Attracting and Killing moths on Bollgard® cotton crops: A New Strategy for Managing *Helicoverpa* spp. on Conventional cotton crops

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Introduction

Cotton farmers, despite the introduction of transgenic (Bollgard®) cotton, continue to grow conventional cotton crops. As a result, *Helicoverpa* spp. remains a major pest on cotton. Subsequently, it is crucial for cotton growers to continue practising Integrated Pest Management (IPM) to minimize over-reliance on synthetic insecticides. To achieve this, there is the need for continue development of integrated pest management tools and strategies that will complement IPM in the cotton industry.

Magnet™ is a blend of synthetic plant volatiles that attracts *Helicoverpa* moths, especially females. Currently, research is determining strategies to utilize this product in cotton pest management. One strategy is to mix Magnet with synthetic insecticides and use the product as attract and kill (Pyke et al. 1987) on Bollgard®) cotton to reduce Helicoverpa populations on adjacent conventional cotton crops.

The study reported here showed that, Magnet™ mixed with insecticide and applied to Bollgard® cotton crops, can reduce populations of *Helicoverpa* spp. on adjacent conventional cotton crops. The study also showed that using Magnet in this way, growers could reduce insecticide use and costs for control of *Helicoverpa* spp. on conventional cotton crops.

Materials and methods

Layout of experiment

The experiment was conducted on irrigated conventional and Bollgard® cotton fields on a farm near Goondiwindi in the Macintyre valley in 2004-05 and 2005-06 cotton seasons. A Bollgard® cotton field (Field 7 (100 ha, Farm A) was selected for treatment with Magnet mixed with insecticide to attract and kill Helicoverpa moths (Figure 1). Six conventional cotton fields (Fields 2 - 7 (Farms B) located perpendicular to the treated Bollgard® field and at distances 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 km away from the Bollgard® field were selected to assess *Helicoverpa* spp. population (Figure 1). The size of the conventional cotton fields ranged from 70-100 ha. The area with and near Magnet® treated Bollgard® fields herewith is referred to as “treated” fields.

At a second location, a Bollgard® field (Farm C) and six conventional cotton fields (Farms D), of similar sizes, all located at least 6 km away from the Magnet® treated Bollgard® cotton field, were selected as control (untreated) (Figure 1).

Application of treatments

A 20 L Magnet™ pack was mixed with 440mL Larvin® 375. The mixture was applied in a narrow (50 cm wide) band on the foliage of single rows of Bollgard® cotton crops at 72 m spacings across Field 7 (Farm A) using a rig fitted to a motor bike. The motorbike speed was between 15-20 km/hr. Magnet mixed with Larvin 375 was applied using the motorbike rig on 26 November and 15 December 2004. A third spray of Magnet mixture was applied on 7 January 2005 using an aircraft. The decision to spray the Magnet mixture on Bollgard® cotton crop was based on consultant and grower observations of moths flying around in the farm. In this paper any mention of Magnet means Magnet mixed with Larvin and used as attract and kill.

Figure 1. Layout of study site at Carbucky near Goondiwindi, 2004-05 and 2005-06

Sampling

Flush counts of adult moths

The adult population of *Helicoverpa* spp. was assessed by flushing moths from plots four by 10 m long in both treated and untreated Bollgard® and conventional cotton crops 24 hours prior to application of Magnet/Larvin mixture.

The flush counts were done by walking 50 m into the field and throwing one handful of dry gravely soil across each 4 X 10 m plot and counting the number of moths that were disturbed and emerged from the canopy. Flush counts were taken at four randomly selected locations in each field.

Dead moth counts

Dead moths were assessed 3 d after each spray by walking 50 m into the crop beside the rows where the Magnet/Larvin mixture was applied. A metre stick was placed in the furrow and all dead moths in that length of furrow were counted. This was repeated at four different locations in the treated and control plots (N/B assessment in the untreated Bollgard® fields was done at 72 m spacing similar to the treated Bollgard® field).

Assessment of *Helicoverpa* spp.

