



Australian Government
Cotton Research and
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Cotton Research & Development Corporation

***IPM in Bollgard cotton –New Tools and
Strategies I: Development of Fungal
insecticides for Managing Helicoverpa &
sucking pests in cotton***

(03DAN001) (July 2007 to June 2010)



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**Industry &
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A Final Report prepared for the Cotton Research and Development Corporation



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Part 1 - Summary Details

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Part 3 – Final Report Guide (due 31 October 2008)

Background

1. Outline the background to the project.

Cotton crops in Australia are attacked by a wide range of pests, the major one being two lepidopteran pests namely *Helicoverpa armigera* (cotton bollworm) and *H. punctigera* (native budworm) (Fitt, 1989). These two lepidopteran pests have been the cause of prophylactic use of synthetic insecticides in the Australian cotton industry since the 1960s (Fitt, 1994) but the current introduction and adoption of transgenic cotton crops by the industry has reduced their importance (Wilson et al. 2004). The transgenic cotton crops contain a *Bacillus thuringiensis* (Bt) gene which expresses Cry 1AC and 2AB toxins that are toxic to *Helicoverpa* spp. and other lepidopteran pests when ingested (Fitt and Wilson 2000). Thus the introduction of the transgenic cotton crops has reduced synthetic insecticide use against *Helicoverpa* spp. by 75-80% (Wilson et al. 2004). In contrast, the introduction of transgenic cotton crops in Australia has resulted in the increase in population of sucking pests such as green mirids (*Creontiades dilutus*), cotton aphids (*Aphis gossypii*), green vegetable bugs (*Nezara viridula*) which are unaffected by the toxin in the transgenic cotton plants (Wilson et al. 2004). Also, the need to control *Helicoverpa* spp. with synthetic insecticides early in the cotton season and which inadvertently suppresses populations of these sucking pests has reduced significantly.

The increase in population of these sucking pests has also resulted in an increase in the use of synthetic insecticides against these pests on both transgenic and conventional cotton crops (Fitt and Wilson 2000). Therefore, the potential for sucking pests as well as *Helicoverpa* spp. developing resistance to some of the important insecticides is a major obstacle in the reduction of synthetic insecticide use in the cotton industry (Wilson et al. 2004). The adoption of transgenic cotton crops has provided the cotton industry a platform for the development of a true IPM program, however, the increase use of synthetic insecticides against sucking pests on transgenic cotton crops may erode the IPM advantage offered by the transgenic cotton technology. For the cotton industry to sustain production by developing a true IPM program for cotton pests, it is crucial for the industry to have access to biological control tools that have minimal effect on beneficial insects.

Presently with our monoculture practices in agriculture and the use of pesticides we are inadvertently discriminating against beneficial insects. Many areas where crops are grown especially cotton growing areas are remote from wide vegetation (Mensah 1999). They are often without trees, bushes, weeds and often lay fallow most part of the year. With no natural refuges and food sources for adult natural enemies of pests, beneficial insect populations decline quickly and make them ineffective (Mensah 1999). There is therefore lack of diversity and instability in the cotton agro-ecosystem, hence the need for the development of biological pesticides to support IPM in cotton agro-ecosystems (Mensah 1999).

Entomopathogenic fungi are known to be important natural enemies of many pests of agricultural crops (Hajek and Leger 1994). Over 750 different species of fungi have been identified to date and these are cosmopolitan organisms which have been isolated from soils and infected insects from around the world (Zimmermann 2007a, 2007b, 2008). All stages of the insects from the egg, larval or nymphal to adult can be killed by fungal pathogens. Fungi

unlike other pathogens such as viruses and bacteria do not require ingestion to infect and kill the host. Therefore, sap sucking phytophagous insects such as sucking pests (viz green mirids, aphids and green vegetable bugs) are also targets to fungi either by primary contact with fungal spore or by secondary uptake of spores from sprayed crops (Moore and Prior 1993). The advantage of using fungi for biological control is that the fungi are self-generating within or on the surface of the plant and can potentially provide ongoing protection as the plant grows, with little effect on non-herbivorous predators. Fungi act as parasite of insect pests and kill or seriously disable these insects through infection process whereby fungal conidia germinate on the insect's cuticle and form appressorium or penetration peg (Clarkson and Charnley 1996). The penetration peg invades the cuticle layers and spread rapidly throughout the host. The cotton ecosystems contain many strains and species of fungi in the soil, plant debris etc that can be exploited for their pathogenic or growth-retarding effects on cotton pests. Several species of entomopathogenic fungi have been developed as alternatives to synthetic insecticides because of the risks they pose to humans, environment and pest resistance (Butt *et al.* 2001). However, only in Australia, only two isolates of *Metarhizium anisopliae* are available commercially for the control of plague locusts and sugar cane grubs. In Australia and other parts of the world, the need to develop and commercialize entomopathogenic fungi to manage pests on agricultural crops as a benign alternative to synthetic insecticides is crucial to minimize the risk posed to humans and the environment.

The present study evaluated the efficacy of BC 639 entomopathogenic fungus against *Helicoverpa* spp., green mirids (*Creontiades dilutus*), green vegetable bugs (*Nezara viridula*), apple dimpling bugs (*Campylomma liebknechti*), cotton aphids (*Aphis gossypii*), silverleaf whiteflies (*Bemisia tabaci*) and beneficial insects viz; predatory beetles, predatory bugs, predatory lacewings and spiders on commercial conventional and transgenic (Bollgard II) cotton crops in 14 different study sites in New South Wales and Queensland from 2006 to 2010. The trials were conducted at sites in New South Wales and Queensland because most of the Australian cotton crops are grown in these states.

