



SUMMER SCHOLARSHIP

Final Report

Part 1 - Summary Details

Cotton Catchment Communities CRC Project Number: 5.10.03.41

**Project Title: Keeping Pest Populations Lower for Longer:
Capturing the Benefits of Native Vegetation**

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Part 3 – Scholarship Report

Executive Summary:

The relative timing of pest and beneficial arrival in the crops, and how the landscape context facilitates or hinders colonization processes is thought to be one of the key processes of lower pest populations. Early removal of pests avoids future damage, and often more importantly, it avoids future damage by the pests' offspring. Using crop scouting reports from the Border Rivers region of 4 fields with either low (<2%) or high (<20%) surrounding native vegetation, we evaluated for focal pests the: a) number of days to reach threshold, b) number of days above threshold, and c) number of above-threshold events. Our results show that pest population rarely reached threshold; only four species broke threshold for a total of 31 times in four years. We found no difference in the number of days to reach threshold between the two native vegetation treatments. However, there was a slight trend for aphids and Green Vegetable Bug (GVB) to spend more days over threshold in fields with low native vegetation (LNV) than in fields with high native vegetation (HNV). The opposite was true for plants infested with mites, which were above threshold for more days in fields with HNV. When considering all of the times that pest populations went above threshold, the LNV fields had an average 'broken-threshold' score twice as high as the HNV fields, and by comparison three organic cotton fields only broke threshold on average once a year. Further, when considering natural enemies, there was a significant but weak correlation between predatory beetles and aphids in HNV fields, but not in LNV fields.

Ultimately this work was undertaken to evaluate the merit of simple measures to capture the value of native vegetation for the ecosystem services of pest control. Although additional study should be undertaken, the results have identified that there is scope to change crop scouting sheets for better capture of information to measure the value of native vegetation, and provide spray decision guidance. The new crop scouting report format could incorporate a section to track population trends of pests and beneficials over time, also allowing for easy accounting of the above measure. The results from this project suggest that these simple measures have merit when trying to link effects from native vegetation with the ecosystem services of pest control, but an investigation of more fields and regions is warranted.

Background:

Cotton pest management in Australia:

Cotton comprises roughly about 40% of the world's natural fibre production, with is grown commercially in about 78 different countries (Naranjo, 2011). Inhabiting these crops are roughly 1300 different herbivores insects, however only a small proportion of these are considered of economic threat (Naranjo, 2011). Due to the large presence of insects and the fragility of cotton, it is of no surprise that cotton growers are the largest users of insecticides worldwide (Perovic et al 2010). Given the large presence of insect pests, the development of *Bt* cotton technology was rapidly embraced. The development of *Bt* cotton was designed to combat lepidopteran pests, as the activation of the crystal (Cry) proteins is triggered by specific receptors and the conditions in the

caterpillars gut (Naranjo, 2011). This technology was initially used to target *Helicoverpa* spp. and *Heliothis* spp., but was found to affect around 30 different lepidopteran pests (Naranjo, 2011). Initially *Bt* cotton only contained one cry protein, however *Bt* cotton has now been developed to contain two different Cry proteins (Bollgard II) expressed in the plant (Naranjo, 2011). This development has assisted in preventing the establishment of insect resistance to the Cry protein (Naranjo, 2011).

Bt Cotton has only been grown in Australia commercially since 1996, and is commercially grown from 12° latitude from Emerald to Murrumbidgee (Cotton Australia 2012). Typically cotton properties are large cleared areas, mostly monocultures, which are often situated near a water source, due to the watering need of the plant (Perovic *et al.* 2010). However, due to the recent economic increase in the value of cotton, many growers are now moving to dry land cotton. Over 400 species of insects are found in Australian cotton (Room 1979). Of these, a couple dozen are pests, and in the past have been managed with synthetic insecticides (Cotton CRC & Australian Government 2005). This over dependence on insecticides has created huge problems in the development of insect resistance, and the disruption to non-target insects (Farrell 2006). These problems have cast doubt over conventional pest management strategies, prompting recent move towards Integrated Pest Management (IPM) by the cotton industry with the aim of minimising insecticide dependence, whilst still producing profitable yields (Farrell 2006). The current operational definition of IPM developed by the United Nations Food and Agriculture Organisation (UN-FAO) can be found in Appendix 1.

IPM involves a myriad of tool and strategies that are crucial to its success; these have been summarized into seven main points for managing pests by Cotton CRC & Australian Government:

1. Growing healthy crops
2. Monitoring pest damage
3. Use Beneficial insects
4. Use insecticides responsibly (prevent insecticide resistance)
5. Manage crop and weeds
6. Use trap crops appropriately
7. Support IPM through communication and training

Part of using insecticides responsibly involves avoiding un-warranted sprays. These include sprays applied without monitoring the crop, or applied before pest threshold is reached. Whitehouse (2011) showed that there is no yield gain when spraying before threshold is reached, and in fact, pre-threshold sprays often results in growers having to respray again later in the season. Unwarranted sprays can also exacerbate insect resistance. The threshold level can be viewed as a decision support tool to give growers confidence that spraying before threshold is a waste of money, because pest numbers are not causing injury leading to economic harm (Whitehouse, 2011). In fact, some damage from pests results in yield gains (Wilson *et al* 2003) Following thresholds and using targeted insecticides that are soft on beneficial insects is a key part of IPM.

Ecosystem service of pest control

As well as the large diversity of herbivores that inhabit cotton, these crops also support a diverse array of beneficial (these are the natural enemies, predators and parasitoids, of pest species; Room

1979, Riechert 1984). These beneficials assist in maintaining potential pests from causing economic injury, and contribute in controlling perennial key pests (Riechert 1984). These insects play an integral component in effectively managing pests of cotton (Australian Cotton Cooperative Research Centre 2002). Because beneficial insects can effectively suppress populations of a wide range of insect pests, the vast majority do not reach outbreak levels in crops. The value of this pest control service is estimated at more than US\$ 400 billion per year worldwide (Costanza *et al.* 1997). However there are many agricultural practices that can compromise this ecosystem service, including extensive clearing of perennial habitat and heavy use of insecticides. The presence of perennial non-crop habitats, such as native remnants, are thought to play a crucial role in maintaining populations of natural enemies of pests in agricultural landscapes because they can provide refuge from insecticide use, shelter, floral nectar resources, alternative hosts and prey (Bianchi *et al.* 2006). However, we have to develop ways to better capture and manage for the ecosystem service of natural pest control.

