November, May & Final Reports

Part 1 - Summary Details

COTTON CRC Project Number: 3.2.13

November Report: □ Due 22-November-02
May Report: □ Due 29-May-02
Final Report: □ Due within 3 months of project completion

Project Title: In Field Evaluation of Assassin Bugs as Biological Control Agents for Cotton Pest Management.

Project Commencement Date: July 2001 Project Completion Date: June 2002
Research Program: 3. Sustainable farming Systems

Part 2 - Contact Details

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The assassin bug, *Pristhesancus plagipennis* (Walker) (Hemiptera: Reduviidae) is a natural enemy of bug and larval insects in both orchard and field crops. Several studies have suggested that *P. plagipennis* may be suited for inundative release against pest insects such as *Helicoverpa* spp. and *Creontiades* spp. with inundative releases resulting in reduced populations of these pests in cotton.

However, a common challenge with the inundative release of beneficial insects such as assassin bugs in cotton pest management programs is achieving a viable balance between predator release rates and biological control efficacy. In this project we examined the post-release establishment and biological control efficacy of assassin bug released at rates of and below 1 nymph per metre crop row.

*P. plagipennis* were released at rates of 1.0, 0.75, 0.5 and 0.25 nymphs per metre row which resulted in respective field populations of 0.75, 0.54, 0.41 and 0.25 nymphs per metre row four weeks after release, indicating that over 72% of the nymphs successfully established in the field. The release of *P. plagipennis* nymphs at 1.0, 0.75 and 0.5 nymphs per metre row of cotton provided significant reductions in *Helicoverpa* spp larvae densities compared with an untreated control over a period of four weeks. The release of 1.0 and 0.75 nymphs per metre row also corresponded with significant decreases in mirid, *Creontiades* spp. densities over a similar period of time. Compared to previous studies, the data suggest that lower release rates of *P. plagipennis* at 1.0, 0.75 and 0.5 nymphs per metre row aided predator establishment whilst maintaining significant reductions in pest insect densities in cotton.

Future research will focus on combining *P. plagipennis* released at rates of 0.5-1.0 nymphs per metre row with other controls such as compatible insecticides, biopesticides or transgenic host plant resistance mechanisms within an integrated pest management program.
1. Outline the background to the project.

Generalist predators, particularly predatory bugs have been largely ignored for their pest management potential in cotton production systems (King & Powell 1992). However, in a monoculture environment where the main pests, *Helicoverpa* spp. (Lepidoptera: Noctuidae) and *Creontiades* spp. (Hemiptera: Miridae) are characterised by migratory behaviour and a multi-voltine lifecycle (Zalucki *et al.* 1986; Miles 1995), generalist predators may have a survival advantage over host-specific natural enemies by being able to switch prey types during fluctuations in host availability (Nyffeler *et al.* 1992; Scholz & Zalucki 1998).

The assassin bug, *Pristhesancus plagipennis* (Walker) (Hemiptera: Reduviidae) is a natural enemy of bug and larval insects in both orchard and field crops (James 1994; Pyke & Brown 1996; Smith *et al.* 1997; Coombs & Khan 1998). Several studies have suggested that *P. plagipennis* may be suited for augmentation against pest insects such as *Helicoverpa* spp. and *Creontiades* spp. with inundative releases resulting in reduced populations of these pests in cotton and soybean (Grundy & Maelzer 2000; 2002). The objective of these studies was to determine an inundative release rate for this predator with results suggesting that effective densities of 1.38 *P. plagipennis* nymphs per metre row being enough to reduce *Helicoverpa* spp. larval densities on cotton (Grundy & Maelzer 2002). However, the effective density of 1.38 nymphs per metre row in this experiment was the residual population that remained after an initial release of 5 nymphs per metre crop row. The release of 5 nymphs per metre row or 50,000 per hectare is unlikely to be an economic proposition for cotton pest management in Australia. A more viable option would be the release of *P. plagipennis* at a rate of or below 1 nymph per metre row or 10,000 nymphs per hectare.

The successful use of lower predator release rates will be dependent on achieving high post-release establishment rates and being able to use compatible insecticides with *P. plagipennis* during periods of peak pest activity during which the level of biological control afforded by low predator densities may be inadequate. Such an integrated approach has been successfully demonstrated with the use of predatory bugs against Colorado potato beetle, *Leptinotarsa decemlineata* (Say) on potato crops (Hough-Goldstein & Keil 1991).

