# Moth Busting for Bt Resistance Management

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## Summary

Targeting the last generation of *Helicoverpa armigera* that typically escape cotton fields prior to pupae busting with the use of summer trap crops has been an integral component of the central Queensland *Bt* resistance management strategy. A superior method for targeting these escapes might be to use area-wide applications of the attract and kill product Magnet® on late season cotton fields. Experiments that aimed to assess the potential efficacy of area-wide applications of Magnet® laced with insecticide for *Helicoverpa* moth control in the Dawson Valley suggest considerable potential for such a strategy with significant reductions in *Helicoverpa* being recorded after each application. Further experimentation to test the validity of area wide Magnet® applications as an alternative strategy to trap cropping will be conducted during the 2006/07 season. This paper outlines the progress of the research to date.

## Background

Growers of Bollgard® cotton varieties in central Queensland (CQ) are required to undertake a number of preventative resistance management actions. Typically this involves growing an unsprayed refuge of pigeon pea with an additional later sowing of pigeon pea as a trap crop. The refuge generates additional susceptible *Helicoverpa* to dilute potentially insecticide-resistant individuals emerging from Bollgard® crops whilst the trap crop attracts the last *Helicoverpa* generation to emerge from cotton so that potentially resistant offspring can be confined and destroyed with cultivation (Sequeira 2001).

The trap cropping strategy has been implemented in CQ since 1997. Patches were required to comprise the greater of 1% or 2 hectares of total farmed area. These patches are sown with pigeon pea after the main cotton crop is established and are ideally managed so that the trap crop is at peak attractiveness to *Helicoverpa* moths as the cotton crop enters post cut out decline (Sequeira 2001). In the 8 years since the introduction of this strategy, several complications have emerged. Firstly the efficacy of trap crops for attracting *Helicoverpa* moths emerging from adjacent cotton fields and capturing their progeny has been difficult to quantify. Secondly the drought conditions of the last 4 years have resulted in some growers not irrigating pigeon pea trap crops in a manner that ensured correct timing of peak attractiveness. Thirdly weed management in pigeon pea has been problematic. The efficacy of poorly irrigated or weedy pigeon pea trap crops is questionable.

With the dependence on Bt varieties likely to remain well into the foreseeable future, the need to seek improvements to the current resistance strategy will remain a research priority. Trap crops represent a potential weak link within the Bt resistance management strategy for CQ. However, alternative methods for targeting end of season moth escapes have not existed until the recent development of the attract and kill product Magnet®, that when laced with insecticide and applied to crop foliage works to lure foraging moths with plant volatiles to feed on toxic residues.

With the imminent commercialisation and registration of Magnet®, potential exists to develop an alternative strategy to trap cropping for targeting last generation *Helicoverpa* spp moth populations. The application of Magnet® in widely spaced strips to all Bollgard® fields within a region post crop cutout with a view to "busting" moths as they emerge may offer the following advantages:

**Strategic** – Can be better timed to coincide with the emergence of last generation moths.

**Direct** – Kills female and male resistance gene-carrying moths directly and it takes the trap to the source crop rather than being remotely located.

**Measurable** – Unlike trap cropping, the impact of Magnet® on local *Helicoverpa* populations can be measured.

**Economic** – Magnet® cost is offset by savings from not trap cropping.

**Uniform** – The whole region would be treated at the same time in the same way.

**Easy** – The product can be applied aerially.

**Proactive** – The CQ industry will have a refined unique strategy and be seen as taking proactive responsibility in preserving Bt technology.

This paper details the first part of an ongoing experiment to examine the potential area-wide deployment of Magnet® to target *Helicoverpa* populations on a regional scale.

## Materials and Methods

### Pilot Study 2004-05 Season

An initial pilot study was conducted in the Dawson Valley to examine the potential impacts of treating a large discrete area of cotton with Magnet®. Two 800 hectare patches of Bollgard® cotton approximately 5 km apart (separated by pastoral and native vegetation) were chosen for the experiment. Magnet® mixed with methomyl was applied by aircraft on the afternoon of 15 February 2005 to one of the patches (Gibber Gunyah district) in 1 metre wide bands, spaced approximately 72 m apart over the entire area.