Visual counts of *Helicoverpa* spp. on cotton plants in each of the treatment and control fields were made two times a week on 60 randomly selected cotton plants (equivalent to a 5 m length of row of cotton in each field). Counts of *Helicoverpa* spp. were separated into eggs and larvae.

Management of *Helicoverpa* spp. on treated and untreated conventional cotton crops

The conventional cotton crops in both treated and untreated (control) cotton fields were managed using IPM strategies previously derscribed in the IPM Guidelines (Mensah *et al.* 2005). The decision to spray the conventional insecticide managed plots was based on the economic threshold of two larvae per metre row of cotton.

At the end of the season, the benefit to the grower by using Magnet™ as an attract and kill strategy was calculated for the conventional cotton crops in terms of the number and quantity of insecticides sprayed, cost of insecticides and insecticide application costs relative to the control.

The study was repeated in the 2005-06 season with the same treatments and methods.

Analysis of data

All data were analysed using repeated measures ANOVA (Graphpad Instat Software, Inc., Version 2.03, San Diego, CA, USA). Treatment and sample dates were the independent variables. Tukey-Kramer multiple comparisons tests were used to separate the means.

In the analysis of dead moths, all data collected 3 days after treatment were transformed by (X + 0.5) before analysis. Arithmetic, rather than transformed means are given in the results.

Results

Flush counts of adult moths

Treatment of Bollgard® cotton crops with Magnet™ mixed with insecticides (Larvin®) resulted in suppression of moths after the second application on 14 December 2004 (Figure 2). The moth population in the conventional cotton crops located 0.5 – 3 km away from the treated Bollgard® cotton crop had significantly fewer (P<0.01) moths than conventional cotton crops located at the same distances from untreated (control) Bollgard™ cotton crops (Figure 2). The number of moths in the treated Bollgard® cotton crops was significantly higher (P<0.01) than the untreated Bollgard® crops (control) (Figure 2). Overall, the treated Bollgard® crops recorded the highest number of moths and the conventional cotton crops near the treated Bollgard® crops the lowest number of moths (Figure 2).