However, before this approach can be taken the impact of lower release rates on predator establishment and biological control efficacy needs to be established. The objective of the present study was to compare post-release nymph establishment and relative efficacy of low release rates of *P. plagipennis* for the control of *Helicoverpa* spp. and *Creontiades* spp. in conventional and Ingard cotton.
2. List the project objectives and the extent to which these have been achieved.

The primary project objective was to evaluate the potential for utilising the assassin bug, *Pristhesancus plagipennis* as an applied biological control for *Helicoverpa* spp. and mirids in conventional and Ingard cotton. Two experiments were conducted in conventional and Ingard cotton to investigate this objective.

3. How has your research addressed the Corporations three outputs: Sustainability, profitability and international competitiveness, and/or people and community?

The current dependence on insecticides for *Helicoverpa* spp. and mirid management in the cotton industry poses some risk in terms of sustainability and profitability. The research conducted during this project aimed further to develop and test the assassin bug, *Pristhesancus plagipennis* potential as a biological control agent for *Helicoverpa* spp. and mirid management in cotton. Research on potential new biological controls such as *P. plagipennis* has provided significant data on how this predator may be developed and used as a biological control in cotton. If successful the future development of *P. plagipennis* would possibly provide a more sustainable and profitable alternative control option for *Helicoverpa* spp. and mirids.

4. Detail the methodology and justify the methodology used.

Experiments were conducted in two separate 2-ha irrigated fields near the township of Biloela, central Queensland (24°22’S, 150°06’E). The cotton varieties Sicot 189 (conventional) and Sicot 289i (Bt cotton) were planted in separate fields on 24 and 28 October 2001 respectively.

Six treatments were compared: Four densities of third instar *P. plagipennis* released at 0.25, 0.5, 0.75 and 1.0 nymphs per m row (2500, 5000, 7500 & 10000 nymphs per hectare respectively); a sprayed treatment which was treated with insecticides for the control of *C. dilutus* and *Helicoverpa* spp.; and a *P. plagipennis* nymph and insecticide free control. Treatment plots were arranged in a randomised block design with six treatment replicates used in each experiment. Plots for the first experiment in conventional cotton were 120 m² (12 rows x 10 m) whereas plots for the second experiment in the Ingard cotton were 80 m² (8 rows x 10 m). Each treatment plot was separated by a 3 m buffer of bare earth on each side.

Treatments were commenced on the 20 December 2001 for the conventional cotton and 23 December for the Ingard cotton whilst both crops were nearing peak square production. *P. plagipennis* nymphs were released singularly onto the terminal shoots of the crop foliage at evenly spaced locations using a camel hair brush on these dates late in the afternoon after 17:00h. The *P. plagipennis* nymphs released in the experiment were the eighth generation of progeny reared from adult bugs originally collected from the Lockyer Valley, Queensland (27°33’S, 152°16’E). Predator nymphs were mass-reared and sent air-express from Pisces Enterprises Pty Ltd laboratories in Brisbane, Queensland. *P. plagipennis* had been reared on a diet of *Tenebrio molitor* (L.) in a constant climate laboratory at 26 ± 1°C and 55-75% RH, with a 15:9 L:D photoperiod supplied by cool white 36 watt fluorescent tubes (Grundy *et al.* 2000).
The sprayed treatment was managed with insecticides using commercially accepted economic thresholds to maintain *Helicoverpa* spp. at or below 1 larva per m row and *Creontiades* spp. at 2 per m row. Insecticide applications on the sprayed plots were made at daybreak whilst wind was minimal to avoid insecticide drift into adjacent plots. A record of the insecticides applied the sprayed treatment is given in Table 1. No pesticides were used on the crop area except for the sprayed treatment plots.