Objectives

2. List the project objectives and the extent to which these have been achieved.

2.1 Develop and commercialize two new fungal insecticides viz; BC667 (*Beauveria* spp) and BC 639 (*Aspergillus* spp.) for control of sucking pests

The two fungi BC 667 and BC 639 were found in field trials to control *Helicoverpa* spp. and sucking pests in cotton similar to conventional insecticides. In 2007/08 season the commercial partner, Becker Underwood Pty Ltd advised CRDC and NSWDC that all research effort be focussed on BC 639 to generate enough field efficacy data to support the registration of the BC 639 fungus because BC639 fungus was easier to grow and produce more spores than BC667. As a result, all research from 2008-2010 focussed on generating field efficacy data for BC639. The efficacy data for BC639 was submitted to Becker Underwood on 26 July 2010 for product registration. Unfortunately, Becker Underwood Pty Ltd could not generate the necessary regulatory data required by APVMA to proceed with the registration of the fungus. On 30 September 2010, NSWDC was informed by Becker Underwood that they were unable to proceed with the registration of BC 639 due to difficulty in generating the required APVMA regulatory data. Rather, Becker Underwood advised both NSWDC and the CRDC to re-direct all research effort back to developing BC 667 (*Beauveria* sp.) and DAT 511 (*Metarhizium anisopliae*). Explanation given was that, it would be easier to register either *Beauveria* or *Metarhizium* species with APVMA because these genus are already in use in Australia and other parts of the world. Also Becker Underwood now have access to the technology that can be used to improve the spore

production of BC667. With the shift of research focus on BC 667, the initial priority was to improve the sporulation of BC667. This has been achieved through a joint research effort between Dr Robert Mensah and Becker Underwood product production team in Australia and South Africa.

With BC667 sporulation problems resolved, a new project was developed and approved by the CRDC (project DAN1101) to generate efficacy data for the commercialization of BC667 and DAT 511. Trials have already commenced in the laboratory, mesh house and field. Results so far indicated that BC 667 and DAT 511 are showing good promise in the control of green mirids. For example results from field trials at Norwood on Bollgard cotton showed that both BC667 and DAT 511 reduced green mirid numbers from 2.5 and 2.83 per metre to 0.33 and 0.66 per metre respectively 3 days after treatment. Product use patent for BC667 and DAT511 will be taken by June 2011.

2.2 Undertake large scale trials to assess BC667 and BC639 for efficacy against green mirids and aphids

Achieved (see results in the report below)

2.3 Evaluate the efficacy of lower rates (below 50g spore/ha) of BC667 and BC639 against green mirids and aphids on cotton;

Achieved (results in the report below)

2.4 Determine mode of action of entomopathogenic fungus on sucking pests and, if necessary identify means of improving the effectiveness of sprays;

Achieved (results in the report below)

2.5 Determine the feeding responses of green mirids and aphids on cotton plants treated with BC 667 and BC639;

Achieved (results in the report below)

2.6 Evaluate the efficacy of different rates of BC667 and BC639 fungal insecticides and identify and compare the optimum rate effective against green mirids, aphids and beneficial insects;

Achieved (results in the report below)

2.7 Collaborate with commercial partner and lodge a provisional patent application

A Provisional patent application for BC639 fungus was filed on 17 November 2009 in the name of the Crown in the right of the state of New South Wales. The title of the patent is "Use of Aspergillus sp. as a pesticide". The Australian Provisional Patent Application number 2009905612

2.8. Collaborate with commercial partner and provide efficacy data for product registration and complete commercialization.

Detailed efficacy data on BC639 was submitted to Becker Underwood Pty Ltd on 26 July 2010. (see objective 2.1)

2.9 Submit a final report to CRDC at the end of the study

Final report has been submitted

Methods

3. Detail the methodology and justify the methodology used. Include any discoveries in methods that may benefit other related research.

3.1 Trials at ACRI in Narrabri – 2005-06

3.1.1 Dose response of BC 639 (*Aspergillus fumigatus*) and BC 667 (*Beauveria bassiana*) to *Helicoverpa* spp. second instar larvae in the laboratory

H. armigera larvae were cultured in the laboratory until they reached 2nd instar stage before being used for the study. The trials were conducted on 10 to 28 February 2005.

The fungal insecticide (BC 639) was tested at 10¹, 10², 10³, 10⁴, 10⁵, 10⁶ and 10⁸ spores/mL. Ten *H. armigera* 2nd instar larvae were placed in a 90mm petri dish lined with filter paper and sprayed separately with each treatment dose. The larvae from each treatment were then transferred individually into separate 45mm petri dishes containing a fresh 19mm conventional cotton leaf disc on filter paper. The petri dishes were sealed and placed in an incubator set at 26 - 28°C. Thus each treatment had ten larvae placed individually in 10 petridishes.

The larvae were checked 1, 2 and 3 days after treatment (DAT) and the number of dead and alive were recorded. The study continued until the surviving larvae reached the 5th instar stages. Mortality in each treatment was calculated and dose – response curve was developed for BC 639 log spores/mL and mortalities of *Helicoverpa* spp. 2nd instar larvae.

3.2 Trials at ACRI in Narrabri – 2006-07

3.2.1a Efficacy of different rates of BC 639 (*Aspergillus fumigatus*) on the survival of green mirids and non-target arthropods on commercial cotton crops

The trial was conducted in an irrigated commercial Bollgard II cotton crops at the Australian Cotton Research Institute farm (River block 3) in Narrabri. A 3-12 rows of sunflower strips were planted on both sides of the field (i.e. sunflower strips sandwich the field) to generate green mirids.

