Managing lucerne crown borer in soybeans: insuring the best result

Widespread adoption of zero-till farming and localised back-to-back soybean plantings are encouraging the build-up of lucerne crown borer populations and contributing to the increasing regularity of infestations. This case study examines the economics of preventative in-furrow, seed and tillage treatment options.

Lucerne crown borer (LCB: *Zygrita diva*) is a key pest of Australian soybeans, particularly in the Lockyer and Fassifern Valleys (SE Qld) and the Northern Rivers (NSW). Sporadic severe outbreaks have also been reported in the Bundaberg and Burdekin regions of coastal Queensland.

LCB overwinter as pupae in soybean stubble, emerging as adults the following season to infest nearby soybean crops. At high infestation levels (90% of plants), undisturbed stubble may result in populations of up to 250,000 LCB pupae/hectare.

Adults lay eggs directly into soybean stems or petioles and hatching larvae tunnel and feed on the pith. Most crop damage occurs during the late larval stage when larvae girdle the stem to plug the pith tunnel, sealing their pupal chamber in the taproot. Plant parts above the girdle die, halting all pod and seed development, resulting in yield loss. Larvae typically don't reach a damaging size until later in the crop's life, but in hot summers girdling can occur at early podfill, and LCB adults can emerge before harvest.

Yield loss depends on LCB infestation severity and timing, and the environmental stresses experienced by the crop. The earlier a plant is girdled, the greater the yield loss as the plant is unable to set or fill pods. Losses of nearly 1 t/ha have been recorded in severely infested plots (>80% of plants). High temperatures and crop moisture stress also increase LCB damage severity, as both hasten the onset of larval girdling. In addition, girdled plants often lodge and their pods are totally lost at harvest. This is most likely in crops with uneven plant stands and/or low plant densities.

Management options

Because LCB larvae feed on pith tissue inside stems, traditional foliar insecticide applications are ineffective. Insecticides (e.g. deltamethrin, indoxacarb) are effective in controlling adult beetles, but multiple foliar spray applications would be required for pre-flowering crops to limit egg-laying, inflicting significant management costs on the grower, and impacting natural enemy populations, with the risk of flaring other pests (mites, silverleaf whitefly or *Helicoverpa armigera*).

However, recent trials show that fipronil seed treatment and in-furrow sprays have potential for LCB management. In a heavily infested site (86% of plants), a fipronil seed treatment (Legion®) at 200 mL/100 kg of seed, reduced plant infestation, girdling and lodging by 57%, 74% and 83% respectively, resulting in a doubling of yield compared to the untreated control, mostly due to the large reductions in the severe damage categories (girdling and lodging). In another trial with only 26% of plants infested, an in-furrow fipronil treatment at 129 mL/ha reduced infestation by 71%, compared to a 100% reduction for the seed treatment. Negligible girdling or lodging was observed in this trial.

A non-insecticidal approach is strip tillage of soybean stubble to kill or bury overwintering larvae. This approach is now much more feasible with GPS tractor steering and only requires a narrow strip (15 cm or 15% of area) be tilled, minimising soil disturbance and moisture loss.

Key findings

1. Lucerne crown borer (LCB) cannot be effectively treated in-crop. As treatment needs to be undertaken pre-planting, the probability of LCB damage occurring in the upcoming season greatly affects the potential benefit of treating.
2. When there is a lower chance of LCB damage long-term (over many years), pre-treatment would be expected to incur a net loss.
3. There are many unknowns that can affect the likely outcome from treating versus not treating LCB. The decision support tool can calculate the probability of economic returns under various scenarios to aid in this decision.
4. Although seed treatment is expected to have a higher efficacy in treating LCB, it is more expensive and therefore has lower net benefits.
5. The tillage treatment may be an economically viable option in treating LCB in soybean; however, the in-furrow treatment with fipronil would be a better option if full registration occurs.

Economic considerations

There are several unknowns that can affect the economic returns of management actions, including crop yield, crop prices, LCB yield losses, probability of LCB damage (in the coming season) and treatment efficacies. All suggested management options above require implementation before or at planting, when there is no way of knowing how badly the infestation will be, but previous LCB paddock history may provide some indication of risk.