**Table 1. Insecticides applied to the sprayed treatment.**

<table>
<thead>
<tr>
<th>Pest</th>
<th>Product</th>
<th>Active</th>
<th>Rate</th>
<th>Application Date</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Creontiades</em> spp.</td>
<td>Regent ®</td>
<td>Fiprinol</td>
<td>100mL/Ha</td>
<td>13 Dec 2000</td>
</tr>
<tr>
<td><em>Helicoverpa</em> spp.</td>
<td>Affirm ®</td>
<td>Emamectin benzoate</td>
<td>650mL/Ha</td>
<td>20 Dec 2001</td>
</tr>
<tr>
<td><em>Creontiades</em> spp. &amp; <em>Helicoverpa</em> spp.</td>
<td>Steward®</td>
<td>Indoxacarb</td>
<td>650mL/Ha</td>
<td>27 Dec 2001</td>
</tr>
<tr>
<td><em>Creontiades</em> spp.</td>
<td>Folimat ®</td>
<td>Omethoate</td>
<td>140mL/Ha</td>
<td>8 Jan 2002</td>
</tr>
<tr>
<td><em>Helicoverpa</em> spp.</td>
<td>Affirm ®</td>
<td>Emamectin benzoate</td>
<td>700mL/Ha</td>
<td>8 Jan 2002</td>
</tr>
</tbody>
</table>

Pre-release insect counts were made prior to predator release and then every 4-7 days until the end of the experiment. The data were expressed as numbers of insects per metre row for each treatment.

*Helicoverpa* spp. and *Creontiades* spp. were abundant during the experiment. *Helicoverpa armigera* (Hübner) was the dominant species, with only low numbers (<20%) of *Helicoverpa punctigera* (Wallengren) observed. Green mirids, *C. dilutus* (Stål) were the dominant species encountered during sampling, with only low numbers (<10%) of brown mirids, *C. pallidifer* (Walker) observed. Visual counts of *Helicoverpa* spp. eggs and larvae on the cotton plants were made on 4 randomly selected 1 m row lengths of cotton plants in each treatment replicate. The growing points and squares of the upper two thirds of the plants canopy were searched for eggs and small larvae because these instars are frequently found in those plant regions (Farrer & Bradley 1985). Flowers and bolls throughout the plants were also inspected for larger larvae. Larvae were recorded as small 2-10mm, medium 11-20mm and large >20mm. Numbers of *P. plagipennis* nymphs were recorded at the same time.

A beat sheet sampling method was used to assess the presence of *Creontiades* spp. and other insects. The sheet used was 1.5m wide by 2m long and made from yellow canvas. A 25mm diameter piece of timber dowel (1.5 m long) was fixed to each end of the sheet to prevent the ends lifting in the wind. Samples were taken by placing the sheet behind the cotton plants to be sampled, along the inter-row and up over
the adjacent row of cotton to create a ‘wall’ to catch flying insects. A one metre long stick was then used to shake 1 m of row onto the sheet for assessment. The cotton bushes were then shaken several times from the base of the plants to the top. Insects were then assessed quickly before flying off the beat sheet. Beat sheet samples were made on 4 randomly selected 1 m row lengths of cotton plants in each treatment replicate Sampling was non-destructive; no insects were removed from the crop.

High densities of *Helicoverpa* spp. larvae had caused considerable crop damage by early February. Therefore the crop was not grown on to maturity for yield assessment.

Count data for *Helicoverpa* spp., *Creontiades* spp. and other insects at each sampling date were analysed using a repeated measures ANOVA with the Genstat version 5.0 computer program (Payne *et al.* 1989). Differences between treatments (*P*<0.05) on each sampling date were determined with the least significant differences.

5. Detail results including the statistical analysis of results.

**Ingard Cotton Experiment**

This experiment failed to meet its objective for testing *P. plagipennis* ability to control *Helicoverpa* and mirids in Ingard cotton. The release of *P. plagipennis* coincided with very low numbers of mirids and *Helicoverpa* spp for the month of January making it difficult to make meaningful assessments. Extensive hot weather during January also interacted with the cotton variety used in this experiment resulting in considerable fruit shed and parrot peaking making the assessment of yield post-release difficult. The experiment was therefore discontinued.

**Conventional Cotton Experiment**

No *P. plagipennis* were recorded in the cotton plots prior to their release on 20 December 2001. Sampling on 18 January recorded field populations of 0.75, 0.54, 0.41 and 0.25 *P. plagipennis* nymphs per metre row from the earlier release of 1.0, 0.75, 0.5 and 0.25 nymphs per metre row on 20 December (Fig 1). These predator densities indicate that over 72% of the nymphs successfully established in the field. The predator releases coincided with increasing population densities of *Helicoverpa* spp and *Creontiades* spp. (Fig. 4 & 5).