The following treatments were evaluated against green mirids: (1) 1L/ha BC 639 (*Aspergillus fumigatus*) (2) 0.75L BC 639 (*Aspergillus fumigatus*), (3) 0.50L BC 639 (*Aspergillus fumigatus*), (5) 62.5ml Fipronil and (6) Unsprayed (untreated) control. The treatment plots were arranged in a randomized complete block design with 6 replicates per treatment. Each replicated plot measured 8 m wide and 220 metres long.

Foliar application of each treatment was made from 22 January 2007. The decision to apply the treatment was made based on the IPM Guidelines and CottonLogic recommended economic threshold of 0.5 green mirids per metre.

Visual counts of green mirid adults and nymphs on cotton plants in each treatment were made at approximately at 3 days after treatments and then weekly intervals in a randomly selected 1 metre length of row of each treatment replicate, i.e. a total of 6 metres were

examined per treatment. Counts were separated into nymphs and adults. Data were expressed as numbers per metre for each treatment.

Cotton in each treated plot was harvested separately using a four-row picker at the end of the season and the average lint yields (bales/ha) were compared between treatments.

3.2.2 Analysis of the data

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

3.2.1b Efficacy of different rates of BC 639 (*Aspergillus fumigatus*) and BC 667 (*Beauveria bassiana*) on the survival of green mirids and non-target arthropods on commercial cotton crops

The trial was conducted in an irrigated commercial Bollgard II cotton crops at the Australian Cotton Research Institute farm (River block 3) in Narrabri. A 3-12 rows of sunflower strips were planted on both sides of the field (i.e. sunflower strips sandwich the field) to generate green mirids.

The following treatments were evaluated against green mirids: (1) 1L/ha BC 639 (*Metarhizium* spp.), (2) 0.75L BC 639 (*Aspergillus fumigatus*), (3) 0.50L BC 667 (*Beauveria* spp.), (4) 0.50L BC 639 (*Aspergillus fumigatus*), (5) 62.5ml Fipronil and (6) Unsprayed (untreated) control. The treatment plots were arranged in a randomized complete block design with 6 replicates per treatment. Each replicated plot measured 8 m wide and 220 metres long.

Foliar application of each treatment was made from 22 January 2007. The decision to apply the treatment was made based on the IPM Guidelines and CottonLogic recommended economic threshold of 0.5 green mirids per metre.

Visual counts of green mirid adults and nymphs on cotton plants in each treatment were made at approximately weekly intervals in two randomly selected 1 metre lengths of row of each treatment replicate, i.e. a total of 8 metres were examined per treatment. Counts were separated into nymphs and adults. Data were expressed as numbers per metre and numbers per metre per sample date for each treatment.

Cotton in each treated plot was harvested separately using a four-row picker at the end of the season and the average lint yields (bales/ha) were compared between treatments.

3.2.1b Analysis of the data

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

3.3 Trials at Norwood near Moree - 2006-07

3.3.1 Efficacy of different rates of BC 639 on the survival of green mirids and non-target arthropods on commercial cotton crops

The trial was conducted in a commercial Bollgard II cotton farms at Norwood near Moree. The trial commenced on 16 November 2006 until 28 February 2007.

The following treatments were evaluated against green mirids: (1) 1L/ha BC 639 (*Aspergillus fumigatus*), (2) 0.75L BC 639 (*Aspergillus fumigatus*), (3) 0.50L BC 667 (*Beauveria* spp.), (4) 0.50L BC 639 (*Aspergillus fumigatus*), (5) 62.5ml Fipronil and (6) Unsprayed (untreated) control. The treatment plots were arranged in a randomized complete block design with 6 replicates per treatment. Each replicated plot measured 40 m (rows) wide and 90 metres long (average).

Pre-treatment counts were made visually of green mirid adults and nymphs, green vegetable bugs, non target arthropods such as beneficial insects viz; predatory beetles, predatory bugs, predatory lacewings and spiders and predatory beetles on cotton plants in each treatment were made. Post -treatment counts were made on 3, 7 and 14 days first treatment application and 3, 7, 14 and 21 days after second treatment application. In each counts, one randomly selected 1 metre length of row of each treatment replicate, *i.e.* a total of 6 metres were examined per treatment. Data were expressed as numbers per metre for each treatment.

3.3.2 Analysis of the data

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

3.4 Trials at Getta Getta in Goondiwindi - 2006-07

3.4.1 Efficacy of different rates of BC 639 on the survival of green mirids, green vegetable bugs, cotton aphids and beneficial insects on commercial cotton crops

The trial was conducted on a dryland commercial Bollgard II cotton farm at Getta Getta in Goondiwindi in the Macintyre valley in Queensland.

The following treatments were evaluated against green mirids, green vegetable bugs, predatory beetles, predatory bugs, predatory lacewings and spiders: (1) 1L/ha BC 639 (*Aspergillus fumigatus*), (2) 0.50L/ha BC 639 (*Aspergillus fumigatus*), (3) 0.25L/ha BC 639 (*Aspergillus fumigatus*), (5) 62.5ml Fipronil and (6) Unsprayed (untreated) control. The treatment plots were arranged in a randomized complete block design with 6 replicates per treatment. Each replicated plot measured 8 m wide and 220 metres long.

The first foliar application of each treatment was made on 31 January 2007 and the second on 25 February 2007. The decision to apply the treatment was made based on the IPM Guidelines and CottonLogic recommended economic threshold of 0.5 green mirids per metre.

Visual counts of green mirid adults and nymphs, green vegetable bugs, predatory beetles, bugs, lacewings and spiders on cotton plants in each treatment were made at approximately weekly intervals in a randomly selected 1 metre lengths of row of each treatment replicate,

i.e. a total of 6 metres were examined per treatment. Counts for green mirids, green vegetable bugs, predatory beetles, predatory bugs, predatory lacewings and spiders were each expressed as numbers per metre for each treatment.