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Estimating economic returns using a decision support tool

The upfront application of insecticide before planting for a possible LCB infestation is similar to undertaking an insurance policy. In most years there may not be any direct benefits (only costs), but it may reduce the impact when an event occurs. Therefore, we are not only interested in the coming year but also the long-term average impact over a number of years—does it pay in the long run?

We have developed a back of envelope risk analysis (BOERA) decision support tool to estimate the economic returns of different management options. Input variables will change from region-to-region, farm-to-farm, and year-to-year; therefore, the focus of this case study is on using the decision support tool rather than the results.

The BOERA uses the minimum, average (expected) and maximum values of each input variable to generate probability distribution for each of the risk drivers including yields, crop price, LCB damage and efficacy. It then randomly selects values from each of the variables' ranges to generate a range of possible outcomes (worst-case through to best-case scenario). There is an assumption that none of the variables are directly correlated with each other.

Case study

To demonstrate the use of the tool, this case study used values estimated for different treatment options in rainfed soybean crops in two regions (Bundaberg and Casino). Note, these values and results do not represent findings for these two regions, but rather provide an example of possible scenarios within these regions to show how BOERA may be used.

The economics of five management options: *No-treatment*, *In-furrow*, *Seed-treatment*, *Tillage*, and *In-furrow + tillage* were investigated. Each options had different costs and treatment efficacies. Fipronil was used as it was an effective insecticide in recent local trials. These analyses relate to off-label APVMA permits:

- In-furrow: PCT Surefire Vista 200SC at 130 mL fipronil/ha (86908).
- Seed coat: Nufarm Legion® Insecticidal Seed Treatment at 200 mL/100 kg seed (86886).

The input values used (derived from trial data, and local agronomist experience) are displayed in Tables 1 and 2. These values can vary substantially between farms, and are only used here as examples. Crop prices are based on the range of on-farm crop prices for the last 10-years (after grading and bagging).

The economic 'net benefit' of each treatment is

$$\textit{Net benefit} = (\textit{Yield}_{treated} \times \textit{Crop price} - \textit{treatment}) - (\textit{Yield}_{untreated} \times \textit{Crop price})$$

Maximum net benefits from treating are likely in years where severe LCB economic damage is suppressed (e.g. when crop yields and prices are high coupled with high early plant girdling). Low to negative net benefits from treatment are expected in years with minimal LCB damage (i.e. low or no LCB populations).

Lucerne crown borer larva in early planted soybean.

Table 1. Case study input values for the range of crop yields, crown borer yield losses in years when LCB damage is detected, probability of LCB damage occurring, and crop prices.

Region	Variable	Minimum	Average	Maximum
Wide Bay-Burnett	Yields without LCB damage (t/ha)	1.5	2.5	4.5
	Yield losses from LCB#	0%	13%	33%
	Probability of damage occurring		30%	
Northern Rivers	Yields without LCB damage (t/ha)	1.7	2.5	4.0
	Yield losses from LCB#	0%	13%	66%
	Probability of damage occurring		60%	
All	Farm gate crop prices	$600/t	$700/t	$800/t

in years when LCB damage is detected within a crop.

Table 2. Costs and efficacy range of case study treatment options compared to *No-treatment*.

Treatment*	Cost	Treatment efficacy		
		Minimum	Average	Maximum
In-furrow	$29/ha	50%	60%	70%
Seed treatment	$78/ha	55%	65%	75%
Tillage	$30/ha	33%	50%	75%
In-furrow + tillage	$59/ha	70%	80%	90%

*Chemical in-furrow and seed treatments used fipronil.

Results

Single year analysis

The possible range of net-benefits for each treatment option in a single year are presented as cumulative distribution functions in Figure 1. The median or expected net benefit of each treatment is given at P=50% (also given in Table 3). The vertical start of the treatment net benefit lines are the cost of treatment without any benefit, (there's a 70% and 40% chance of no LCB damage occurring in the coming season at Bundaberg and Casino respectively (Table 1)).