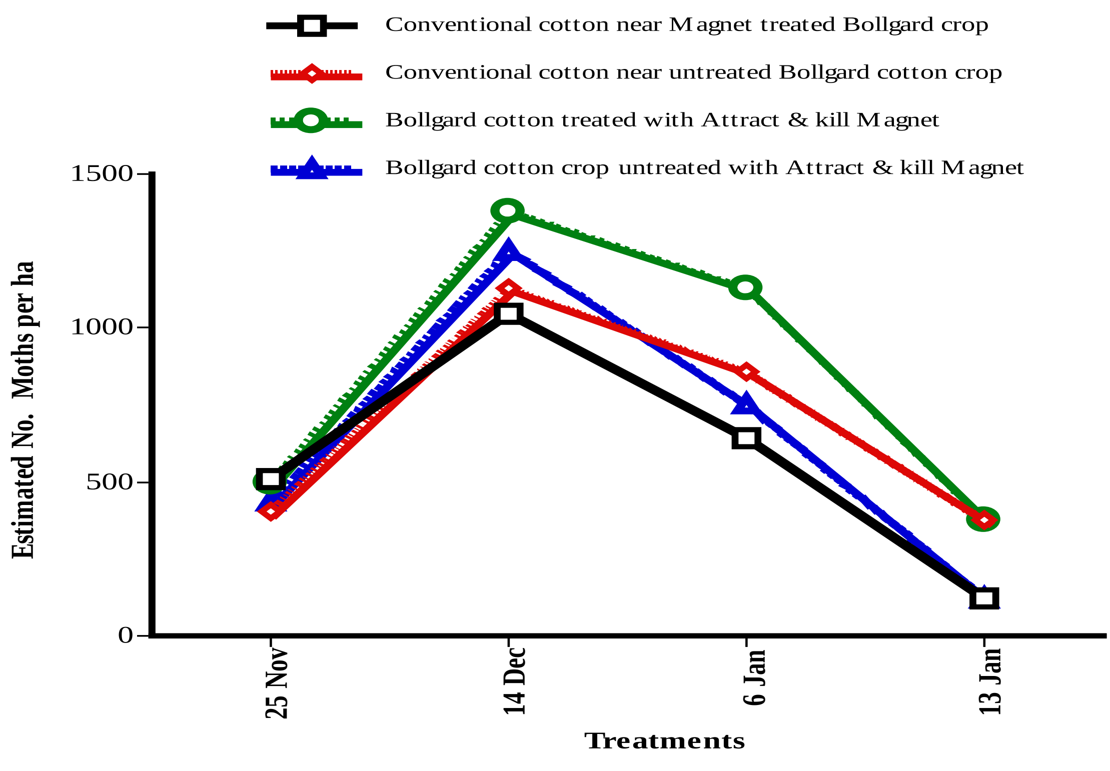


Figure 2. Suppression of *Helicoverpa* spp. on conventional cotton crops located 500 m to 3 km from Bollgard® crops treated with Magnet mixed with Larvin at Carbucky near Goondiwindi in 2004-05

Dead moth counts

Counts of dead moths provide only a rough estimate of the actual death because many of the moths are eaten by ants or falls into holes of the cracked soil. The number of dead moths in the treated

Bollgard® crops was significantly higher (P<0.0001) than those recorded in the untreated Bollgard® crops (control) and the conventional cotton crops (Table 1).

No dead moths were found in any of the plots prior to treatment with the Magnet/Larvin mixture (Table 1). However, at 3 days after treatment at each Magnet application most of the dead moths were found in the treated Bollgard® crops followed by the conventional cotton crops located 500 m to 1.0 km away from the treated Bollgard® crop (Table 1). No dead moths were found in the treated conventional cotton crops located 2 to 3 km away from the treated Bollgard crop as well as the control plots (Table 1).

Table 1. Counts of dead *Helicoverpa* spp. adults found in 1 metre row sample strips treated Bollgard® and conventional cotton fields at Carbucky near Goondiwindi in 2004-05 (*n* = 4 m)

Treatments	Helicoverpa density (dead moths/m)					
	Pre-treatment 25 Nov	3DAT 29 Nov	Pre-treatment 14 Dec	3DAT 17 Dec	Pre-treatment 6 Jan	3DAT 10 Jan
Bollgard® crop treated with Magnet mix with Larvin® (Treated)	0	3.25 a	0 a	4.50 a	0	0.50 a
Conventional cotton field(0.5 km away)	0	0.25 b	0 a	0.50 b	0	0 b
Conventional cotton field (1.0 km away)	0	0.25 b	0 a	0 c	0	0 b
Conventional cotton field (1.5 km away)	0	0 b	0 a	0 c	0	0 b
Conventional cotton field (2.0 km away)	0	0 b	0 a	0 c	0	0 b
Conventional cotton field (2.5 km away)	0	0 b	0 a	0 c	0	0 b
Conventional cotton field (3.0 km away)	0	0 b	0 a	0 c	0	0 b
Untreated Bollgard® crop (Control)	0	0.25 b	0 a	0 c	0	0 b
Conventional cotton field(0.5 km away)	0	0 b	0.25 a	0.25 bc	0	0 b
Conventional cotton field (1.0 km away)	0	0 b	0 a	0 c	0	0 b
Conventional cotton field (1.5 km away)	0	0 b	0 a	0 c	0	0 b
Conventional cotton field (2.0 km away)	0	0.25 b	0 a	0 c	0	0 b
Conventional cotton field (2.5 km away)	0	0 b	0 a	0 c	0	0 b
Conventional cotton field (3.0 km away)	0	0 b	0 a	0 c	0	0 b

Means within columns followed by the same letter are not significantly different (P>0.05), Tukey-Kramer multiple comparison test (DAT = days after treatment)

Helicoverpa spp. assessments on treated and untreated Bollgard® crops

Eggs and larval counts

The study showed that the number of eggs laid on the Bollgard® cotton crop treated with Magnet mixed with Larvin was significantly higher (P<0.001) than the number of eggs per metre recorded on the untreated Bollgard® cotton crops (Figure 3). The number of eggs recorded on the treated Bollgard® cotton crops ranged from 5-30 per metre compared with 0-10 per metre on non-Magnet treated Bollgard® crops (Figure 3).