3.4.1.1 Analysis of the data

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

3.4.2 Efficacy of different rates of BC 639 on the survival of *Aphis gossypii* on commercial cotton crops

The trial was conducted on a dryland commercial Bollgard II cotton farm at Getta Getta near Goondiwindi in the Macintyre valley.

The following treatments were evaluated against green mirids: (1) 1L/ha BC 639 (*Aspergillus fumigatus*), (2) 0.50L/ha BC 639 (*Aspergillus fumigatus*), (3) 0.25L/ha BC 639 (*Aspergillus fumigatus*), (5) 0.25L + 0.2% v/v Pulse Penetrant and (6) Unsprayed (untreated) control. The treatment plots were arranged in a randomized complete block design with 6 replicates per treatment. Each replicated plot measured 8 m wide and 220 metres long.

The first foliar application of each treatment was made on 31 January 2007 and the second on 25 February 2007. The decision to apply the treatment was made based on the IPM Guidelines and CottonLogic recommended economic threshold of 50 per cent of plants infested to first open boll.

The cotton aphid numbers were assessed by randomly collecting 50 leaves in each treatment by taking one leaf per plant from the main stem from 3-4 nodes below the terminals. The terminals from each treated plot were placed in a separate and a clearly marked plastic bag. The samples were kept in a freezer for a day and then gently washed with 70% ethanol solution onto a filter paper in a petridish. This was then counted under a binocular microscope in the laboratory. Data was expressed as number of aphids per leaf per treatment.

3.4.2.1 Analysis of the data

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

3.5 Trials at ACRI in Narrabri – 2007-08

3.5.1 Efficacy of lower rates of BC 639 and BC 667 on the survival of green mirids, beneficial insects and non-target arthropods on commercial cotton crops

The trial was conducted in an irrigated commercial Bollgard II cotton crops at the Australian Cotton Research Institute farm in Narrabri. A 3-12 rows of sunflower strips were planted on both sides of the field (i.e. sunflower strips sandwich the field) to generate green mirids.

The following treatments were evaluated against green mirids, green vegetable bugs, apple dimpling bugs and beneficial insects viz; predatory beetles, predatory bugs, predatory lacewings and spiders: (1) 500 mL/ha BC 639 (*Aspergillus fumigatus*), (2) 250 mL/ha BC 639 (*Aspergillus fumigatus*) (3) 250 mL/ha BC 667 (*Beauveria bassiana*), (5) 62.5ml Fipronil and (6) Unsprayed (untreated) control. The treatment plots were arranged in a randomized complete block design with 6 replicates per treatment. Each replicated plot measured 16 m wide and 250 metres long.

Foliar applications of each treatment were made on 3 and 30 January 2008. The decision to apply the treatment was made based on the IPM Guidelines and CottonLogic recommended economic threshold of 0.5 green mirids per metre.

Pre-treatment counts were made visually of green mirid adults and nymphs, green vegetable bugs, apple dimpling bugs and beneficial insects such as predatory bugs, predatory lacewings, spiders and predatory beetles (viz; red and blue beetles, ladybird beetles) on cotton plants in each treatment were made. Post -treatment counts were made on 3, 7 and 14 days first treatment application and 3, 7, 14 and 21 days after second treatment application. In each counts, two randomly selected 1 metre lengths of row of each treatment replicate, i.e. a total of 6 metres were examined per treatment. Data were expressed as numbers per metre for each treatment.

Cotton in each treated plot was harvested separately using a four-row picker at the end of the season and the average lint yields (bales/ha) were compared between treatments.

3.5.1.1 Analysis of the data

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

3.6 Trials at Norwood near Moree in 2007-008

3.6.1 Efficacy of different rates of BC 639 against *Helicoverpa* spp. and beneficial insects on conventional cotton crops at Norwood near Moree in 2007-08

The trial was conducted on a commercial conventional cotton farm at Norwood near Moree. The trial commenced on 16 November 2007 until 11 March 2008.

The following treatments were evaluated against *Helicoverpa* spp. eggs, very small and small, medium and large larvae and beneficial insects: (1) 1L/ha BC 639 (*Aspergillus fumigatus*), (2) 0.50L BC 639 (*Aspergillus fumigatus*), (4) Conventional insecticides (Affirm insecticide (1st spray and Steward insecticide (2nd spray application) and (6) Unsprayed (untreated) control. The treatment plots were arranged in a randomized complete block design with 4 replicates per treatment. Each replicated plot measured 40 m (rows) wide and 90 metres long (average). A 40 m – wide buffer separated the conventional insecticide – treated plots and the fungus and unsprayed plots.

Counts of insects were made 24 hr before treatment and then 3, 7 and 14 days after treatment in each spray application. Foliar application for each treatment was made on 30 January 2008 (1st spray) and

25 February 2008 (2nd spray) using a high clearance tractor. On each occasion treatments were applied using 100 litres water per hectare. The control plot was left unsprayed.

3.6.1.1 Helicoverpa spp. eggs, very small and small (VS+S) and medium and large (M+L) larvae on conventional cotton crops

Visual counts of *Helicoverpa* spp. stages on whole cotton plants were made in 4 selected 1 – metre lengths of row of each treatment replicate. Counts were separated into *Helicoverpa* spp. eggs, very small and small (1st to 3rd instar stage) and medium and large (4 to 6th instar stage). Data were expressed as numbers per metre for each treatment.

