyworm based on a total potential loss of 0.5 t/ha per larva per square metre.

<table>
<thead>
<tr>
<th>Grain price ($/t)</th>
<th>Cost of control (chemical and application)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ground ($15)</td>
</tr>
<tr>
<td>200</td>
<td>0.15</td>
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<tr>
<td>220</td>
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<td>250</td>
<td>0.12</td>
</tr>
<tr>
<td>270</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Clearly these threshold estimates are significantly lower than the nominal 2-3 larvae/m² that is commonly used as a threshold for armyworm in barley. So this season we set out to test the damage potential of armyworm in barley.

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What we did this season

To do this we set up a trial where we introduced armyworm larvae at different densities to ‘caged’ sections of crop. The larvae were checked weekly, and new larvae introduced to maintain densities at the required levels. The cage trial yielded no result as the behaviour of the larvae was changed by being physically located. Apparently this has been the experience previously with these types of trials (G. McDonald pers. comm.), which meant we were dependant on monitoring infestations in situ.

To do this we sampled 6 fields weekly in the Croble and North Star region of NSW, where there were natural armyworm infestations from the vegetative stage until maturity/harvest. Of particular interest was the relative usefulness of the beatsheet, sweep net and digging in providing estimates of armyworm densities. We also looked at the levels of defoliation and other crop damage, and the incidence and potential impact of natural enemies (predators and parasitoids).

Sampling and estimating armyworm densities effectively

Figure 1 illustrates a number of things relevant to making decisions about armyworm:

1. not all larval stages are sampled equally well by a beatsheet and sweep net. Sampling below the canopy, on the soil surface and just below, is critical to getting a good estimate of the number of large larvae in the crop. Overall the beatsheet was more effective in determining the number of small and medium larvae. The dig (soil sampling) was most effective at determining the number of large larvae.

2. Neglecting to sample the soil for larvae and pupae not only potentially underestimates the most damaging life stages, but also misses information that would help predict the rate at which larvae are pupating and therefore no longer posing a risk to the crop.

Figure 1. Combined data from across the 6 barley crops showing the relative efficacy of sweep, beatsheet and digging in estimating armyworm numbers through the critical crop stages. Sweep net data is an average of 20-25 x 10 sweeps; beatsheet is an average of 20 x 1m row samples; and digging the average of 10 x 1m row samples each date.
Crop damage – head damage and defoliation

One of the 6 sites was treated for armyworm (Crooble 1). This field had larval numbers far in excess of any threshold, the highest levels of defoliation, and visible damage from grazing on grain and awns. In the remaining 5 sites we did not see head lopping although densities and larval age were consistent with the expectation that significant head lopping would occur (Table 2).

Table 2. Armyworm densities at 19 September, 2013 in maturing barley crops in NNSW, and levels of damage to grain and heads.

<table>
<thead>
<tr>
<th>Location</th>
<th>Large larvae (/m²)</th>
<th>Total larvae (/m²)</th>
<th>Total number of tillers examined</th>
<th>Number of tillers with feeding damage to awns/grain</th>
<th>% tillers with feeding damage to grain/awns</th>
<th>Number of tillers with heads lopped</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crooble 1</td>
<td>1.3</td>
<td>23</td>
<td>1000</td>
<td>2</td>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>Crooble 2</td>
<td>2.6</td>
<td>8.6</td>
<td>774</td>
<td>24</td>
<td>3.1</td>
<td>0</td>
</tr>
<tr>
<td>Crooble 3</td>
<td>1.3</td>
<td>6</td>
<td>888</td>
<td>3</td>
<td>0.3</td>
<td>0</td>
</tr>
<tr>
<td>North Star 1</td>
<td>sprayed</td>
<td>sprayed</td>
<td>746</td>
<td>44</td>
<td>5.9</td>
<td>0</td>
</tr>
<tr>
<td>North Star 2</td>
<td>4</td>
<td>22</td>
<td>938</td>
<td>4</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>North Star 3</td>
<td>1.3</td>
<td>26</td>
<td>1148</td>
<td>10</td>
<td>0.9</td>
<td>0</td>
</tr>
</tbody>
</table>

In addition to low levels of grain and awn damage there was considerable leaf feeding, and concern amongst agronomists about the level of defoliation of the flag, flag-1 and flag-2, and the potential impact that may have on grain fill. To determine the extent of the damage, weekly samples were taken from each field and an estimate made of the level of defoliation (Figure 2). What is evident from the data is that the defoliation progressed over the 4-5 weeks that the crops were monitored. Ultimately, there was little difference between the levels of defoliation of the flag, flag-1 and flag-2. The armyworm larvae fed on the available green leaf. The levels of overall defoliation did vary between crops with Crooble 1 and 3 low, and North Star 1 high. There were no consistent growth variations in these crops to explain the differences, nor do the defoliation rates correlate consistently with larval densities.
Natural enemies (beneficials)

The predators recorded were largely species we associate with aphid infestations, as the majority of the sites had had some aphids earlier in the season. However, it is likely that some of these species may contribute to the mortality of armyworm eggs and small larvae. The most frequently encountered species included the lacewings, ladybeetles, and hoverflies. Overall numbers averaged 0.5 – 5 per square metre.