*Helicoverpa* spp. moth populations were assessed pre and post treatment using light traps and flush counts. Four light traps were placed randomly in each of the two treatment patches and cleared of insects daily. Each trap's contents were stored in ethanol and returned to the laboratory for later examination. Flush counts were made on randomly selected fields throughout the two patches every 1-2 days to estimate moth densities per hectare of cotton. Flush counts were conducted by throwing handfuls of soil at the crop along a 100 m transect and counting *Helicoverpa* moths as they emerged. The flush count technique was initially "calibrated" by following disturbed moths and identifying them, indicating that at least 85% of the flushed moths were likely to be *Helicoverpa* species. Eight transects were conducted in each of the two patches on each sampling occasion.

### 2005-06 Experiment

A more intensive experimental design was used for the study in the 2005-06 season to overcome the logistical problems of replication over large areas and possible interactions between the Magnet® treated patches and the control. Replication of the treatments over time and two additional treatments were used. Additional treatments consisted of a Magnet® without insecticide treatment to allow for comparison with the Magnet®/Insecticide treatment without the influence of any direct or indirect sink effects as well as two control patches, one remote (15 km away) and the other directly adjacent to and within 5 km of the Magnet® treated areas (Figure 1). Each of the treatment areas comprised of approximately 800 hectares of cotton that were separated from each other by pastoral land and native vegetation.

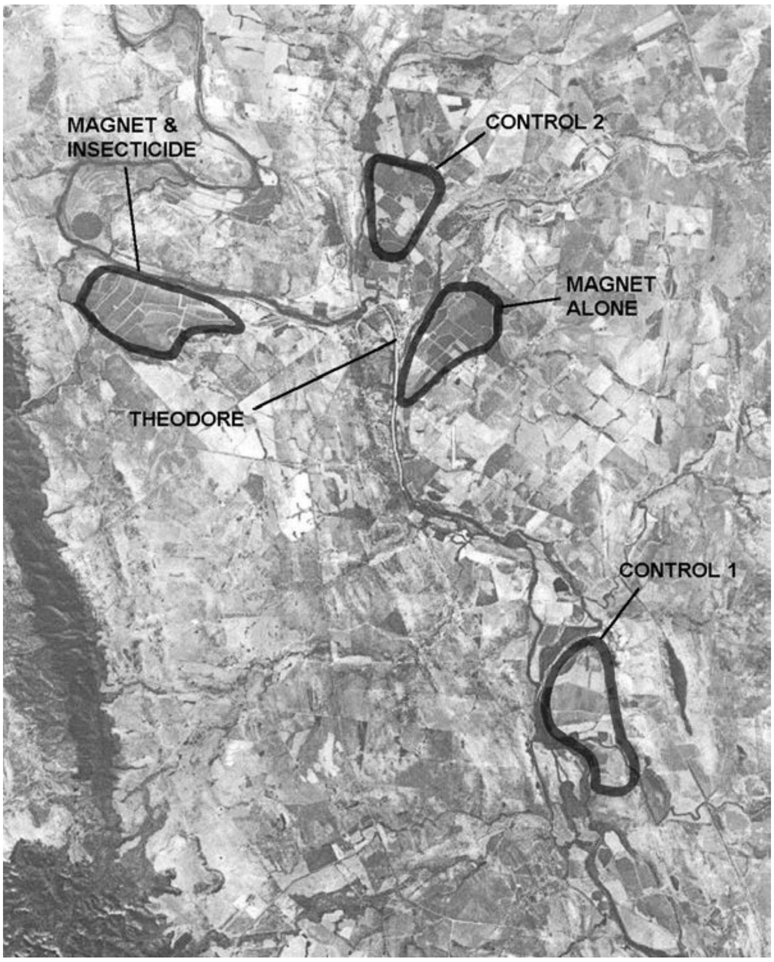


***Figure 1***. An aerial photo showing the Theodore channel irrigation area showing the approximate location of the two Magnet® treatment areas as well as the distant (control 1) and nearby controls (control 2).