Various beneficial arthropods were observed in the plots during the experiment a list of which is given in Table 2. Of these species only damsel bugs, *Nabis kinbergii* (Reuter) (Hemiptera: Nabidae), were present at high densities for an extended period during the experiment. There were no significant differences (*P*>0.05) for *N. kinbergii* abundance between treatments except for the sprayed control, which had significantly lower (*P*<0.05) densities of this beneficial insect than all other treatments from 27 December to 17 January (Fig.2).
Table 2 Beneficial arthropod species recorded during beat sheet sampling.

<table>
<thead>
<tr>
<th>Class</th>
<th>Order</th>
<th>Sub Order</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insecta</td>
<td>Coleoptera</td>
<td>Coccinellidae</td>
<td>Coccinella transversalis (F.)</td>
</tr>
<tr>
<td>Insecta</td>
<td>Coleoptera</td>
<td>Coccinellidae</td>
<td>Micraspis frenata (Erichson)</td>
</tr>
<tr>
<td>Insecta</td>
<td>Coleoptera</td>
<td>Coccinellidae</td>
<td>Harmonia octomaculata (F.)</td>
</tr>
<tr>
<td>Insecta</td>
<td>Coleoptera</td>
<td>Coccinellidae</td>
<td>Coelophora inaequalis (F.)</td>
</tr>
<tr>
<td>Insecta</td>
<td>Coleoptera</td>
<td>Melyridae</td>
<td>Dicranolaius belulus (Guérin-Méneville)</td>
</tr>
<tr>
<td>Insecta</td>
<td>Hemiptera</td>
<td>Pentatomidae</td>
<td>Oechalia schellenbergii (Guérin-Méneville)</td>
</tr>
<tr>
<td>Insecta</td>
<td>Hemiptera</td>
<td>Pentatomidae</td>
<td>Cermatulus nasalis (Westwood)</td>
</tr>
<tr>
<td>Arachnida</td>
<td>Anyphaenida</td>
<td>Nabidae</td>
<td>Nabis kinbergii (Reuter)</td>
</tr>
<tr>
<td>Arachnida</td>
<td>Oxyopidae</td>
<td></td>
<td>Cheiracanthium spp.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Oxyopes spp.</td>
</tr>
</tbody>
</table>

A repeated measures ANOVA detected no significant differences between treatments ($P>0.05$) over time for the numbers of *Helicoverpa* spp. eggs per metre row during the experiment. The crop was subjected to an extended period of high *Helicoverpa* spp. egg densities with a peak of 81.09 ± 2.82 per metre row recorded on 27 December 2001 (Fig 3.).

A repeated measures ANOVA for larval numbers of each size (small, medium & large) demonstrated significant changes ($P<0.05$) between treatments for *Helicoverpa* spp. larvae densities over time after the release of *P. plagipennis* nymphs on 20 December 2001 (Fig 4).

From 27 December to 8 January, the mean numbers of small larvae in all of the predator treatments were significantly lower ($P<0.05$) than those of the control (Fig. 4a). The number of small larvae in the sprayed treatment were significantly higher ($P<0.05$) than all other treatments on 20 and 27 December and 8 January. There were no significant differences in the density of small larvae in the predator treatments except on 3 January when the 1 nymph per m row treatment had fewer small larvae than the 0.25 nymph per m row treatment (Fig. 4a).

The ANOVA for medium sized larvae suggested greater abundance ($P<0.05$) of medium larvae in the sprayed treatment compared to all other treatments on 27 December (Fig 4b). There were then no significant differences between treatments on 3 January, however, the control had significantly more medium sized larvae than all other treatments on 8 January (Fig 4b). The predator treatments had significantly lower medium larvae densities ($P<0.05$) than the control, with the 1 nymph per m row treatment having fewer ($P<0.05$) larvae than the other three predator treatments (Fig 4b). The 1, 0.75 and 0.5 nymph per m row treatments continued to have significantly lower medium sized larvae densities than the control on 14 January.
The 0.25 nymph per m row treatment was not significantly different to the control on 14 January (Fig 4b).

All of the predator treatments carried significantly ($P<0.05$) lower densities of large sized larvae than the control from 8 January to 18 January (Fig 4c). There were no significant differences between predator treatments for the numbers of large larvae present during this period. No large larvae were recorded in the sprayed treatment for the month of January (Fig 4c).

When the larvae counts for the three sizes are pooled for each date and the data analysed, it suggests that the four predator treatments had significantly fewer *Helicoverpa* spp. larvae than the control from 27 December to 18 January (Fig 4d).