Parasitoids, although much less visible, had a significant impact on the armyworm populations. Figure 3 shows the level of larval parasitism ranging from 5 – 25% of collected larvae (50 per site), and 10-50% for pupae (<10 per site).

The contribution of these predators and parasitoids to the suppression of armyworm, helicoverpa and other potential pests both in the barley and successive summer crops is potentially valuable.
Impact of aphids on canola

The cabbage and turnip aphids colonise the terminals and flowering and podding racemes of canola. When infestations develop rapidly they retard or prevent the development of the raceme where the colony is located. Visually, it appears that the aphids are limiting the flowering and podding capacity of the infested racemes. Infestations are typically patchy in a field with many racemes uninfested. Infestations tend to occur late in flowering once the crop has already set the bulk of the pods. The patchiness of infestations combined with the difficulties associated with sampling a crop adequately, has resulted in significant uncertainty about aphid management.

The only empirical threshold information available to guide agronomists and growers is from trial work in WA in the 1990s. Early work showed very high levels of infestation (up to 100% of racemes) resulted in no yield or oil content loss if the crop had adequate moisture. This work makes clear reference to the capacity of the crop to compensate (adequate moisture, limited insect and disease stresses). Current threshold recommendations are to control when 20% of racemes are infested – no reference to compensation.

Australia is relatively unique in controlling aphids in canola. In Canada and North America, for example, it is pest that is considered of little consequence in most seasons. Primarily this is because aphids are only considered potentially damaging if they infest crops during flowering and early pod set. Although later infestations may prevent the further growth of raceme, it is considered unlikely that this portion of the raceme would have contributed to yield. The contribution of natural enemies (beneficials) to the suppression and control of aphid populations is a major factor in considering if insecticidal control is warranted.

This season we established three trials to attempt to quantify the compensatory capacity of a dryland canola crop when subjected to artificial damage. Artificial damage is used because of the difficulties in maintaining aphid infestations in the field (usually decimated by natural enemies).

The results of the trial that most closely simulates late aphid infestation are presented here (Table 3). In this replicated plot trial, we attempted to simulate the impact of late aphid infestation by preventing the ongoing development of the racemes. The damage was simulated by removing the terminals from the racemes at 23 days after first flower. The treatments were different levels of damage applied to each plot (10%, 50% and 100%) of racemes damaged by terminal removal (cutting at least 25mm of stem). Plots were kept free of aphids and helicoverpa until harvest. Plots
were hand harvested with a plot thresher. Yield was assessed for each plot as was oil content and plant architecture.

The results for yield are in Table 3, and show no significant differences between the treatments. We do not yet have the oil analysis results.

**Table 3.** No significant differences in treatments simulating aphid infestation of canola at 10, 50 and 100% of racemes. Trial conducted in a dryland crop at Allora, SE Qld, 2013.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>2.07 a</td>
</tr>
<tr>
<td>10% of terminals removed</td>
<td>1.93 a</td>
</tr>
<tr>
<td>50% of terminal removed</td>
<td>1.98 a</td>
</tr>
<tr>
<td>90% of terminal removed</td>
<td>2.01 a</td>
</tr>
</tbody>
</table>

Treatments followed by the same letter are not significantly different (P<0.05).

This result shows that the loss of primary reproductive structures in canola does not directly result in yield loss. In this trial it is likely that the later flowers that were removed in these treatments would have contributed relatively little to yield and their removal had no impact on yield. This outcome is consistent with flower – pod set data presented in Figure 4.

![](image)

**Figure 4.** Total flowers produced, and productive pods formed, *B. napus.*

**What don’t we know that would help in managing aphids in canola?**

An understanding of canola crop physiology and what can reasonably be expected from the varieties in the different growing regions is desperately needed. Until an agronomist can make a reasonable assessment of what the crop potential is, how the crop is responding to the environmental conditions and what compensatory ability it has, it is extremely difficult to make decisions about the likely impact of late aphid infestations on crop yields.

In the absence of thresholds, an assessment of whether the canola crop is likely to have the capacity to continue to set harvestable pods should be made when aphid infestations are detected. In conjunction with an assessment of natural enemy activity, this information can be used with greater confidence in the northern region than a fixed threshold derived in a very different environment and with different varieties.

**Acknowledgements**

We are extremely grateful to the agronomists who alerted us to the armyworm outbreak and held their nerve long enough for us to collect this data. We are also grateful to the growers who allowed us to regularly sample their fields and take samples. In particular Tim Thorne (Allora) who
accommodated the compensation trial in his crop. The processing of samples was a tedious undertaking and assistance was provided to the authors by Jamie Hopkinson, Samuel Rojas Ponce and Thomas Noble.