Schellhorn and Bianchi (2010) identify one possible pathway, which includes: (i) identification of the key natural enemy species providing natural pest control, (ii) assess whether natural enemies move between non-crop habitats and crops (iii) assess the time of crop colonization, (iv) determining whether they can suppress pest population effectively, and finally (v) assess whether they can prolong the time that pest populations are below economic threshold levels. Currently there are few studies that have highlighted the importance of the early establishment of beneficial species in the continued suppression of pest numbers (Bianchi *et al.* 2006). The argument for this theoretical concept is that the early removal of pest species will avoid future damage cause by itself and its offspring. This theory states that early predation results in pest numbers being lower for longer, as it takes the pest population longer to recover from early predation before they become established, rather than later predation (Schellhorn and Bianchi 2010).

Several of the steps listed in the pathway above have been the subject of funding from Cotton Communities Catchment CRC, with the last step being the focus of this summer scholarship project.

Aims and Objectives:

The primary aims of the study were to: 1. Determine whether pest populations stay a) lower for longer and b) have a slower rate of increase in cotton fields on farms with > 20% native vegetation at 1 km radius, compared to fields on farms with little (<1.8%) or no native vegetation, 2. identify any correlation between the presence of pests and beneficial insects as it relates to the amount of native vegetation, and 3. identify whether there are simple measures that can be used by crop scouts / growers to quantify the benefits of pest control services from native vegetation management.

Materials and Methods:

To achieve our aims, we conducted a desk-top study using existing pest scouting data from fields and farms with high amounts of native vegetation, and low or no native vegetation. The scouting reports were accessed from Bredan Griffith of Griffith Scouting Service from the Border River region of Goondiwindi, QLD. This region is considered a hot growing area (Kilby 2005).

Study area and site selection:

The client farms of Griffith Crop Scouting service (hereafter called GCS) were evaluated to determine if any fields on their farm met the treatment criteria of having either low or no native vegetation (hereafter LNV) (<2%), or greater than 20% native vegetation (hereafter HNV) within the 1 km radius. The surrounding landscape of the border rivers region ranged from completely agricultural (all cleared) to extremely diverse (> 20% native vegetation). Roughly 90% of cotton cultivated in this region is transgenic (Bollgard II). The land use and composition around each study field serviced by GSS was first determined using satellite images. From here, fields which looked to roughly meet the treatment criteria were further assessed using Geographical Information Systems (GIS) and ArcGIS. The centroid of each study field was located, and the proportion of the landscape containing native remnant vegetation was calculated. Out of a total of 7 properties meeting the first broad criteria, 4 properties and 8 fields met the treatment categories; 4 with more than 20% native vegetation, and 4 with less than 1.8%. Properties Barra (field 14 and 15) and Wondoogle (field 3 and 5) had fields with high proportion of remnant vegetation, and properties Eumorella (field 10) and Norlin (field 4, 6, and 7) had very little to no remnant vegetation remaining (<1.8%) (Appendix 2). A third site was also examined, and this came from Boggabilla, which is also considered a hot growing region. Three organic fields (no insecticides used) were analysed and these were Brigadoon, Kilmarnock and Nandewar which were surrounded by 2.3, 5.07 and 9.9% of native vegetation respectively.

Data collection:

Once the study fields were identified, the associated scouting reports spanning several years were identified and mined for data. These reports identified the presence of *Heliothis spp.* (white eggs, brown eggs, hatchlings, very small larvae, medium larvae, and large larvae), Mirids (nymphs, and adults) Thrips, Aphids, Mites, whitefly, Apple Dimpling Bugs, Green Vegetable Bug, Cotton Staining Bugs, Spiders and Predatory beetles. Although many different people were responsible for collecting data over several years, they were all trained by Griffiths Crop Scouting.

Study Species:

Of all of the species listed, five pests and two beneficial groups were the focus of our investigation. These include as collected on the scouting report: *Helicoverpa spp.*, green vegetable bug, aphids, mirids, mites, predatory beetles and spiders. The larvae of *Helicoverpa spp.* is a major pest of cotton. However this species is the main target of Bollgard II, and thus has drastically reduced the need to use insecticide (Australian Cotton Industry Development & Delivery Team 2011). On Bollgard II the threshold for this species is 2 larvae (<3mm)/m over two consecutive checks, or 1 medium or large larvae per meter) (Australian Cotton Industry Development & Delivery Team 2011).

Hemipteran pests are also important to the cotton industry. Green Vegetable bug (GVB) is a sporadic pest in cotton causing the most damage in mid- to late season (Australian Cotton Industry Development & Delivery Team 2011). Both adult and nymphs of this pest can damage bolls; this damage is visible from external marks on the bolls (black spots) and warts and stained lint inside the bolls (Australian Cotton Industry Development & Delivery Team 2011). This pest has a threshold of 1.5 per check (beatsheet + visual) (Australian Cotton Industry Development & Delivery Team 2011).

Mirids are another important Hemipteran pest of cotton in Australia. This sucking pest is present all through the season (Australian Cotton Industry Development & Delivery Team 2011). This pest is responsible for the blackening and desiccation of plant tissue caused by pectinase released from its stylets during feeding (Australian Cotton Industry Development & Delivery Team 2011). This pest of cotton has a threshold limit of 5.3 per check (beatsheet + visual) from planting to first flower, and 4 per check (beatsheet + visual) from first flower to first open boll.

Aphids are a yellow-green small oval shaped hemipteran. Severe infestations of aphids can result in wrinkling, stunting and cupping of leaves (Australian Cotton Industry Development & Delivery Team 2011). Aphids affect cotton in three ways, they reduce plants available area for photosynthesis, and thus reduce yield, they produce honeydew which promotes the growth of sooty mould and can stain cotton fibres, and finally it spreads Cotton Bunchy Top Disease (Australian Cotton Industry Development & Delivery Team 2011). Aphids have a threshold level in cotton of 50% plants infected per visual check.

Mites are also a common pest found in cotton, using their piercing mouthparts to feed on the cell contents of the plant. This pest is often responsible for the bronzing of upper leaves surfaces, with heavy infestations causing leaves to desiccate and falling off, and thus can reduce yields (Australian Cotton Industry Development & Delivery Team 2011). This arthropod pest has a threshold level of 30% plants infected from planting to first bolls opening, then the threshold increases to 60% plants infected from first bolls opening to harvest.

Predatory beetles are common in cotton fields. Although all predatory beetles were grouped together on scouting reports, the majority were several species of coccinellids and red & blue beetles, all of which are known to prey on aphids (Cheneaux *et al.* 2011). Spiders were the other dominant beneficial. They too are important generalist predators in cotton fields and are thought to be the first predators to colonize newly emerging fields (N Schellhorn, personal communication). The absence of these beneficial arthropods may lead to an increase in the spraying of insecticides, with previous studies finding correlations between the presence of native vegetation and beneficial insect numbers (Perovic *et al.* 2010).