3.6.1.2 Predatory beetles, bugs, lacewings and spiders on conventional cotton crops

Pre-treatment counts were made visually of predatory insects such as predatory beetles, predatory bugs, predatory lacewings and spiders on cotton plants in each treatment were made. Post –treatment counts were made on 3, 7 and 14 days after each treatment application. In each counts, two randomly selected 1 metre lengths of row of each treatment replicate, *i.e.* a total of 4 metres were examined per treatment. Data were expressed as numbers per metre for each treatment.

3.7 Efficacy of different rates of BC 639 on green mirids, apple dimpling bugs and green vegetable bugs on Bollgard cotton crops at Norwood, 2007-08.

The trial was conducted on a commercial Bollgard cotton crops at Norwood near Moree. The trial commenced on 16 November 2007 until 11 March 2008.

The following treatments were evaluated against green mirids, apple dimpling bugs and green vegetable bugs: (1) 1L/ha BC 639 (*Aspergillus fumigatus*), (2) 0.50L BC 639 (*Aspergillus fumigatus*), (4) Conventional insecticides and (6) Unsprayed (untreated) control. The treatment plots were arranged in a randomized complete block design with 4 replicates per treatment. Each replicated plot measured 40 m (rows) wide and 90 metres long (average). A 40 m – wide buffer separated the conventional insecticide – treated plots and the fungus and unsprayed plots.

Foliar application for each treatment was made on 14 January 2008 and 26 February 2008 using a high clearance tractor. On each occasion treatments were applied using 100 litres water per hectare. The control plot was left unsprayed.

Pre-treatment counts were made visually of green mirid adults and nymphs, apple dimpling bugs and beneficial insects such as predatory bugs, predatory lacewings, spiders and predatory beetles on cotton plants in each treatment were made. Post –treatment counts were made on 3, 7 and 14 days after each treatment application. In each counts, one randomly selected 1 metre lengths of row of each treatment replicate, *i.e.* a total of 4 metres were examined per treatment. Data were expressed as numbers per metre for each treatment.

3.7.1 Analysis of the data

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

3.8 Trials at Getta Getta in Goondiwindi – 2007-08

3.8.1 Efficacy of different rates of BC 639 and BC 667 on the survival of green mirids and non-target arthropods on commercial Bollgard cotton crops

The trial was conducted in a dryland commercial Bollgard II cotton farm at Getta Getta near Goondiwindi in the Macintyre valley.

The following treatments were evaluated against *Helicoverpa* spp. eggs, green mirids and beneficial insects: (1) 1L/ha BC 639 (*Aspergillus fumigatus*), (2) 0.50L/ha BC 639 (*Aspergillus fumigatus*), (3) 0.25L/ha BC 639 (*Aspergillus fumigatus*), 0.25L/ha BC 667 (*Beauveria* spp.), (5) 62.5ml Fipronil and (6) Unsprayed (untreated) control. The treatment plots were arranged in a randomized complete block design with 3 replicates per treatment. Each replicated plot measured 8 m wide and 220 metres long.

The first foliar application of each treatment was made on 14 January 2008 and the second on 4 February 2008. The decision to apply the treatment was made based on the IPM Guidelines and CottonLogic recommended economic threshold of 0.5 green mirids per metre.

Visual counts of green mirid adults and nymphs on cotton plants in each treatment were made 3, 7, 14 days after first treatment application and 3, 7, 14 and 21 days after the second treatment applications. In each counts, two randomly selected 1 metre lengths of row of each treatment replicate, *i.e.* a total of 3 metres were examined per treatment. Counts were made of green mirid adults and nymphs, *Helicoverpa* spp. eggs and beneficial insects such as predatory beetles, bugs, lacewings and spiders. Data were expressed as numbers per metre for each treatment.

3.8.1.1 Analysis of the data

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

3.9 Trials at ACRI in Narrabri – 2008-09

3.9.1 Efficacy of different rates of BC 639 on the survival of *Helicoverpa* spp., green mirids, beneficial insects and non-target arthropods on commercial cotton crops

The trial was conducted in an irrigated commercial Bollgard II cotton crops at the Australian Cotton Research Institute farm in Narrabri during 2008-09 season. A 3-12 rows of sunflower strips were planted on both sides of the field (*i.e.* sunflower strips sandwich the field) to generate green mirids.

The following treatments were evaluated against *Helicoverpa* spp. eggs, green mirids, apple dimpling bugs, predatory beetles, bugs, lacewings and spiders: (1) 750 mL/ha BC 639 (*Aspergillus fumigatus*), (2) 500 mL/ha BC 639 (*Aspergillus fumigatus*) (3) 250 mL/ha BC 639 (*Aspergillus fumigatus*), (5) 62.5ml Fipronil and (6) Unsprayed (untreated) control. The treatment plots were arranged in a randomized complete block design with 8 replicates per treatment. Each replicated plot measured 16 m wide and 250 metres long.

Foliar applications of each treatment were made on 8 January 2009. The decision to apply the treatment was made based on the IPM Guidelines and CottonLogic recommended economic threshold of 0.5 green mirids per metre.

Pre-treatment counts were made visually of green mirid adults and nymphs, apple dimpling bugs and beneficial insects such as predatory bugs, predatory lacewings, spiders and predatory beetles (viz; red and blue beetles, ladybird beetles) on cotton plants in each treatment were made. Post -treatment counts were made on 3, 7 and 14 days after treatment application. In each counts, two randomly selected 1 metre lengths of row of each treatment replicate, *i.e.* a total of 8 metres were examined per treatment. Data were expressed as numbers per metre for each treatment.