Magnet® treatments commenced once the crop had reached row closure and moths had become abundant in the region. Consecutive treatment applications were then made once the impacts of the previous treatment had ceased across the 4 patches. The first application of Magnet was made on 5 Dec 2005 with the treatments being applied aerially in 1-2 metre wide bands spaced approximately 145 m apart (twice as widely as the label recommended distance). Thiodicarb was used as a mixing partner at the Magnet label recommended rate. A second treatment was conducted on 12 Dec 2005 using the same application method. No further treatments could be made due to a lack of moths in the region after this time.

Moth populations were monitored using the same techniques as for the pilot study. *Helicoverpa* spp. egg densities per metre of crop row were recorded on Bollgard ® crops throughout the 4 treatment patches during the experiment. 15 patches of conventional cotton (8 rows by 50 metres) not treated with any insecticides were established randomly throughout the two Magnet® treatments and the distant control to also examine if the repeat applications of Magnet® had any influence on pupae recruitment over time. Sampling for pupae was conducted every 2-3 weeks during the season.

## Results

### Pilot Study 2004-05 Season

The Magnet® treatment had an immediate impact on moth population densities with a reduction of 97% recorded during the first 48 hours post-treatment (Fig 2). Light trap catches during the experiment also suggested a reduction in *Helicoverpa* numbers post-treatment compared to the control (Fig 3). A similar impact was also recorded for *Spodoptera litura* (a secondary cotton pest) — of which the larvae were observed abundantly throughout Bollgard® II crops during the 2004/05 season (Fig 4).

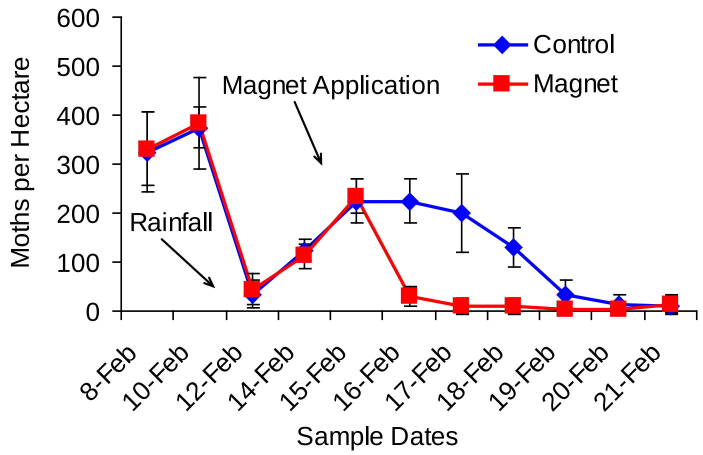


**Figure 2.** The mean estimated number of *Helicoverpa* moths recorded per hectare using flush counts in the control and Magnet® and insecticide treatment areas.

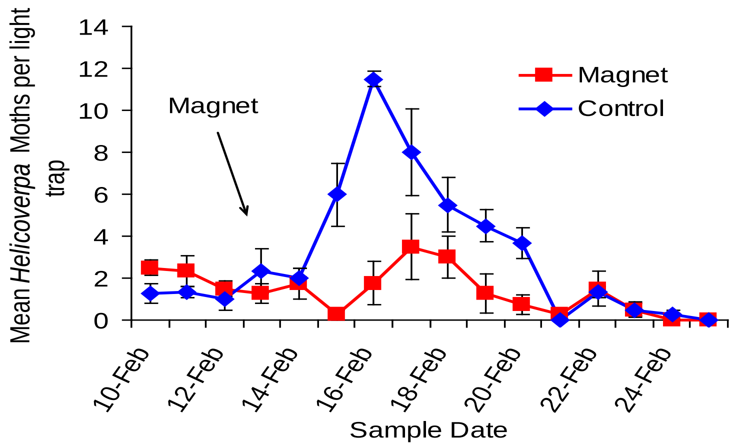


***Figure 3***. Mean number of *Helicoverpa* moths caught per trap in the control and Magnet® and insecticide treatment areas.