Statistical analysis:

Using industry standard pest thresholds as the criteria we compared between treatments the: 1. number of days from planting to reaching pest thresholds, thus warranting spray, 2. number of times throughout the season that pests reach the spray threshold, and 3. number of days above threshold. The analyses were also repeated with a lower threshold reduced by 33% of the industry standard to simulate the other factors that assist agronomists in recommending spray applications. For the beneficial insects we compared the densities of beneficials between the two treatments. Additionally we compared whether there was any relationships between aphids and predatory beetle densities, and predatory and spider densities and whether that was affected by treatments.

In all analysis, the unit of replication was the field. Several analyses were conducted, in part to provide the Scholarship awardee exposure to different approaches. To determine whether pest numbers took longer to reach threshold in the HNV treatment compared to the LNV treatment we used a mixed model analysis of variance where the response variable was number of days to reach threshold, field was a random factor, treatment, and year were fixed factors. The number of days to

reach threshold were determined by setting a standard starting date (because all scouting did not start on the same date) and adding the days until threshold was reached. To determine, whether pest populations remained over threshold longer in the LNV compared to the HNV we used a mixed model analysis of variance, where days above threshold was the response variable, field the random factor, and treatment, species and year as fixed factors. A mixed model analysis of variance tests whether the time for pests to reach threshold and the amount of time above threshold was dependant on the landscape treatment, year, and species. To determine if the proportion of days above threshold varied between the treatments we used a logistic regression. A contingency table using the X^2 test statistic was conducted to test whether treatment was independent of the number of times above threshold. Each analysis was repeated with a reduced threshold level to simulate the other factors (weather, stage of plants) that may assist and influence agronomists in recommending spray applications.

To determine whether there were significantly more beneficial insects in the HNV compared to the LNV treatment, a T-test was used to compare the total density of predatory beetles and spiders for the seasons. A Pearson’s correlation coefficient was used determine whether there was a relationship between predatory beetle densities and aphids, and between predatory beetles and spiders in each treatment.

3. Results:

Overall this study analysed over 7000 individual pest arthropods recorded in scouting reports from eight fields with over four years of data for some fields (Norlin 4). Table 1 highlights the years each pest was present with *Helicoverpa* spp. larvae only visible in the past three years 2009-10, 2010-11, 2011-12. In addition, 1,389 individual predatory beetles and spiders where counted over the eight fields.

Table 1. Pest species recorded on scouting reports. If pest species were not recorded, then they were assumed to be absent or at levels below detection.

Dates of Scouting Reports	Mirids	Heliothis Larvae (3-7mm)	Heliothis large and medium Larvae	Green Vegetable Bugs	Aphids	Apple Dimpling Bug	Mites
2011-12	present	present	present	Not present	present	Present	Not present
2010-11	present	present	present	present	present	Present	present
2009-10	present	present	present	Not present	Not present	Not present	Not present
2006-7	present	Not present	Not present	Not present	Not present	Not present	Not present

3.1 Time Taken for Pests to Reach Threshold & Number of Days Above Threshold:

From the Scouting reports only four pest species broke threshold a total of 31 times in four years, and these were Green Vegetable Bugs (hereafter GVB), mirids, mites (plants with mite damage), and aphids (number of plants with Aphids). The results from the mixed ANOVA of this analysis found that

there was no significant difference between the two treatments for the amount time to reach threshold ($P > 0.05$). However, there was a trend for aphids and GVB to spend more days over threshold in fields with low / no native vegetation than in fields with high native vegetation. The unit of observation is the field, and with only four per treatment, the variation is too high to see a treatment difference. There was a significant difference among the species for the proportion of days above threshold ($F=4.23$, $df= 3$, $P = 0.0131$), and this was independent of treatment or time. For example, mirids were hardly ever over threshold whereas GVB was. Additionally, it was found that all other pests regardless of the treatment spent on average a longer time over threshold than mirids. This analysis also found that Aphids spent significantly more time over threshold than mirids and mites in field with little or no native vegetation (p -value of 0.0031, 0.0297, respectively). A mixed ANOVA was conducted on the response variable of mean number of days above threshold. There was no significant difference for any of the focal pest species except for that of mites ($t= -2.59$, $df=24$, $P= 0.0161$) (Fig. 1).

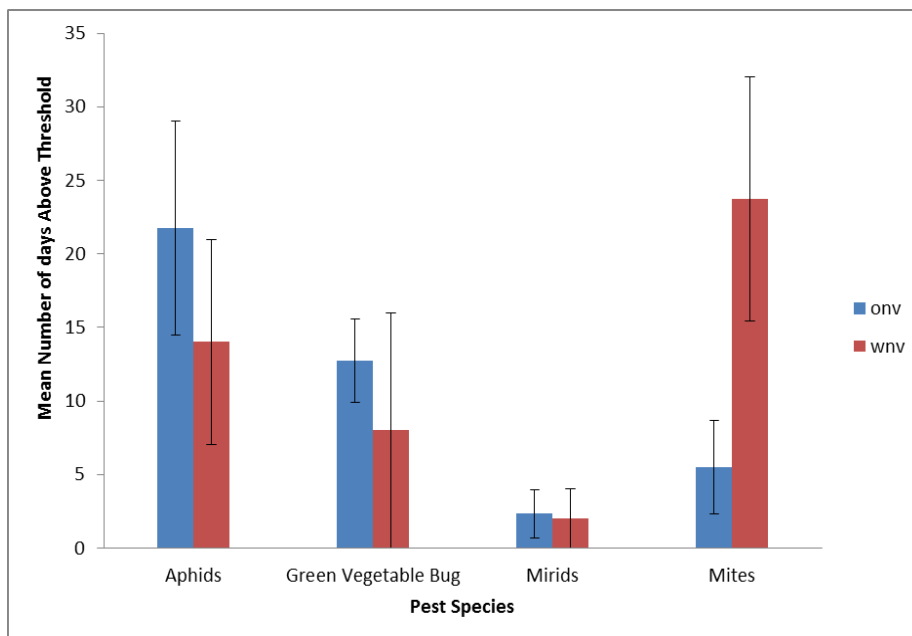


Fig. 1: This figure illustrates the differences between the two treatments (wnv) and without native vegetation (onv) on the average amount of time each species spent above threshold for 2010-2011 season.