3.9.1.1 Analysis of the data

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

3.10 Trials at ACRI in Narrabri – 2008-09 – Aerial application of BC 639

3.10.1 Efficacy of aerial application of BC 639 on the survival of green mirids, apple dimpling bugs and beneficial insects on commercial cotton crops

The trial was conducted in an irrigated commercial Bollgard II cotton crops in a commercial cotton farm at Mirrabooka in Narrabri during 2008-09 season.

The following treatments were evaluated: (1) 500 mL/ha BC 639 (*Aspergillus fumigatus*) (2) 62.5ml Fipronil and (3) Unsprayed (untreated) control. The treatment plots were arranged in a randomized complete block design with 4 replicates per treatment. Each replicated plot measured 48 m wide (2 swath widths of a fixed wing aircraft) and 800 m long.

Foliar applications of each treatment were made on 23 January 2009. It rained 6 days after spray application, therefore spray was repeated on day 7. The decision to apply the treatment was made based on the IPM Guidelines and CottonLogic recommended economic threshold of 0.5 green mirids per metre.

Pre-treatment counts were made visually of green mirid adults and nymphs, apple dimpling bugs and beneficial insects such as predatory bugs, predatory lacewings, spiders and predatory beetles (viz; red and blue beetles, ladybird beetles) on cotton plants in each treatment. Post -treatment counts were made on 3, 7 days after treatment application. In each counts, one randomly selected 1 metre lengths of row of each treatment replicate, *i.e.* a total of 4 metres were examined per treatment. Data were expressed as numbers per metre for each treatment.

3.10.1.1 Analysis of the data

All experimental data were analysed using repeated measures ANOVA (Graphpad Instat and Prism Software, Inc. v. 2.03, San Diego, CA, USA). Treatment and sample dates were the

independent variables. Tukey-Kramer Multiple comparisons tests were used to separate means.

3.11 Trials at ACRI and Merah North – 2008-09) – Silverleaf whitefly trials

3.11.1 Efficacy of entomopathogenic fungi (BC 639 and BC 667) on the survival of *Bemisia tabaci* (silverleaf whitefly) on commercial cotton crops at ACRI in Narrabri

The trial was conducted in an irrigated conventional cotton crops in a commercial cotton farm at the Australian Cotton Research Institute farm in Narrabri. Two trials were conducted from 26 February to 19 March 2009.

The following treatments were evaluated against *B. tabaci* – b- type (silverleaf whitefly) adults and nymphs: (1) 500 mL/ha BC 639 (*Aspergillus* spp.) (2) 500 mL/ha BC 667 (*Beauveria* spp.) (3) Unsprayed (untreated) control. The treatment plots were arranged in a randomized complete block design with 3 replicates per treatment. Each replicated plot measured 24 m wide 100 m long.

Foliar applications of each treatment were made on 26 February 2009. Pre-treatment counts were made visually of *B. tabaci* adults and nymphs, on the under-surface of leaves of cotton plants in each treatment. Post – treatment counts were made on 3, 7, 14 and 21 days after treatment application. In each sampling date, twenty (30) plants from each treatment replicate were randomly selected and *B. tabaci* adults on one leaf from the 5th node below the terminal of each plant (during the early morning hours (9-10am) were counted visually by carefully turning the leaf over and counting the number of individual adults present.

In the case of nymphs, one leaf from the 5th node below the terminal of each of the 20 plants was cut, removed and carefully placed individually in a plastic bag. The plastic bags containing the leaves were brought to the laboratory and the *B. tabaci* nymphs were counted under a binocular microscope. Data of both adults and nymphs were expressed as numbers per leaf for each treatment.

3.11.2 Efficacy of entomopathogenic fungi (BC 639 and BC 667) on the survival of *Bemisia tabaci* (silverleaf whitefly) on commercial cotton crops at Merah North at WeeWaa

The trial was conducted in an irrigated conventional cotton crops in a commercial cotton farm at Merah North at WeeWaa from 24 March to 7 April 2009.

The following treatments were evaluated against *B. tabaci* – b- type adults and nymphs: (1) 500 mL/ha BC 639 (*Aspergillus* spp.) (2) 500 mL/ha BC 667 (*Beauveria* spp.) (3) Unsprayed (untreated) control. The treatment plots were arranged in a randomized complete block design with 3 replicates per treatment. Each replicated plot measured 24 m wide 60 m long.

Foliar applications of each treatment were made on 26 February 2009. Pre-treatment counts were made visually of *B. tabaci* adults and nymphs, on the under-surface of leaves of cotton plants in each treatment. Post – treatment counts were made on 3, 7, 14 and 21 days after treatment application. In each sampling date, twenty (30) plants from each treatment replicate were randomly selected and *B. tabaci* adults on one leaf from the 5th node below the terminal of each plant (during the early morning hours (9-10am) were counted visually by carefully turning the leaf over and counting the number of individual adults present.

In the case of nymphs, one leaf from the 5th node below the terminal of each of the 20 plants was cut, removed and carefully placed individually in a plastic bag. The plastic bags containing the leaves were brought to the laboratory and the *B. tabaci* nymphs were counted under a binocular microscope. Data of both adults and nymphs were expressed as numbers per leaf for each treatment.

3.12. Comparison of the efficacy of entomopathogenic fungi (BC 639 and BC 667) and conventional insecticides on the survival of *Bemisia tabaci* (silverleaf whitefly) on commercial cotton crops at Merah North in WeeWaa, 2008-09.

The trial was conducted in an irrigated conventional cotton crops in a commercial cotton farm at Merah North at WeeWaa from 22 March to 5 April 2009.

The following treatments were evaluated against *B. tabaci* – b- type adults and nymphs: (1) 500 mL/ha BC 639 (*Aspergillus* spp.) (2) 500 mL/ha BC 667 (*Beauveria* spp.) (3) 500 mL/ha Pyriproxyfen (conventional insecticide) and (4) Unsprayed (control). The treatment plots were arranged in a randomized complete block design with 3 replicates per treatment. Each replicated plot measured 24 m wide 100 m long.