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Mouse plague prediction models – relevant forecasts for growers in Queensland

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Key words
Mouse plagues, management, monitoring, modelling, forecast, zinc phosphide, rodenticide

GRDC code
IAC00002

Take home message
High mouse abundance is expected in the central Darling Downs area of Queensland in May 2014 and may cause damage to maturing sorghum crops. Growers need to monitor their crops closely and determine if they should use zinc phosphide bait to reduce damage to summer crops and protect newly sown winter crops. Growers are reminded that there is a two week withholding period for zinc phosphide baits prior to harvest. Talk to your neighbours and coordinate a baiting program to reduce reinvasion.

Background
The house mouse (Mus domesticus) is a serious pest to agriculture in Australia. Mouse populations occasionally undergo widespread eruptions (mouse plagues) in the grain-growing regions of Australia. On the central Darling Downs in the past, damaging mouse densities occur every 2 years and a plague every 4 years. Large parts of the grain-growing regions of south-eastern Queensland were hit by a mouse plague in 1995, but outbreaks have occurred also 1997, 2000, 2002 and more recently in a minor outbreak in 2010/2011. It is generally believed that dry conditions are needed before a mouse outbreak in Queensland, which is in contrast to the wet conditions needed for outbreaks in southern states (SA, Vic, southern NSW).

GRDC have funded a 3-year study to monitor mouse populations and forecast the likelihood of mouse outbreaks. The project is a collaboration between Landcare Research (New Zealand), CSIRO Ecosystem Sciences and the Invasive Animals Cooperative Research Centre. Mouse populations are monitored in typical grains farming systems in Western Australia, South Australia, Victoria, New South Wales and Queensland (Figure 1) at 3 key times each year. The monitoring provides data on the abundance and breeding status of mouse populations. This information is used in models that have been developed progressively over the last 20-30 years to predict mouse outbreaks.

Mouse monitoring
Currently, monitoring of mouse populations occurs at 3 levels of intensity across 11 sites:

(1) **Benchmark sites** in the Adelaide Plains (SA), Northwest Victoria, and the central Darling Downs (Qld), where long-term trapping has been conducted (>20 years) and where forecast models have been developed. Live trapping data are collected at 3 key times a year and the data are used in the models to predict the likelihood of outbreaks for those regions.

(2) **Quantitative rapid-assessment sites** in WA (Geraldton and Ravensthorpe), Victoria (Horsham and Walpeup), NSW (Riverina and Moree), SA (Roseworthy) and Queensland (Central Queensland and central Darling Downs) where there are two types of monitoring: mouse chew cards set out overnight (ten bait cards or canola squares at 10 m spacing along 100 m survey lines), and active burrow counts along 100 m survey lines. Monitoring is conducted 3 times a year.
(3) **Qualitative monitoring networks** in all the areas with rapid-assessment sites plus Eyre Peninsula (SA) and Central West NSW where key farmers and agronomists are contacted to collect information about mouse activity in the region as well as any reports of the use of rodenticides.

![Figure 1](image.png)

**Figure 1.** Approximate locations of mouse monitoring occurring in WA, SA, Vic, NSW and Qld.

**Current situation for the central Darling Downs, Queensland, and prediction of a mouse outbreak?**

Mouse monitoring on a transect between Mt Tyson and Cecil Plains on the Darling Downs was conducted in September 2013 (spring) and December 2013 (summer). Trap results for September indicated that mice were present in higher numbers than usual for spring, and were causing damage to maturing wheat crops.

The December trap index was 9.5% trap success (Figure 2). The short-term model predicts that the **March 2014 population index will be moderate** and the **May 2014 population index will be high**. Most adult females were pregnant. Plague prediction modelling of this latest data confirms that mouse numbers are increasing, with a high population density index expected during the period leading up to May 2014. The next routine monitoring will occur in March 2014.

The practical implication of this prediction for grain growers on the Darling Downs is the potential for increased levels of mouse-related crop damage in maturing sorghum crops. GRDC suggests that growers should closely monitor their crops for mouse activity and damage in the lead up to harvest, and consider baiting with a zinc phosphide-based product to reduce damage to both summer and planned winter crops.

Because of the high variability observed in mouse abundance across the 32 km transect, it is necessary for farmers to monitor mouse activity themselves on their own properties and to make a decision about whether they should take preventative action such as baiting with zinc phosphide.

Growers are reminded that there is a two week withholding period for zinc phosphide baiting prior to harvest. Other mouse management activities that can be carried out include mowing/slashing fence line and roadside verges to reduce alternative shelter and food sources, and cleaning up grain spillages that occur during harvest.
Figure 2. Current monitoring of mouse populations in central Darling Downs QLD (December 2013) compared mouse abundance in the past.

Current situation in other areas

Recently completed monitoring of mice in the Dawson and Callide Valleys in central Queensland and around Moree in northern NSW shows mouse numbers are slightly up on what was seen during September, but that populations are not high enough to be causing economic damage to crops, or to justify the expense of baiting.

There is a chance that mouse abundance will be relatively high at sowing of winter cereal crops in the Eyre Peninsula and Yorke Peninsula, South Australia, and the central Darling Downs, Queensland. Mouse populations are low across all other locations where we have monitoring data. The forecasts are based on information about the abundance of mice and rainfall over the growing season of the winter cereal crops. The next routine monitoring will occur in March 2014.

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