Mites from fields with high native vegetation spent significantly more days over threshold than those from fields with minimal native vegetation. This same pattern was found when the threshold was reduced by 33.33%, with mites being the only pest that spend significantly longer mean number of days over threshold in fields with high levels of native vegetation than those from fields with minimal native vegetation ($P= 0.0354$). The logistical regression analysis showed that there was no significant difference in the proportion of time that each pest spent over threshold in the two different treatments except for that of mites ($Z=-1.89$, $df=24$, $P= 0.0594$), which spent a longer proportion of time over thresahold in fields with high native vegetation. Once again this pattern remained the same when the threshold level was reduced by 33%.

3.2 The Number of Times Pests went above Threshold

To determine if any fields were susceptible to breaking threshold, the total number of times threshold was broken was calculated for each field. This number was then multiplied by the number of years over which this event occurred (Table 2). For example Norlin 4 broke threshold eight times with the threshold being broken in 3 of 4 years, giving a score of 24. From this, the data illustrates a trend towards fields with low native vegetation (LNV) breaking threshold more often. For example, the average 'Broken-Threshold Score' for HNV=4.25 and for LNV=8.5, and it should be noted that the organic fields rarely broke threshold

Table 2. The number of time within a season and the number seasons the pest threshold is broken per field from all scouting reports. These two values are multiplied to give a 'Broken-T Score'. The first four fields are from the low native vegetation treatment (LNV), the next four are from the high native vegetation treatment (HNV), and the last three are from the organic fields.

	LNV-N4	LNV-N6	LNV-N7	LNV-E10	HNV-B14	HNV-B15	HNV-W3	HNV-W5	Org - BRGD	Org- Nandewar	Org- KLMRC
No. times pests were over T	8	4	5	1	1	5	3	4	1	0	1
No. years T broken	3	1	1	1	1	1	1	2	1	1	1
Broken-T Score	24	4	5	1	1	5	3	8	1	0	1

3.3 The Number of Times Insecticides Were Sprayed

Through the scouting reports it was found that 13 insecticide sprays occurred over all eight fields (see Appendix3). These Insecticides were both broad spectrum and specific in the pests they targeted. Aphid populations declined rapidly, then surged, then increased to nearly 100% of plants infested approximately 3 weeks after spraying.

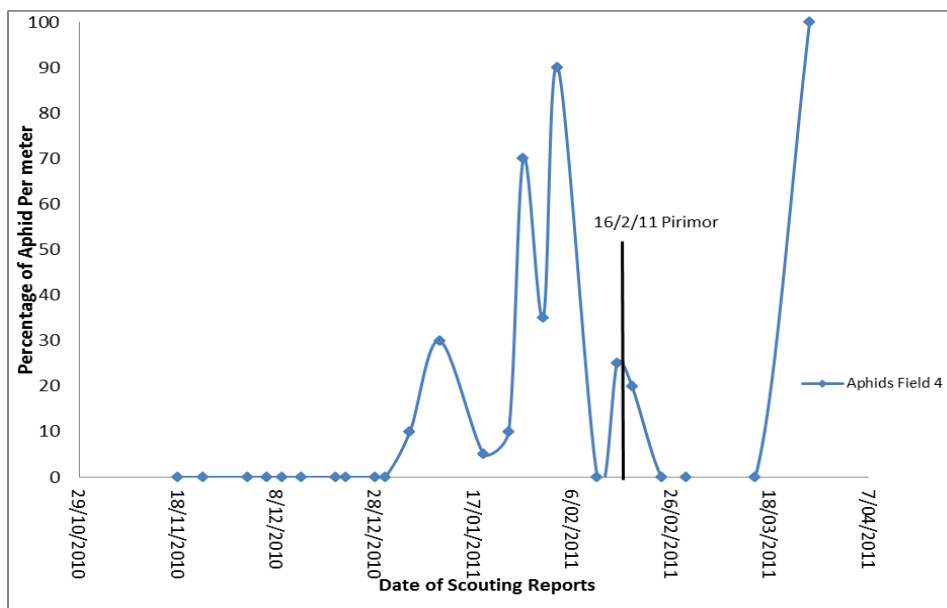


Figure 5: Aphid populations at Norlin4 and the aphid dynamic after the application of Piramor.

3.5 Density of predatory beetles and spiders in Field with High and Low Levels of Native Vegetation:

The total annual density of beneficial insects was significantly different between the two treatments in two of the cotton seasons (2009-10 and 2010-11; Appendix 4a-b) (Table 3). In 2009-10, there were significantly more beneficials in the fields with little native vegetation surrounding it. In 2010-11, the opposite was true with field with a large percentage of native vegetation surrounding it having higher densities of beneficial arthropods. The mean number of beneficials was also calculated to see if there was any obvious trend (Table 3). This showed that beneficials arthropod densities were at their highest mid-season in field with little or no native vegetation, whereas fields with high percentage of native vegetation around it beneficial arthropod densities peaked mid to late in the season.

Table 3: Total annual mean number of predatory beetles and spiders per m² for three seasons in fields with low or high amount of surrounding native vegetation.

	P-Value	Mean Beneficial Density in low Native Vegetation	Mean Beneficial Density in high Native Vegetation	df	T	T-Critical
Years						
2011-12	0.162	1.187	1.033	91	0.990	1.661
2010-11	0.011	2.121	3.205	199	2.298	1.652
2009-10	0.0003	2.195	1.4	163	3.350	1.654

Further, the results from the Pearson's correlation analysis showed a significant, but weak correlation (P-value 0.002) between predatory beetles and aphids in fields with high amounts of

native vegetation, but not relationships between predatory beetles and aphids in field with little or no native vegetation in 2010-11. In the analysis of predatory beetles and spiders there were significant but weak correlations between their densities in both categories of fields in the 2009-10 and 2010-11 seasons, however there were no significant relationships in the 2011-12 season.

Discussion and Conclusions

This study focused on the amount of time it took pests to reach threshold, how many times they went above threshold, how many days they spent above threshold, and whether this was dependant on native vegetation surrounding the field. Beneficials densities and their relationship with each other and pest species were also investigated.

Firstly, pest did not reach or go above threshold often. Fields were monitored approximately 20 times in a growing season. Eight fields monitored for four pests over four years for 20 observations per year equals 2560 times that a pest could be over threshold. However, only 31 times in four years were pests over threshold or ca. 1%. Furthermore, sprays were usually applied prior to reaching threshold (Appendix 5). Multiple factors (eg. plant stress, weather) are considered when making a spray decision however, there may be room to further reduce insecticide application. As evidenced by the results from the organic fields that showed thresholds were rarely reached.