Despite the high number of eggs recorded on the treated Bollgard® crops, the number of larvae per metre was not significantly different (P>0.05) between the treated and untreated Bollgard® crops (Figure 3). The number of larvae recorded on both treated and untreated Bollgard® cotton crops ranged from 0 – 0.5 per metre (Figure 3) indicating that any eggs that might have hatched on the Magnet treated Bollgard® crops were killed by the Bollgard® toxin.

In contrast to the results achieved in 2004-05 season, Helicoverpa moth numbers during the 2005-06 season were very high and similar among treatments. As a result of the high Helicoverpa pressure, no differences in egg lay and larvae were detected in treated and untreated Bollgard® cotton crops.

Helicoverpa spp. egg and larvae on treated and untreated convention cotton crops

The study showed that the conventional cotton crops located close to the Bollgard® crop treated with Magnet™ mixed with Larvin® had significantly lower (P<0.01) *Helicoverpa* spp. eggs and larvae than the conventional cotton crops close to the non-Magnet™ treated Bollgard® cotton crop (Figure 4). After first application of the Magnet, the number of *Helicoverpa* spp. eggs recorded on the conventional cotton crops located near the treated Bollgard® cotton crops ranged from 0.5-2.5 per metre compared to 5.0-10.0 per metre recorded on the conventional cotton crops located near the non-Magnet™ treated Bollgard® cotton crops. The number of larvae ranged between 0.5 – 2.0 per metre (treated conventional crops) and 0.5 – 3.5 per metre (untreated conventional crops).

In the treated conventional cotton crops, *Helicoverpa* spp. eggs and larvae per metre were not significantly different (P>0.05) from conventional crops located 0.5 - 1.0 km away from the treated Bollgard® field but was significantly lower (P<0.001) than conventional crops located 1.5 to 3.0 km away (Figures 4 and 5). However, *Helicoverpa* spp. eggs and larvae per metre recorded on the untreated conventional cotton crops were not significantly different (P>0.05) (Figure 5).

In 2005-06 season, we detected no significant differences (P>0.05) in the number of eggs and larvae on the treated and untreated conventional cotton crops. This may be due to the high *Helicoverpa* spp. pressure experienced in study site.