A repeated measures ANOVA for *Creontiades* spp. numbers suggested significant changes ($P<0.05$) between treatments over time after the release of *P. plagipennis* nymphs on 20 December 2001 (Fig 5). *Creontiades* spp. numbers increased on 13 December with no significant differences between treatments before declining on 20 December. The decline in *C. dilutus* numbers coincided with storm rain that fell two days earlier on 18 December. Populations then again increased on the 27 December and significant differences ($P<0.05$) between the predator treatments and the sprayed treatment were observed (Fig 5). The 1 nymph per metre row treatment had significantly fewer ($P<0.05$) *Creontiades* spp. from 8 January to 25 January but was not significantly different ($P>0.05$) to 0.75 nymphs per metre row (Fig 5). The 0.75 nymphs per metre row treatment also had significantly lower numbers of *Creontiades* spp. than the control from 13 January to 25 January. The release of 0.25 and 0.5 nymphs per m row was only significantly different to the control on the 17 January (Fig 5). The sprayed treatment had significantly fewer ($P<0.05$) *Creontiades* spp. than the control on all occasions except 13 and 27 December and 1 and 7 February (Fig 5).

The crop was subjected to un-seasonally hot conditions during the trial. Compared to the average temperatures for central Queensland, the crop experienced 80 days of above 38°C conditions between December and February (fig 6. still to come).

The majority *P. plagipennis* nymphs were observed to have developed to the fifth instar by 8 January whilst adults were observed in the plots by 18 January. All *P. plagipennis* sampled had reached the adult stage by 30 January.
Fig 1. Time series showing numbers per m row of *Pristhesancus plagipennis* nymphs in the cotton plots for the four predator release densities, sprayed treatment and untreated control. The bars denote se. No nymphs were recorded in the sprayed and control treatments. (+), untreated control; (×), sprayed treatment; (▲), 1.0 per m row; (◆), 0.75 per m row; (△), 0.5 per m row; (◇), 0.25 per m row.

Fig 2. Time series showing numbers per m row of the damsel bug, *Nabis kinbergii* in the cotton plots for the four predator release densities, sprayed treatment and untreated control. The bars denote se. (+), untreated control; (×), sprayed treatment; (▲), 1.0 per m row; (◆), 0.75 per m row; (△), 0.5 per m row; (◇), 0.25 per m row.
Fig 3. Time series showing numbers per m row of *Helicoverpa* spp. eggs in the cotton plots for the four predator release densities, sprayed treatment and untreated control. The bars denote se. (+), untreated control; (×), sprayed treatment; (▲), 1.0 per m row; (●), 0.75 per m row; (△), 0.5 per m row; (○), 0.25 per m row.

Fig 5. Time series showing numbers per m row of *Creontiades* spp. nymphs in the cotton plots for the four predator release densities, sprayed treatment and untreated control. The arrow represents the date of predator release. The bars denote se. (+), untreated control; (×), sprayed treatment; (▲), 1.0 per m row; (●), 0.75 per m row; (△), 0.5 per m row; (○), 0.25 per m row.
Fig 4. Time series showing numbers per m row of (a) small, (b) medium, (c) large and (d) total Helicoverpa spp larvae in the cotton plots for the four predator release densities, sprayed treatment and untreated control. The arrows represent the date of predator release. The bars denote se. (+), untreated control; (X), sprayed treatment; (▲), 1.0 per m row; (œ), 0.75 per m row; (△), 0.5 per m row; (○), 0.25 per m row.
6. Discuss the results, and include an analysis of research outcomes compared with objectives.

The release of *P. plagipennis* onto Ingard cotton in this experiment was unsuccessful. The expression of Bt toxin by the plants resulted in very low levels of *Helicoverpa* spp. activity for a month post release making assessments on this pest impossible. Low mirid activity was also recorded in the crop making assessments of this pest difficult. In hind site the release of this predator in Ingard crops should be timed to coincide with the reduction of Bt gene expression later in the season, when *Helicoverpa* spp survival is likely to increase.

The conventional cotton experiment was much more successful and yielded valuable information on how *P. plagipennis* may be augmented in conventional cotton. *P. plagipennis* nymphs established successfully in the conventional crop with post-release sampling indicating predator retention levels of 72% or more four weeks after release (Fig 1). The retention rates observed in this experiment represented a significant improvement in nymph establishment compared to previous experiments where less than 30% of released nymphs were observed post-release (Grundy & Maelzer 2000; 2002). The increased prey abundance and lower predator release rates in this experiment are likely to have contributed to an improvement in nymph establishment as both factors would reduce competition between individual nymphs for prey resources.