Secondly, the number of days to reach threshold was similar for fields with low and high native vegetation. This means that beneficial insects are not differentially slowing the rate of increase of pest populations in the two treatments. This may be due to the way in which data was collected, eg. The same plants were not repeatedly sampled, or that there is no difference in how fast beneficial insects respond. However, plants infested with mites were above threshold for longer in fields with HNV, compared to LNV. There was a trend for the opposite for GVG and number of plants infested with aphids; more days above threshold in fields with LNV, compared to HNV. When the threshold was lowered by 1/3, GVB spent more days over threshold in fields with LNV, the opposite for mites.

Thirdly, the average 'Broken-Threshold Score' for all focal species was twice as high in LNV (8.5) compared to HNV (4.25), suggesting that over time thresholds are broken more often in LNV fields. However, these are rough observations and many other factors can be contributing to pest dynamics. For example, some fields (Norlin 6 and 7 and Barra 15) are surrounded by grazing land, 10.7, 16.7 and 29.6 %, respectively, which has been shown in other current projects (eg. GRDC National Pest Suppressive Landscapes) to host many pests of crops. This could cause the threshold to break more frequently as these areas are traditionally not managed (no insecticides applied) and thus can act as a reservoir for many pest species. Conversely, it was found that on average of Andrew Watson's three organic cotton fields only broke threshold on average once a year even though there was no application of insecticides.

Our findings are similar to those of Whitehouse (2011) where often 'insurance' sprays occur before pests reach threshold levels, and that thresholds were found to be rarely broken. However, it's understood that there are many biotic (pest densities, fruit retention, square and tip damage, and age of the plant) and abiotic (weather) factors that contribute to spray decisions (Gordon *et al.* 2007). However, our scenario of a 1/3 threshold reduction, to simulate more conservative behaviour, did not make any dramatic differences to number of times pests broke threshold, and the

amount of time they spent over threshold. This sentiment is also held by Whitehouse who stated that “researchers focus on pests that are caught, while pest manager’s focus on the possible pests they may have missed”, this interpretive difference is often an issue with threshold compliance. Another interesting observation was that *Helicoverpa* spp was present in the last three years, as it was not present in scouting reports from 2006-2007.

This study found no clear relationship between the total number of predatory beetles and spiders present and the percentage of native vegetation at 1 km radius. In the 2010-11 cotton season there was a significant correlation between beneficial density and the presence of native vegetation, but the opposite was true in 2009-10. Although other studies have found that field with higher native vegetation contain higher numbers of beneficial insects (Perovic *et al.* 2010), beneficial insect numbers can be the result of many factors included high pest loads. Higher densities of predatory beetles were associated with aphids in fields with HNV, but not LNV, eventhough LNV fields trended towards more aphids. Additionally there was a correlation between predatory beetle and spider densities regardless of the composition of the land around the field, this may be due to the fact the spiders are generalist and therefore with increasing predatory beetle numbers they have an increase in a food source to thus support a high density of spiders in that field. The absence of any correlations between predatory beetles and spiders in the 2011-12 season may be due to the fact that there has been very few pest insects present in crops this year and thus there is not enough resources to support both these predators.

Ultimately this work was undertaken to evaluate the merit of simple measures to evaluate capture of ecosystem services of pest control from native vegetation. Although the findings are not conclusive and additional study should be undertaken, there is scope to change crop scouting sheets for better capture of information to measure the value of native vegetation. For example, a new crop scouting sheet is used every time a field is monitored. This prevents an immediate indication of population trends of pests and beneficials, which goes into decision making. In addition, a newly designed scouting report could also incorporate information like, the number of days before reaching threshold, number of days below threshold, number of times above threshold, the effectiveness of the insecticide and the area surrounding the field, eg. native vegetation three sides, sorghum.

The negative implications of landscape simplifications caused by agriculture are well documented, with land containing high native vegetation being positively correlated with higher densities of beneficial insects (Perovic *et al* 2010). However, the results from this study are more variable, but with some interesting patterns. This study relied on coarse data collected by many people and a fairly low number of samples per collection, and four replicates. However, it also represented many years of data from the same fields, which is not often available. Further investigation should be pursued to look at more fields in more regions, combine the crop scouting report analysis with the evaluation of field measures, and refine scouting reports to allow for easy capture of these measures.

Highlights:

Mr Jordan Biron: My highlight of this experience have been having the opportunity to work with industry leading researchers, and having the chance to manage and conduct an independent research project. Ultimately the highlight has been learning and developing my skills in research.

Presentations and Public Relations:

Results and findings from this research were briefly presented at the CRC conference in March 2012, by Dr. Nancy Schellhorn.

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Appendix 1.

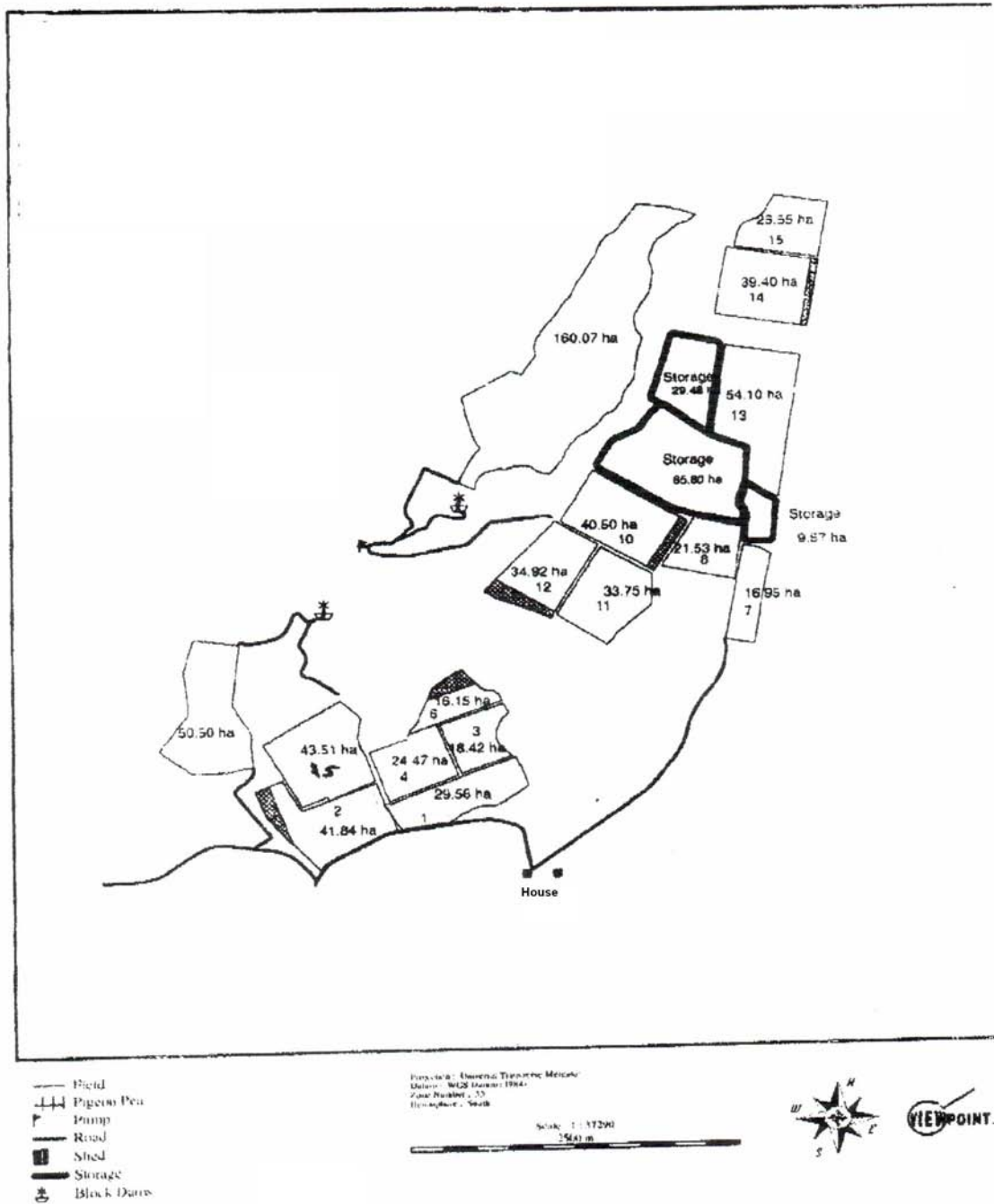
Definition of IPM developed by the United Nations Food and Agriculture Organisation (UN-FAO):