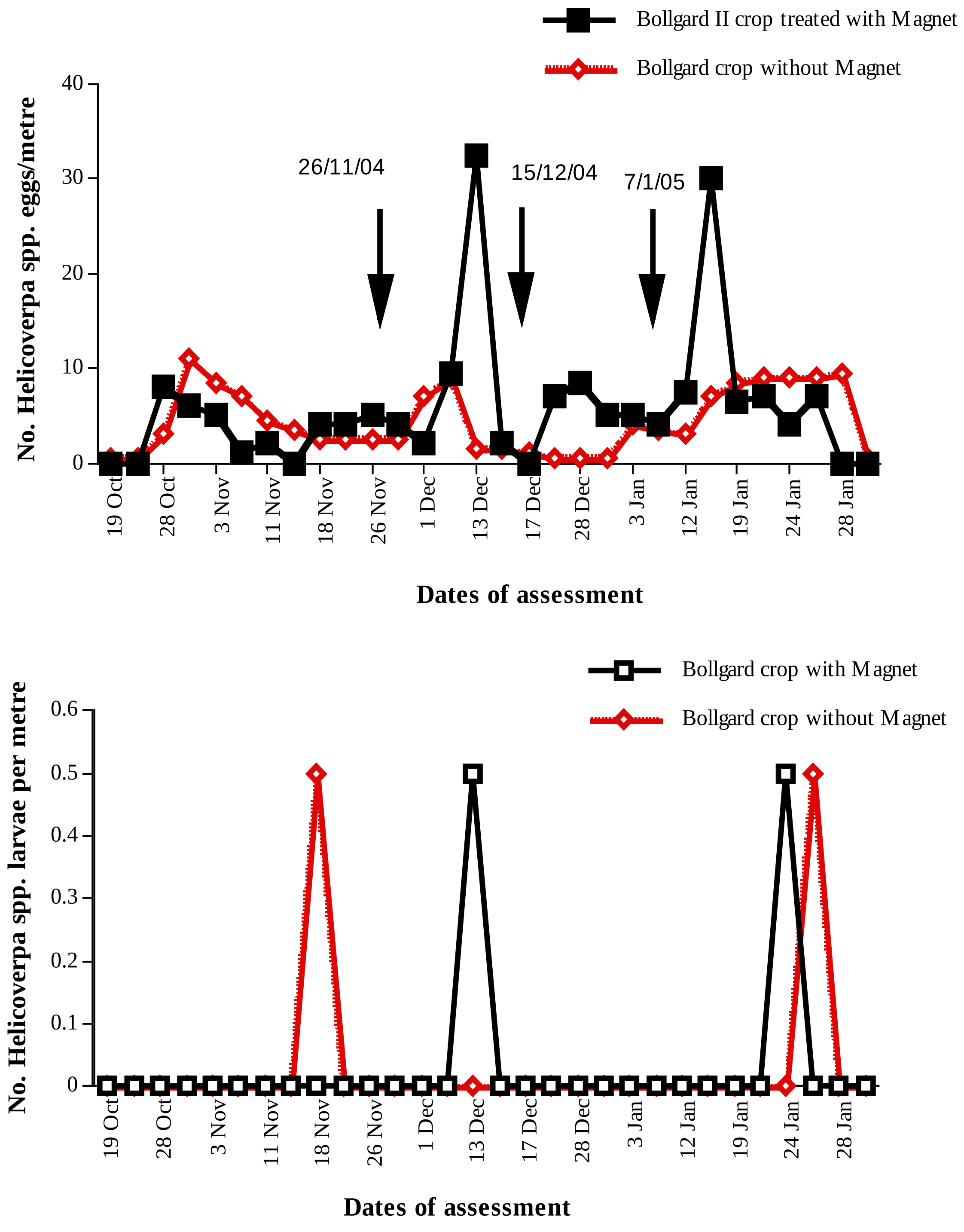


Figure 3. Effect of application of Magnet® mixed with Larvin on Bollgard® cotton crops on oviposition and larval survival of *Helicoverpa* spp. at Carbucky near Goondiwindi in 2004-05.

Management of *Helicoverpa* spp. on treated and untreated conventional cotton crops

An IPM program was used to manage *Helicoverpa* spp. on both treated and untreated conventional cotton crops. The products used were Canopy® oil, Dipel® (Foliar Bt), Tracer®, Steward®, Affirm® and Pegasus®.

Application of sprays on the treated conventional cotton crops commenced on 23 November 2004 and the last spray occurred on 23 March 2005. In contrast, the first spray applied to the untreated conventional cotton crops was on 1 December 2004 and the last spray on 2 April 2005.

The number of spray products (biological and insecticides) applied to both the treated and untreated conventional cotton crops were the same (8 for the season). However, since *Helicoverpa* spp. populations on the treated conventional crops were often lower than the untreated crops, the pesticide products used were usually applied at half the label rate mixed with Canopy® oil. In contrast, full label rate of pesticides mixed with Canopy® oil were applied on the untreated conventional cotton crops on each spray application. This resulted in a grower benefit of $20 per hectare on the treated conventional cotton crops over the untreated conventional crops.