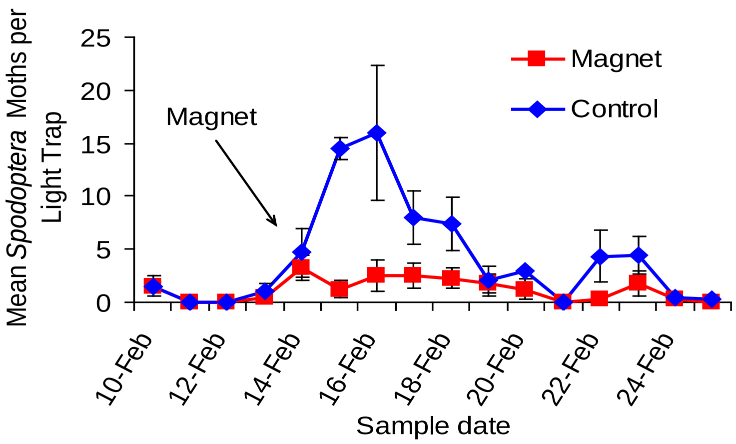


***Figure 4***. Mean number of *Spodoptera litura* moths caught per trap in the control and Magnet® and insecticide treatment areas.

**2005-06 Experiment**

The Magnet® treatments were applied twice during the first half of the season after which moths became scarce throughout the region, preventing additional applications. The first two applications coincided with the presence of *H. punctigera* that were probably migrating into the region at very high densities during a period of north-westerly wind patterns during December. Collections of dead moths from the Magnet®/insecticide treated area suggested that the populations during the period of the first two applications consisted of >90% *H. punctigera* with the remainder being *H. armigera*.

The application of Magnet® both with and without insecticide caused significant changes to the local moth densities compared with the untreated controls. Significant increases in moth density were observed following the application of Magnet® WITHOUT insecticide on each occasion. Alternatively, significant decreases in moth numbers observed when Magnet® was applied WITH insecticide compared to either control (Fig 5). This contrast is best illustrated by Figure 6. These results are particularly striking when it is considered that the application rate of Magnet® was half the recommended rate

The oviposition trends observed in each of the treatment patches over time exhibited similar patterns to those recorded for moth abundance (Fig 7). However, the rate of oviposition was very low in compared to the high numbers of moths recorded in the area at the time. Pheromone traps placed throughout the area for both *Helicoverpa* species failed to capture any *H. punctigera* moths despite their high abundance. A collection of 200 eggs was conducted on 15 December and returned to the laboratory and grown out for identification. Of those that successfully hatches and allowed subsequent identification, 88% were *H. armigera*.

Sampling conducted in each of the 15 unsprayed conventional cotton patches found very few pupae of which none were viable (all either diseased or parasitised).