Foliar applications of each treatment were made on 26 February 2009. Pre-treatment counts were made visually of *B. tabaci* adults and nymphs, on the under-surface of leaves of cotton plants in each treatment. Post – treatment counts were made on 3, 7, 14 and 21 days after treatment application. In each sampling date, twenty (30) plants from each treatment replicate were randomly selected and *B. tabaci* adults on one leaf from the 5th node below the terminal of each plant (during the early morning hours (9-10am) were counted visually by carefully turning the leaf over and counting the number of individual adults present.

In the case of nymphs, one leaf from the 5th node below the terminal of each of the 20 plants was cut, removed and carefully placed individually in a plastic bag. The plastic bags containing the leaves were brought to the laboratory and the *B. tabaci* nymphs were counted under a binocular microscope. Data of both adults and nymphs were expressed as numbers per leaf for each treatment.

3.12.1 Analysis of the data

All experimental data were analysed using repeated measures ANOVA (Graphpad Instat and Prism Software, Inc. v. 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.

3.13 Trials at Morella in Goondiwindi, 2009-10

3.13.1 Efficacy of BC 639 against green mirids, green vegetable bugs, apple dimpling bugs and silverleaf whiteflies on Bollgard cotton crops at Morella in Goondiwindi, 2009-10

3.13.1.1 Efficacy against green mirids

The trial was conducted in an irrigated commercial Bollgard II cotton crops in a commercial cotton farm at Morella in Goondiwindi during 2009-10 season.

The following treatments were evaluated against green mirids: (1) 500 mL/ha BC 639 (*Aspergillus fumigatus*) (2) 62.5ml Fipronil and (3) Unsprayed (untreated) control. The treatment plots were

arranged in a randomized complete block design with 6 replicates per treatment. Each replicated plot measured 6 ha.

Foliar applications of each treatment were made on 19 January and 9 February 2010. The decision to apply the treatment was made based on the IPM Guidelines and CottonLogic recommended economic threshold of 0.5 green mirids per metre.

Pre-treatment counts were made visually of green mirid adults and nymphs. Post – treatment counts were made on 4, 7, 14 and 21 days after treatment application. The 21 DAT count was used as pre-treatment counts for spray 2. In each counts, one randomly selected 1 metre lengths of row of cotton of each treatment replicate, *i.e.* a total of 6 metres were examined per treatment. Data were expressed as numbers per metre for each treatment.

3.13.1.2 Efficacy against silverleaf white flies

The trial was conducted in an irrigated commercial Bollgard cotton crops in a commercial cotton farm at Morella in Goondiwindi.

The following treatments were evaluated against *B. tabaci* – b- type adults and nymphs: (1) 500 mL/ha BC 639 (*Aspergillus* spp.) (2) 500 mL/ha Pyriproxyfen (conventional insecticide) and (3) Unsprayed (control). The treatment plots were arranged in a randomized complete block design with 3 replicates per treatment. Each replicated plot measured 24 m wide 100 m long.

Foliar applications of each treatment were made on 17 February 2010. Pre-treatment counts were made visually of *B. tabaci* adults and nymphs, on the under-surface of leaves of cotton plants in each treatment. Post – treatment counts were made on 3, 7, 14 and 21 days after treatment application. In each sampling date, twenty (20) plants from each treatment replicate were randomly selected and *B. tabaci* adults on one leaf from the 5th node below the terminal of each plant (during the early morning hours (9-10am) were counted visually by carefully turning the leaf over and counting the number of individual adults present.

In the case of nymphs, one leaf from the 5th node below the terminal of each of the 20 plants was cut, removed and carefully placed individually in a plastic bag. The plastic bags containing the leaves were brought to the laboratory and the *B. tabaci* nymphs were counted under a binocular microscope. Data of both adults and nymphs were expressed as numbers per leaf for each treatment.

3.13.1.3 Analysis of the data

All experimental data were analysed using repeated measures ANOVA (Graphpad Instat and Prism Software, Inc. v. 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.

3.14 Trials at Australian Cotton Research Institute (ACRI) in Narrabri, 2009-10

3.14.1 Efficacy of BC 639 against silverleaf whiteflies on Bollgard cotton crops at ACRI in Narrabri 2009-10

The trial was conducted in an irrigated commercial Bollgard cotton crops in a commercial cotton farm at Merah North at WeeWaa from 22 March to 5 April 2009.

The following treatments were evaluated against *B. tabaci* – b- type adults and nymphs: (1) 500 mL/ha BC 639 (*Aspergillus* spp.) (2) 500 mL/ha Pyriproxyfen (conventional insecticide) and (3)

Unsprayed (control). The treatment plots were arranged in a randomized complete block design with 3 replicates per treatment. Each replicated plot measured 24 m wide 100 m long.

Foliar applications of each treatment were made on 26 February 2010. Pre-treatment counts were made visually of *B. tabaci* adults and nymphs, on the under-surface of leaves of cotton plants in each treatment. Post - treatment counts were made on 3, 7, 14 and 21 days after treatment application. In each sampling date, twenty (20) plants from each treatment replicate were randomly selected and *B. tabaci* adults on one leaf from the 5th node below the terminal of each plant (during the early morning hours (9-10am) were counted visually by carefully turning the leaf over and counting the number of individual adults present.

In the case of nymphs, one leaf from the 5th node below the terminal of each of the 20 plants was cut, removed and carefully placed individually in a plastic bag. The plastic bags containing the leaves were brought to the laboratory and the *B. tabaci* nymphs were counted under a binocular microscope. Data of both adults and nymphs were expressed as numbers per leaf for each treatment.