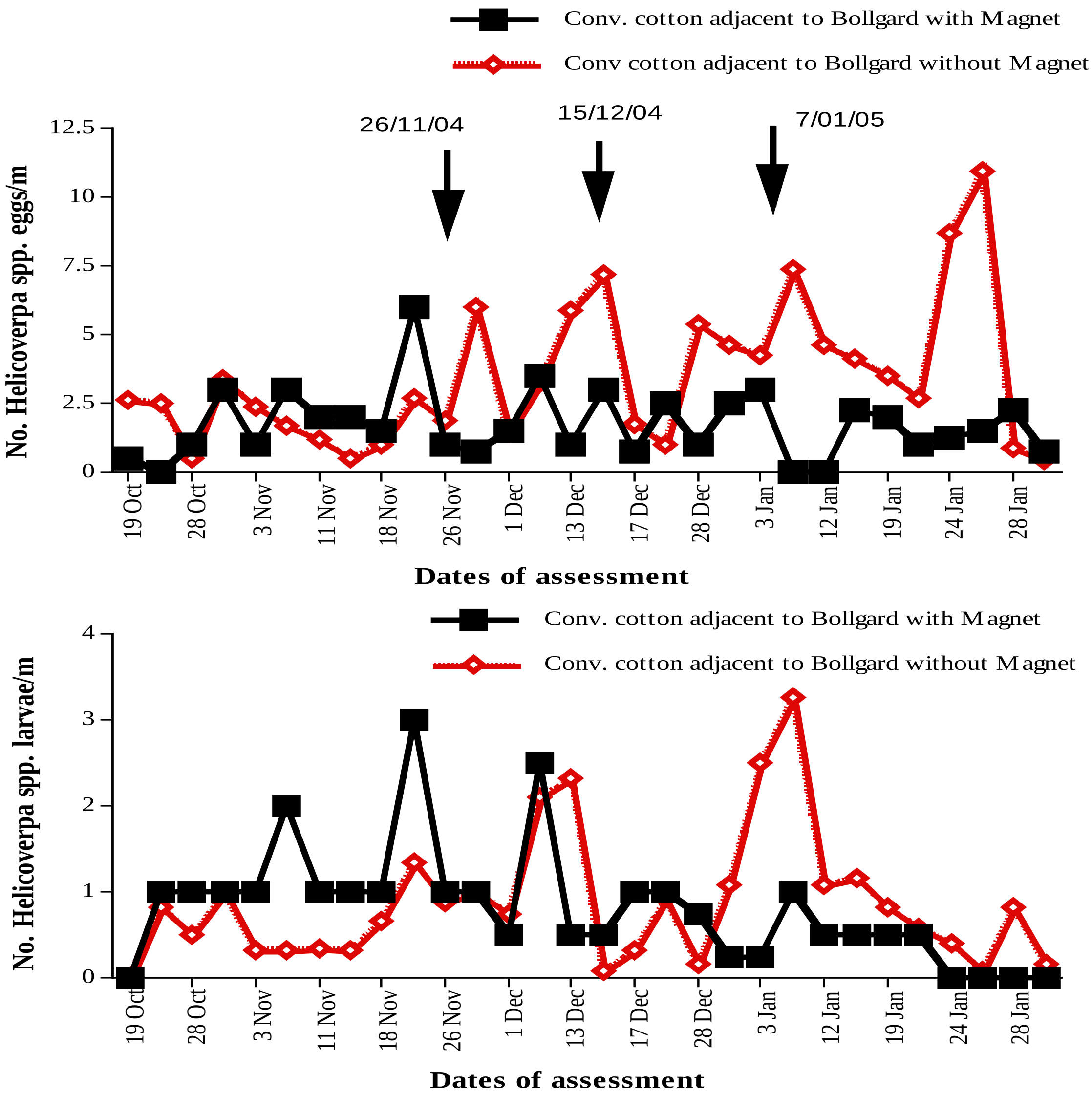