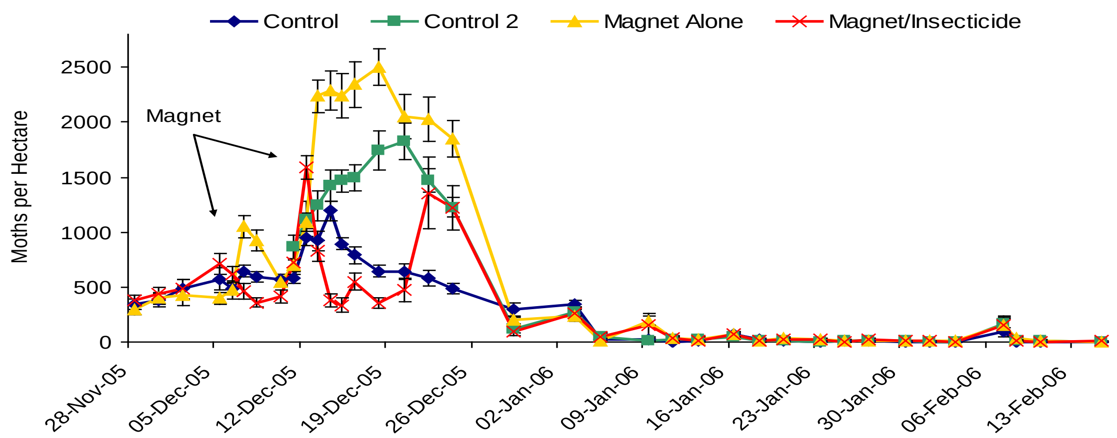


**Figure 5**. The mean densities of moths per hectare assessed using flush counts in both controls and the Magnet® with and without insecticide treatments. Sampling in the control 2 was commenced later than the other three areas when it was recognised that a nearby second control would provide an additional comparison to the more distant first control area.

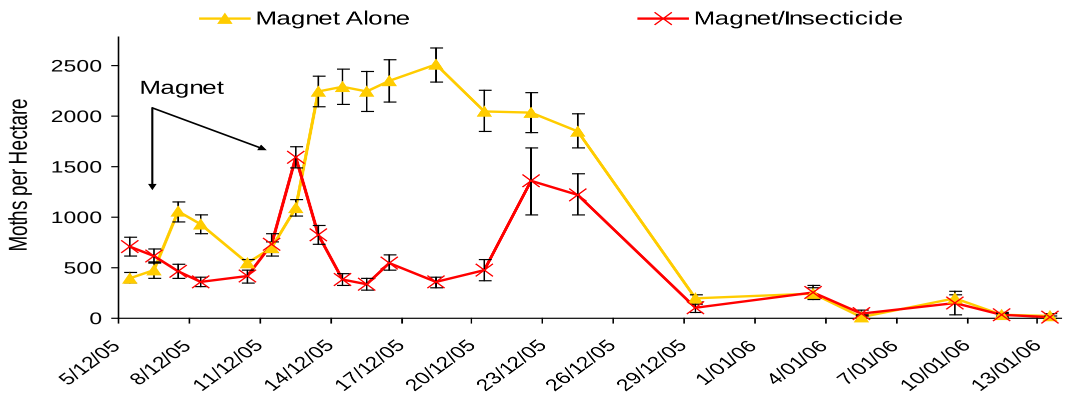


**Figure 6**. The same data as for figure 5 with the two controls omitted. The two treatments depicted are the use of Magnet® with and without an insecticide.