The higher densities of *Helicoverpa* spp. larvae in the sprayed treatment on 20 and 27 December compared to the untreated control suggests that the rate of *Helicoverpa* spp. egg or neonate survival was greater in these plots. The application of Fiprinol to the sprayed treatments prior to these sample dates on the 14 December (Table 1) may have reduced the number of *Helicoverpa* spp. natural enemies in the plots. This trend was observed for the damsel bug, *N. kinbergii* (Fig 2) that is a frequently observed predator of *Helicoverpa* spp. eggs and small larvae in cotton crops (Pyke & Brown 1996). A reduction in the guild of observed natural enemies (Table 2) in the sprayed plots as observed for *N. kinbergii*, is a likely cause for the greater survival of *Helicoverpa* spp. larvae observed in the sprayed treatments. Conversely the flaring of *Helicoverpa* spp. in the sprayed controls suggests the possibility that a guild of natural enemies were also having an impact on the larvae densities observed in the untreated control and *P. plagipennis* treatments.

Significant reductions in *Helicoverpa* spp. larvae numbers were observed in each of the *P. plagipennis* treatments. Of these treatments, the release of 0.25 gave the most marginal result with no-significant difference with the control for medium larvae on 14 January (Fig 4b.). The release of nymphs at 1.0, 0.75 and 0.5 nymphs per metre row of cotton provided significant reductions in *Helicoverpa* spp. densities over a month long period. The release of 1.0 and 0.75 nymphs per m row corresponded
with significant decreases *Creontiades* spp. densities, whereas 0.25 and 0.5 nymphs per metre row were largely ineffective (Fig. 5.).

The results suggest that releases of *P. plagipennis* particularly at the higher rates of 0.75 and 1.0 nymph per metre row can cause significant reductions in *Helicoverpa* spp. and *Creontiades* spp. numbers on cotton. The release of nymphs at these rates may also assist in predator establishment by reducing competition for prey between individuals, which could have caused poor nymph establishment during previous experiments where up to 12 nymphs per metre crop row were released (Grundy & Maelzer 2000).

Although not sufficient to provide complete economic control, the reductions in pest numbers associated with the release of *P. plagipennis* nymphs during this experiment compared to the unsprayed control was encouraging, particularly when the total quantity of available prey insects is considered. The un-seasonally hot weather may have also impacted the efficacy of *P. plagipennis* in restricting foraging activity to the cooler parts of the day and accelerating pest growth and activity.

In situations of lower pest activity *P. plagipennis* nymphs released at rates of 1.0 and 0.75 may be adequate for the control of *Helicoverpa* spp. or *Creontiades* spp. in cotton. Alternatively *P. plagipennis* nymph releases may be best combined with other controls such as compatible insecticides, biopesticides or transgenic host plant resistance mechanisms within an integrated pest management program, with the latter approach being the most likely reliable and cost effective approach to augmenting this predator in cotton. Further research is needed to identify whether *P. plagipennis* exhibits any feeding preferences for *Helicoverpa* spp. and *Creontiades* spp. so as to identify which pest is most likely to be biologically controlled in a situation where both prey species are present. Insecticide products effective on the lesser preferred pest, that have minimal impact on both *P. plagipennis* and other natural enemies, could then combined with *P. plagipennis* as part of an integrated control program.

7. **Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. Where possible include a statement of the costs and potential benefits to the Australian cotton industry and future research needs.**

The results from this study do not have an immediate impact for the cotton industry. The use of assassin bugs as biological control agents is still in the developmental phase and future research is required before they can be utilised within IPM programs.

8. **Describe the project technology (eg. commercially significant developments, patents applied for or granted licenses etc).**

N/A
9. Provide a technical summary of any other information developed as part of the research project. Include discoveries in methodology, equipment design, etc.

N/A

10. Detail a plan for the activities or other steps that may be taken;

(a) to further develop or to exploit the project technology.

The use of assassin bugs as biological control agents is being further developed under a CRDC project DAQ122C.

(b) for the future presentation and dissemination of the project outcomes.

The findings of this study have been disseminated to industry through cotton tales and the 12 Australian Cotton Conference proceedings.

11. List the publications arising from the research project.


12. Are changes to the Intellectual Property register required?

N/A

13. References