Long term analysis

While in hindsight it would have been better not to treat if LCB damage does not occur, there can be very high net benefits (>$400/ha) in years where LCB damage does occur (P=100%). The expected or median return (P=50%) in the coming year is the cost of treatment without benefits (Figure 1a, Table 3). So, the dilemma is: in the long run over a number of seasons is it worth treating for LCB despite most seasons resulting in net economic losses, in the hope of avoiding severe LCB damage?

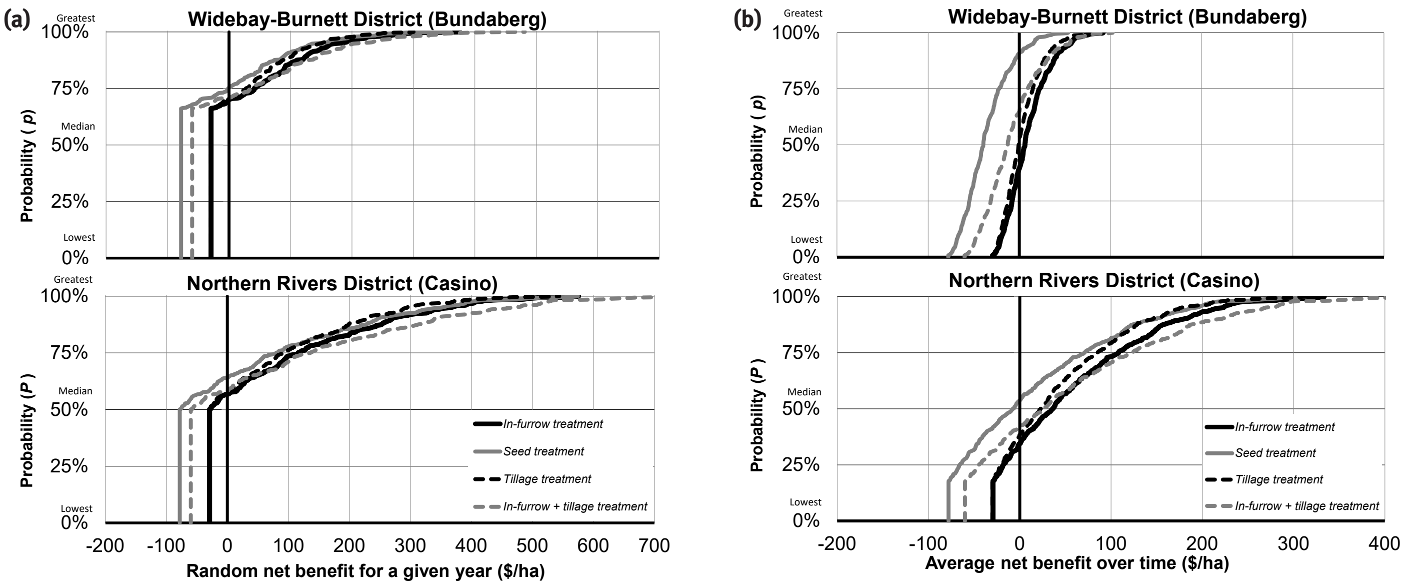

Figure 1. (a) Distribution of potential net benefits in the upcoming season and (b) the range of longer-term averaged net benefits that could occur for each of the LCB treatment options versus *No-treatment*.
P=50% is the expected net benefit, *P*=0% is the worst-case scenario (treatment costs and no economic benefits), *P*=100% is the best-case scenario, where high yield loss was avoided. The vertical line (zero on the x-axis) is the probability of breaking even.

Table 3. The expected (median) net incomes, net benefit, probability of being the best control option, return on investment (ROI), probability of breaking even for different control options in two different regions.