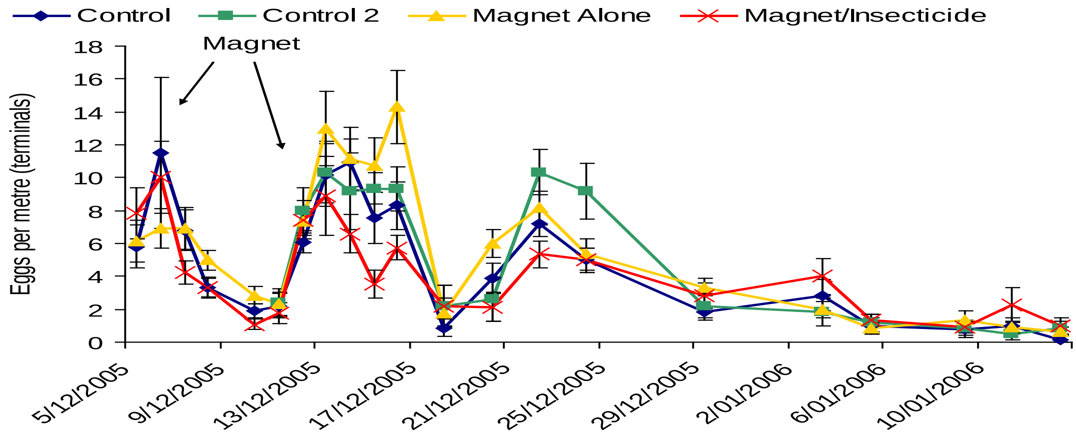


**Figure 7**. The mean densities of *Helicoverpa* spp. eggs laid on the terminal shoots per metre of crop row in both controls and the Magnet® with and without insecticide treatments. Sampling in the control 2 was commenced later than the other three areas when it was recognised that a nearby second control would provide an additional comparison to the more distant first control area.

## Discussion

The results from each experiment suggest that Magnet® laced with insecticide and aerially applied over large areas caused significant reductions in *Helicoverpa* moth densities. The pilot trial in 2005-06 suggested that Magnet® caused an immediate large decrease in moth populations throughout the treated area. The patterns of moth abundance in response to the application of Magnet® with and without insecticides provided additional insight on the impacts of area-wide applications. Whilst the application of Magnet® with insecticide on each occasion gave significant reductions in local moth densities, the application of Magnet® alone at the same time suggested that the product also served to attract or retain additional moths within the treated area, potentially masking the real treatment impact.

The question of whether Magnet® served to attract additional moths or just retained a high proportion of the moths passing through the region at the time of treatment is not entirely clear. The apparent lack of influence that the Magnet® had on the controls during the experiment further suggest that the patterns observed were more likely to be a function of retaining migrating moths rather than attracting moths away from nearby cropping areas such as control 2. Further experimentation is planned for 2006/07, which may provide further insights on these processes.

The low egg densities recorded on the Bollgard crops compared to the very high numbers of moths observed within the region during December was unusual (Fig 2 & 4). Identification of dead moths collected off the ground from the Magnet®/insecticide treated area suggested that the 90% or more of the moths inhabiting the region during December were *H. punctigera*. Yet of the eggs collected during the same period 88% of the progeny were *H. armigera* suggesting that the high densities of *H. punctigera* were generally reproductively inactive whilst passing through the area. This conclusion is possibly further supported by the total lack of response by *H. punctigera* moths to sex pheromone traps located throughout the area during the December period (data not presented here).

It was anticipated that the impact of the Magnet® might have been detectable in terms of changing pupae recruitment over time. However, the complete absence of viable pupae in the 15 patches of conventional cotton prevented comparisons. Observations within the unsprayed cotton plots suggested that beneficial insects were very abundant as well as epizootics of NPVs. The natural mortality induced by these agents combined with the generally low levels of oviposition may explain the lack of viable pupae.

In terms of treatment response, the first application had less impact than the second during the 2005-06 experiment. The main factors for the observed difference in performance may be explained by the greater losses of applied product due to the younger crop (reduced canopy leaf area) and the advent of rainfall 3 days after application, as well as lower than recommended application rates. With regard to utilising regional applications of Magnet®, there would be more than sufficient crop canopy to capture aerially applied Magnet® on late season crops. However, the susceptibility of Magnet® to post-application dilution from rainfall could be a significant problem for which risk management strategies would need to be developed should such a strategy be implemented.

The lack of continued moth activity during January and February prevented further applications and therefore our results at this stage are incomplete. Further experiments are planned for the 2006/07 season and it is anticipated that these will provide sufficient data to project the likely impacts for using Magnet® as an area-wide moth busting tool and its potential for end of season *Bt* resistance management.

It is also anticipated that when complete, these results may also be utilised to project the potential benefits for using attract and kill technologies for other population manipulation purposes. This might include relieving the pressure from Bollgard during peak *Helicoverpa* activity periods such as was observed in many regions during the 2005/06 season or for manipulating refugia strategies.

At this stage the use of Magnet® for regional management of *Helicoverpa* appears to be highly promising. Future research will consolidate these finding and focus on scientific and technical questions.

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