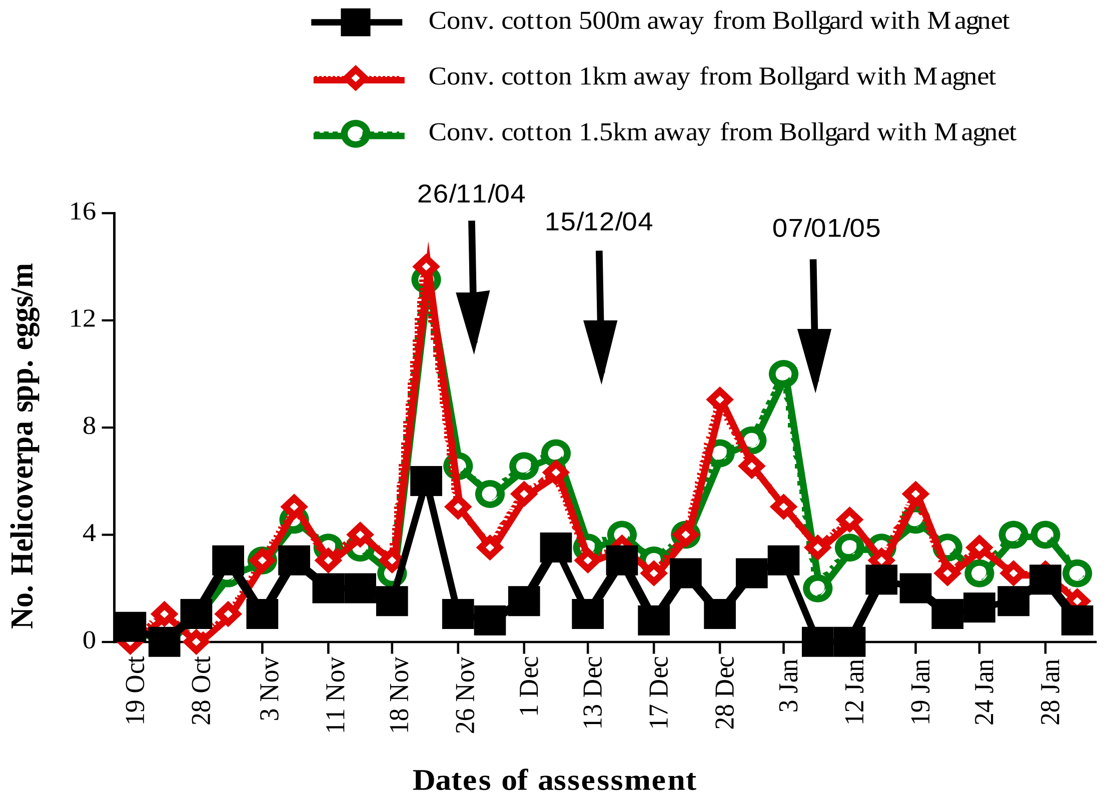