Measurement	Treatment				
	No-treatment	In-furrow	Seed coat	Tillage	In-furrow + tillage
Wide Bay-Burnett District (Bundaberg)					
Expected (*P*=50%) net benefit ($/ha)	NA	$6	-$40	-$1	-$13
Time that control is the best option	39%	59%	0%	0%	2%
Expected (*P*=50%) benefit:cost ratio		0.25	-ve	-ve	-ve
Probability of breaking even		61%	9%	48%	35%
Northern Rivers District (Casino)					
Expected (*P*=50%) net benefit ($/ha)	NA	$37	-$8	$23	$27
Time that control is the best option	34%	28%	0	0%	38%
Expected (*P*=50%) benefit:cost ratio		1.25	-ve	0.78	0.45
Probability of breaking even		66%	46%	62%	58%

For the **Bundaberg** case-study, the BOERA tool estimated the long-term range of possible outcomes, even when risk drivers are not normally distributed (Figure 1b). In the long run the expected net benefit is $6/ha, far better than the expected -$29/ha (being the treatment cost) if you are only considering a single season.

Just like the pokies it possible to get a big win, but it is highly unlikely that this will occur consistently over time; the greatest (*P*=100%) possible net benefit in a single year was >$400/ha, which reduced to <$100/ha long-term.

The chosen treatment will be based on the level of risk aversion to LCB damage. On average, there is little benefit ($6/ha) from the *In-furrow* fipronil treatment even in the long run, but it avoids incurring big losses in a bad LCB year (>$400/ha). From an economic perspective, the only treatment better than the *In-furrow* treatment was the *In-furrow + tillage* treatment, but only when there was very high LCB damage (~2% of the time).

In contrast at **Casino**, in the long-run it is expected the grower would be better off with the *In-furrow* fipronil treatment by $37/ha. The second-best option is *In-furrow + tillage* with a net benefit of $27/ha, then *Tillage*, with a net benefit of $23/ha. While they could be up to $400/ha better off with the *In-furrow + tillage* treatment, the loss under the worst-case scenario is twice that of the *In-furrow* treatment, and there is still a 34% chance of not breaking even. On the upside, treating with no or very little damage is not necessarily a bad outcome, like paying for an insurance policy and not needing to claim.

The 'time that control is the best option' in Table 3 is based on the frequency a treatment offers greatest net benefit (furthest right in Figure 1b). For example, for Casino 34% of the time the *No-treatment* is the best option; the *In-furrow* treatment offered higher net benefits 28% of the time and *In-furrow + till* offered the highest net benefits 38% of the time. The other two treatments were not the best option at any stage.

Although the *In-furrow* treatment had a lower efficacy than the seed-treated option, it resulted in higher net benefits as it had a lower treatment cost. This is also reflected in the expected median benefit:cost ratio (Table 3). In Casino the expected benefit:cost ratios were greatest for the *In-furrow* treatment followed by the *Tillage* treatment and lastly by the *In-furrow + till* treatment. As the tillage treatments returned lower net benefits and cost-benefit ratios, not to mention other agronomic considerations, caution is advised when considering these treatment options.

Severe damage with plant girdled (indicated by arrow).
Insert: Adult in late podfill soybean, prior to emergence.

Considerations

1. When expected long-term net benefits are negative for the best treatment, 2 questions need to be asked:
   a. Can I survive a big LCB hit without treatment?
   b. Can I afford the expected net loss of treatment?
2. This case study used a set of parameters to demonstrate how the tool works and how to interpret the results for on-farm decisions. These results will change for different regions and paddocks. With persistent treatments LCB pressure should decrease and so will the tools input parameters and outputs over time.
3. Last season's treatment and LCB population pressure influences the upcoming LCB population pressure. Likewise, planting a second consecutive soybean crop increases the risk of LCB pressure.
4. If using tillage, it is suggested to do it shortly after harvest to reduce the risk of soil moisture losses.
5. Break crops of non-LCB hosts (e.g. maize, sorghum or mungbeans) may reduce LCB pressure. Pigeon pea, lucerne, phasey bean and sesbania are LCB hosts.
6. Estimated yield losses from LCB are likely to change with planting time (i.e. early vs late varieties).
7. Given the severe damage LCB can inflict, as well as its variable incidence, the Australian soybean industry would benefit from a detailed survey of the pest's temporal and spatial incidence, and the impact of tillage, crop rotation practices and seasonal conditions.

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References

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