- The Presence of pests does not automatically require control measures; numbers may not have passed threshold level.
- When pest control measures are deemed necessary, a system of non-chemical pest methodologies should be considered before the decision is taken to use pesticides.
- A suitable pest control strategy should be used in an integrated manner and pesticides should be used appropriately.

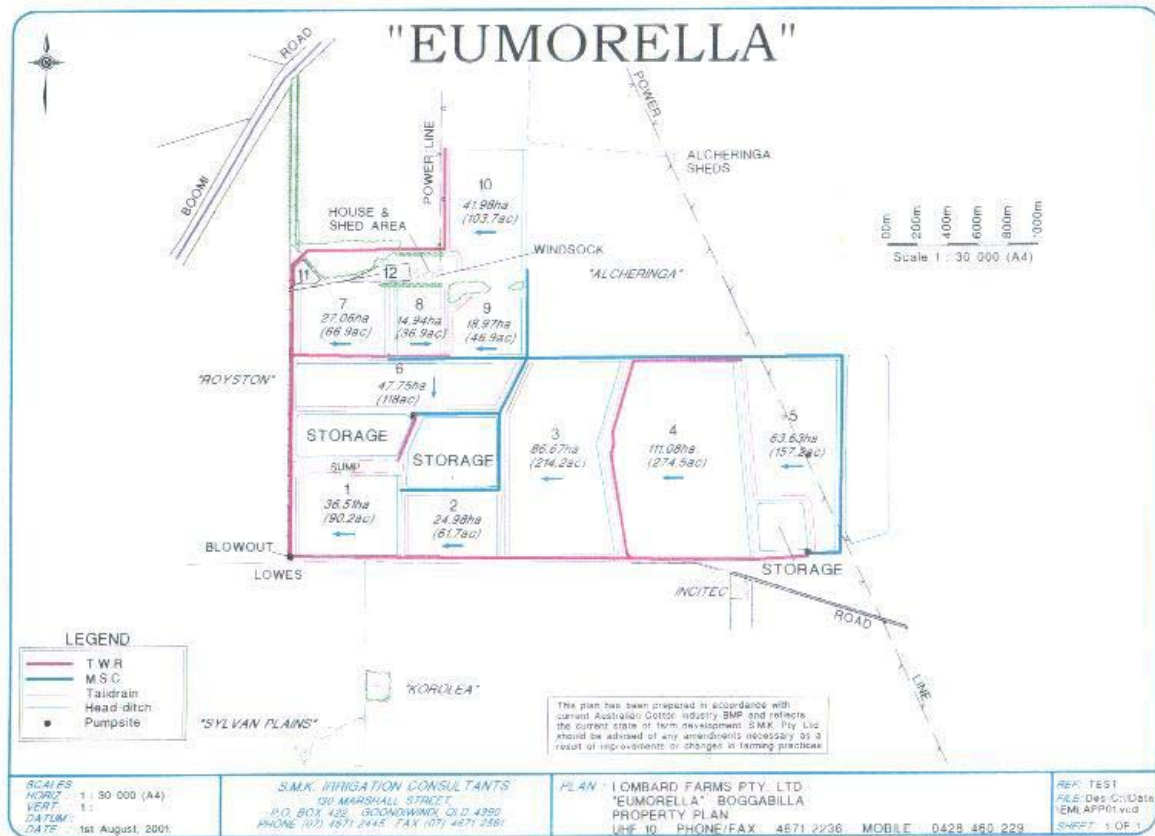
Intervention with broad spectrum synthetic pesticides is seen as a last resort when pest levels exceed thresholds and there are no effective selective management options available.

Appendix 2a. Map of Barra property. Field 14 and 15 were the study fields.