Figure 4. Effect of application of Magnet™ mixed with Larvin® on Bollgard cotton crops on *Helicoverpa* spp. oviposition and larval survival on conventional cotton crops located at 500 m away from Magnet™ treated and untreated Bollgard® crop at Carbucky near Goondiwindi in 2004-05.



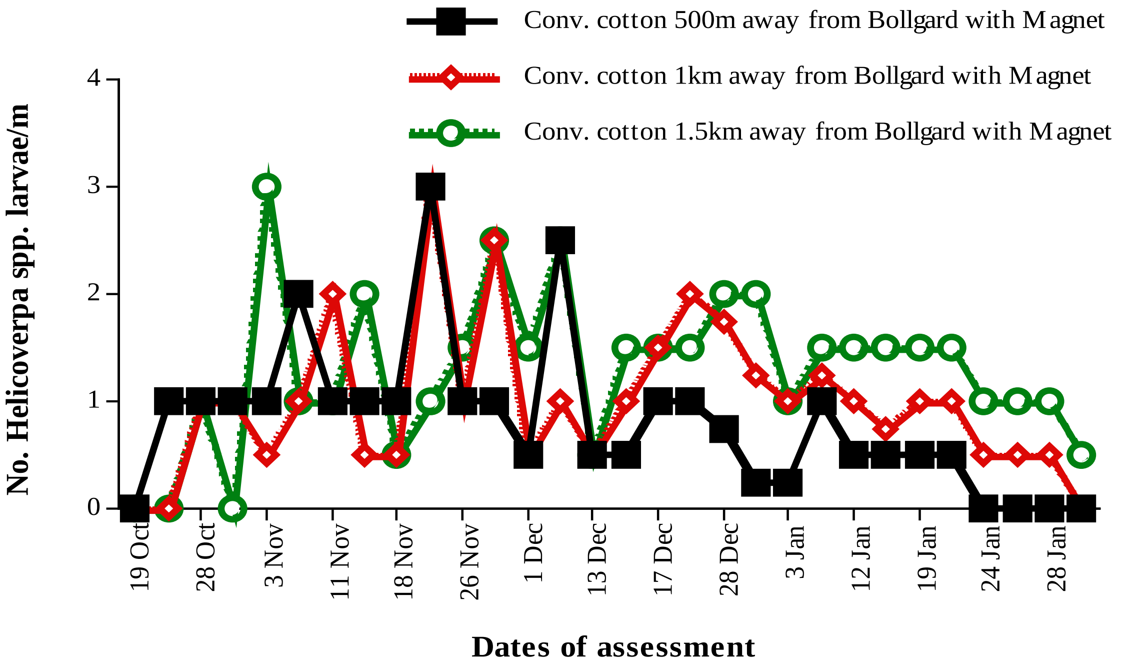


Figure 5. Effect of application of Magnet™ mixed with Larvin® on Bollgard cotton crops on *Helicoverpa* spp. population on conventional cotton crops located 0.5, 1.0 and 1.5km away from the Bollgard® crop at Carbucky near Goondiwindi in 2004-05

DISCUSSION

The study showed that Magnet™ applied as attract and kill on Bollgard® cotton crops can reduce *Helicoverpa* spp. populations on adjacent conventional cotton crops. After the first application of the Magnet™ mixed with insecticide (Larvin®) on Bollgard cotton crops, the number of Helicoverpa eggs per metre recorded on adjacent conventional cotton crops was 4-10 times less than the that recorded on conventional cotton crops adjacent to untreated Bollgard® cotton crops (control). Similarly, the number of larvae per metre was 1.75 times less on the treated compared to the untreated conventional crops.

Regarding the Bollgard® crops, the treated Bollgard® crops had 3-5 times higher numbers of eggs per metre than the untreated Bollgard® cotton crops. The higher number of eggs recorded on the treated Bollgard® crops could mean that *Helicoverpa* spp. female moths that were attracted and killed with Magnet™ mixed with Larvin® on Bollgard® crop (1) were mated females and (2) laid eggs on the Bollgard® crop before they fed and died. Nevertheless, the number of larvae per metre recorded on the treated Bollgard® crops was the same as on the untreated Bollgard® crops. This indicates that the Bt toxin might have killed any larvae that hatched from the eggs laid on the treated Bollgard® crops. Application of Magnet™ on Bollgard® crop in this way will not put any undue resistance pressure on the Bollgard® technology.

In our opinion, the cost of cotton production in Australia is too high and looking at the current world cotton prices, growers need a way to reduce their production costs. In this study, the benefit to the cotton grower of using Magnet as attract and kill on Bollgard® cotton crops was the reduction in *Helicoverpa* spp. pressure on adjacent conventional cotton crops. The grower acheived $20 per hectare in the cost of insecticide use on the conventional cotton crops adjacent to the Magnet™ treated Bollgard® cotton crops over the conventional crops adjacvent to the untreated Bollgard® crops. This benefit may vary between season depending on *Helicoverpa* spp. pressure. At high *Helicoverpa* spp. pressure year, as experienced in 2005-06 season, no benefit was gained by using Magnet™ in an attract and kill strategy on Bollgard® cotton crops. This is because there were so many moths in the study site that all of them could not be attracted at once and killed. Residual moths were found across the conventional cotton crops resulting in over 50 eggs per metre (average) recorded in the mid and late season sampling. Both treated and untreated conventional crops recorded very high numbers of *Helicoverpa* spp. eggs and larvae.

In conclusion, the study has shown that using Magnet™ in an attract and kill strategy on Bollgard® cotton crops can help to reduce *Helicoverpa* spp. populations on adjacent conventional cotton crops, resulting in a cost saving to the grower.

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