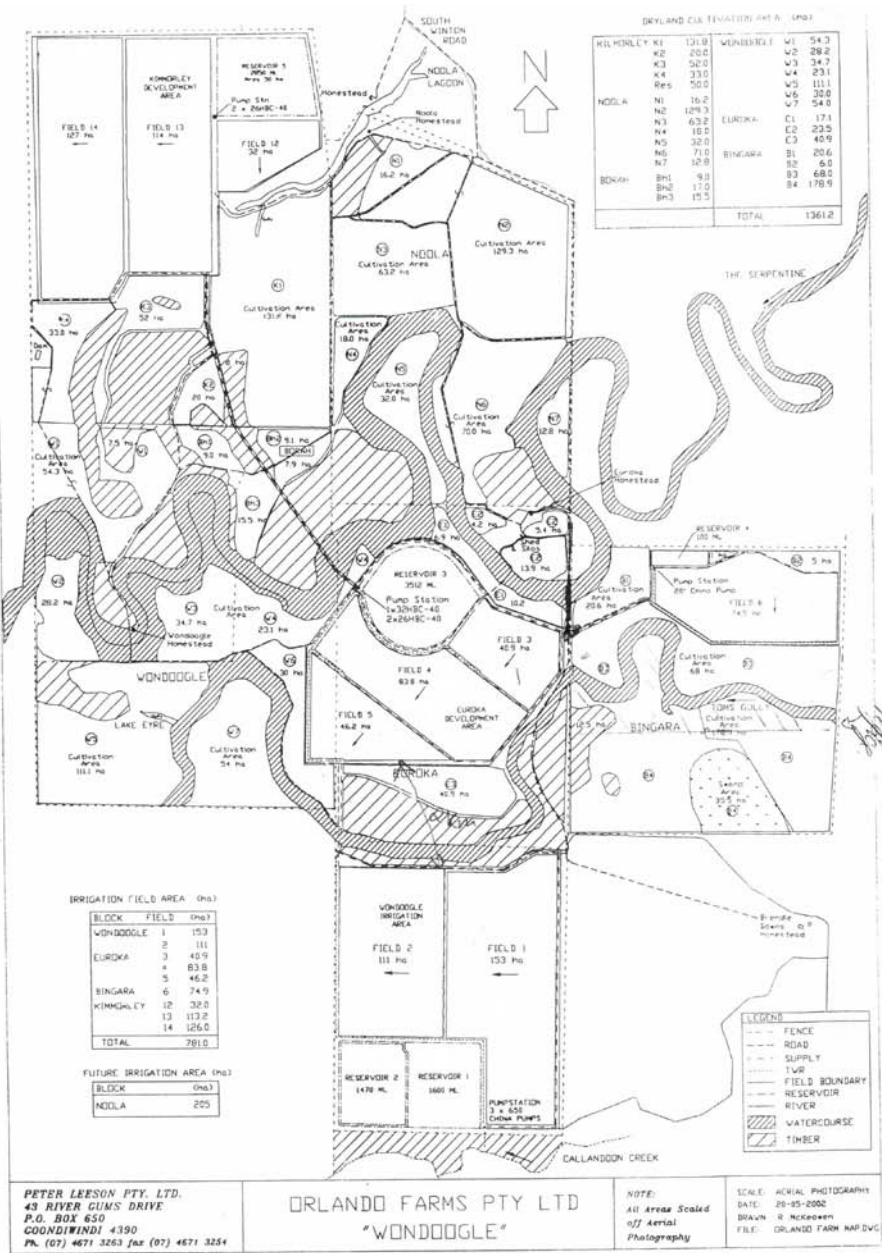
Barra



Appendix 2b. Map of Eumorella property. Field 10 was the study field.



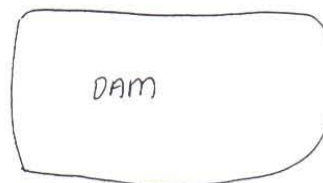
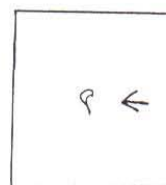
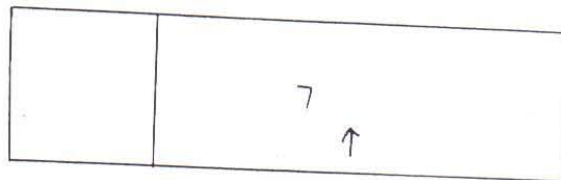
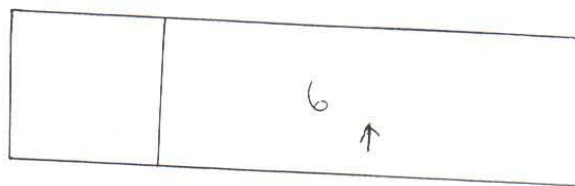
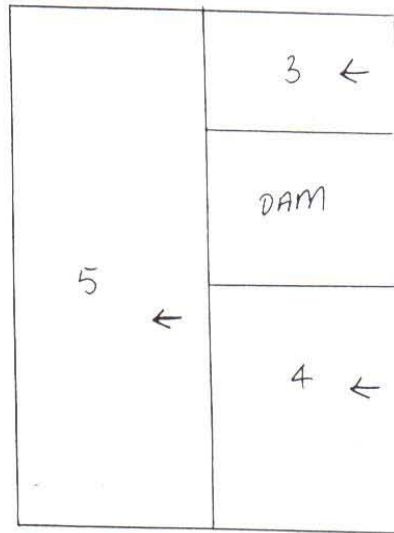
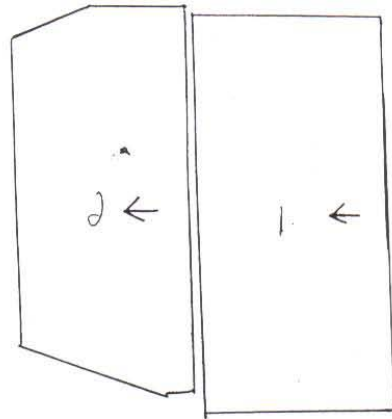
Appendix 2c. Map of Wondoogle property study fields 3 and 5.



Appendix 2d. Map of Norlin property study fields 3, 6 and 7.



NORLIN



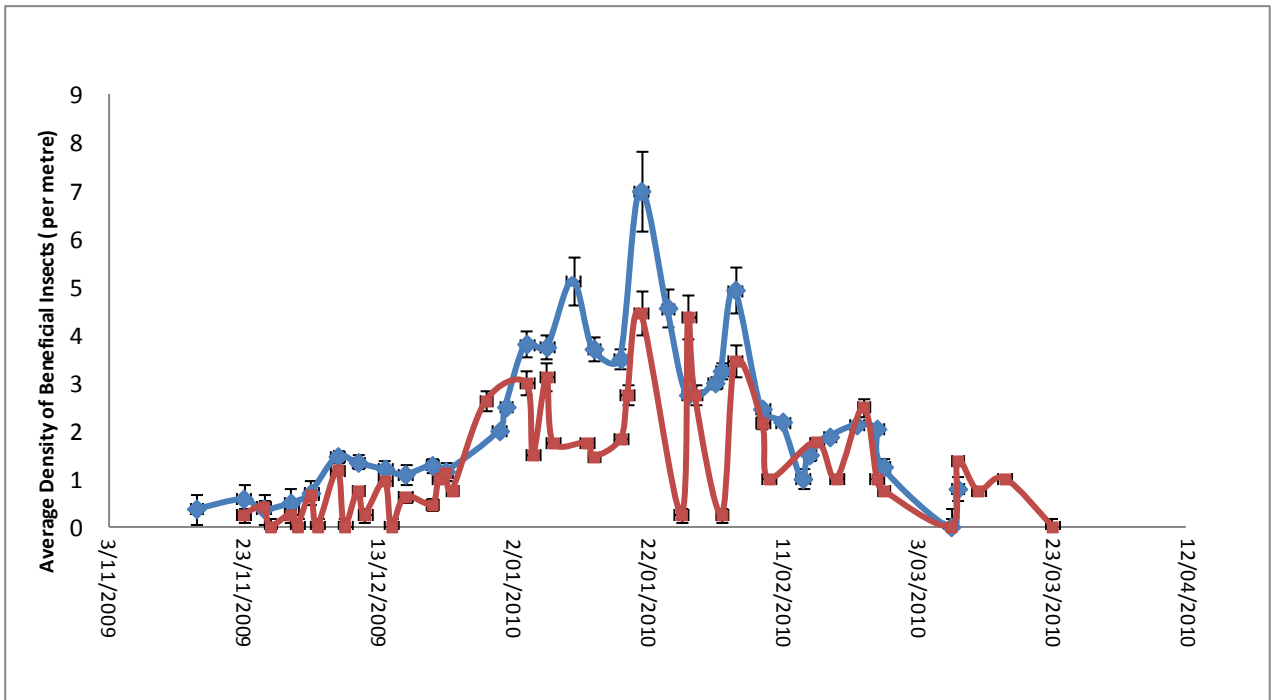
JEE
ENTRY
IGUNDY

300m

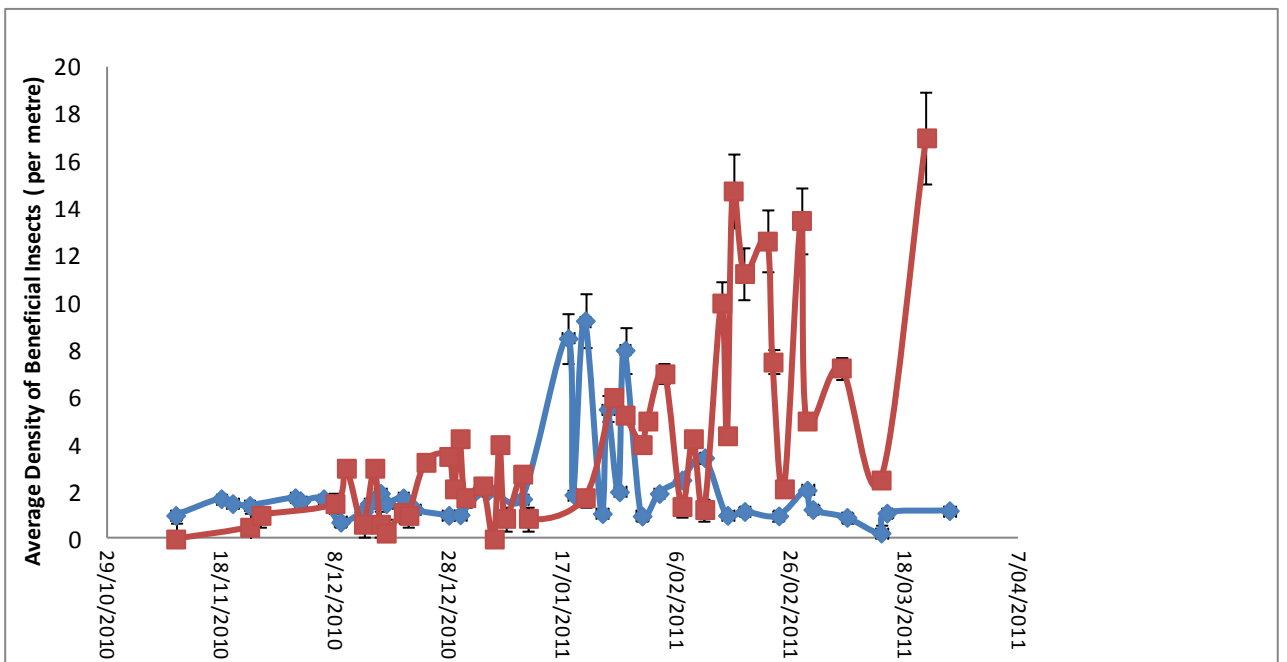
Appendix: 3. This figure show the dates on which pest broke threshold and when insecticide spraying events occurred for each field, and what insecticides were applied.

	Pirimor	Shield	Regent	Amitraz	Abamectin	Threshold broken
Norlin 4	16/2/11	16/2/11	14/12/10			4/1/11 27/1/11 3/2/11 11/2/11 18/2/11 26/3/11
Norlin 6			14/12/10			4/1/11 27/1/11-3/2/11 18/2/11 26/3/11
Norlin 7			14/12/10			27/1/11 3/2/11-7/2/11 18/2/11 26/3/11
Eumorella 10				16/12/10	7/1/11	8/3/11
Barra 14			10/12/10 5/1/11			11/1/11-31/1/11
Barra 15			10/12/10 5/1/11			29/12/10 7/1/11 31/1/11 1/3/11
Wondoogle 3			30/12/10			16/2/11 7/3/11
Wondoogle 5			30/12/10			10/1/11-28/1/11 4/2/11

Appendix 4a: Average densities of beneficial insects (predatory beetles and spiders) from field with LNV (blue) and HNV (red) in 2010-11 season.



Appendix 4b: Average densities of beneficial insects (predatory beetles and spiders) from field with LNV (blue) and HNV (red) in 2009-10 season.



Appendix 5.

Insecticides commonly used on cotton.

There are a variety of insecticides that are commonly used on cotton. These include: Shield (Group 4A Insecticide) which is an insecticide that is used in the control of aphids and mirids in cotton. Regent (Group 2C insecticide) which is a general insecticide which is used to control a variety of pests in cotton, and is often considered a 'soft' insecticide (PestGenie 2012). Pirimor (Group 1A Insecticide) is another insecticide which is a specialised spray which is extremely selective for aphicide (PestGenie 2012). Amitraz (Group 19 Insecticide) is an insecticide which causes the death of the ovum of *Heliothis* spp. and thus this insecticide helps to control *Heliothis* egg numbers, and thus improves the overall control of *Heliothis* (PestGenie 2012). Finally the last insecticide used is Abamectin (Group 6A insecticide); this insecticide is used for the control of mites and Budworms on cotton (PestGenie 2012). All of these chemicals can assist in keeping pest numbers low; however it is only economically beneficial to spray when pest numbers are over the threshold level causing economic damage.