3.14.2 Analysis of the data

All experimental data were analysed using repeated measures ANOVA (Graphpad Instat and Prism Software, Inc. v. 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.

4.0 Results

4. Detail and discuss the results for each objective including the statistical analysis of results

4.1 Dose response of BC 639 to *Helicoverpa* spp. second instar larvae in the laboratory at ACRI, 2005-2006

The result of the response of the test insects to BC 639 and BC 667 are summarized in dose-response curves in Figures 3.1.1a and b. Exposure of *Helicoverpa* spp. second instar larvae to progressively increasing concentrations of BC 639 and BC 667 resulted in the deaths of the test organisms from 10^2 to 10^8 spores/mL (Figures 4.1.1ab). The optimum dose required to kill over 50% of the insects was recorded as 1.0×10^7 spores/mL (Figures 4.1.1ab).

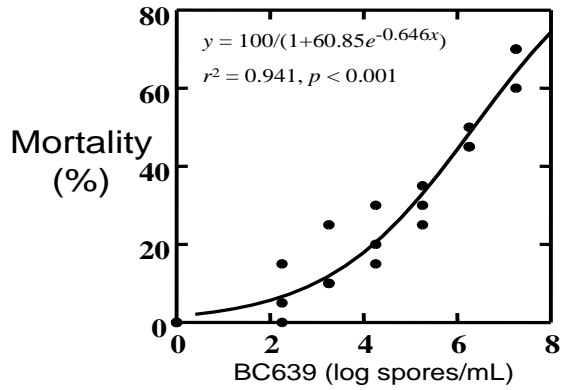


Figure 4.1.1. Dose-response curve for BC639 and mortalities of *H. armigera* 2nd stage larvae in the laboratory, 10-28 February 2006.

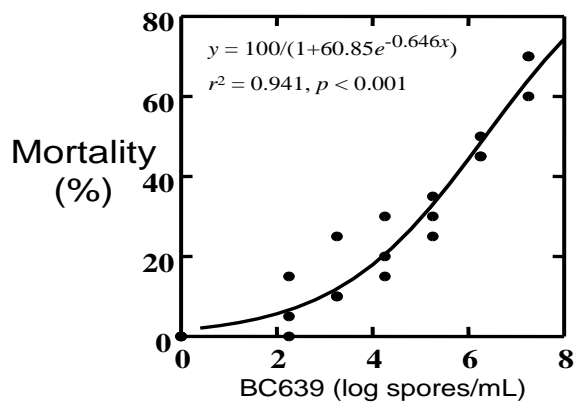


Figure 4.1.1a. Dose-response curve for BC639 and mortalities of *H. armigera* 2nd stage larvae in the laboratory, 10-28 February 2006.

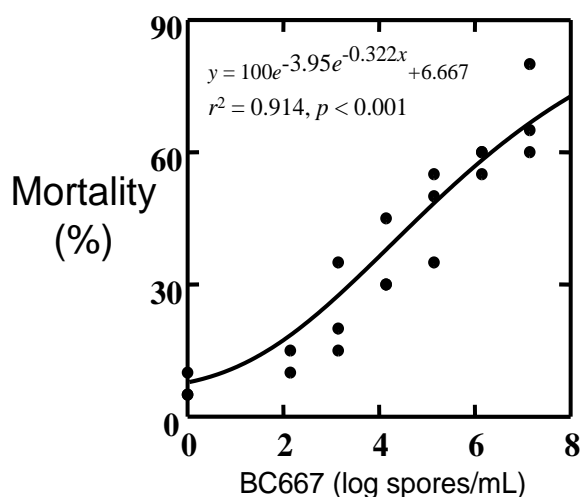


Figure 4.1.1b. Dose-response curve for BC639 and mortalities of *H. armigera* 2nd stage larvae in the laboratory, 10-28 February 2006.

Conclusion

Exposure of *Helicoverpa* spp. second instar larvae to increasing concentrations of BC 639 and BC667 resulted in the deaths of the test organisms from 10² to 10⁸ spores/mL. The optimum dose required to kill over 50% of *Helicoverpa armigera* second instar larvae was recorded as 1.0 x 10⁷ spores/mL

4.2 Trials at ACRI in Narrabri - 2006-07

4.2.1a Efficacy of different rates of BC 639 on the survival of green mirids on commercial transgenic (Bollgard II) cotton crops

The results of the study showed that the BC 639 fungal insecticides can invade green mirids killing them within 3-7 days. The number of green mirid adults and nymphs recorded on plots treated with different rates of BC 639 fungus 3 to 28 days after treatment (DAT) were the same as plots treated with the recommended rate of Fipronil (Tables 4.2.1.1 and 4.2.1.2). The number of green mirid adults and nymphs per metre recorded in the unsprayed plots were significantly higher (P<0.0001) than plots treated with different rates of BC 639 or Fipronil insecticide (4.2.1.1 and 4.2.1.2). Plots treated with Fipronil at the recommended rate have the same number of green mirids adults and nymphs per metre as plots treated with different rates of BC 639 (4.2.1.1 and 4.2.1.2).

Table 4.2.1.1: Efficacy of different rates of BC 639 fungal insecticides against *C. dilutus* adults per metre in transgenic (Bollgard II) cotton crops at the Australian Cotton Research Institute farm in Narrabri, 2006-07

Treatments	Pre-treatment counts	3 DAT	7 DAT	14 DAT	21 DAT	28 DAT
1L/ha	1.00±0.26a	0.33±0.21a	0.00±0.00a	0.33±0.21a	0.00±0.00a	0.00±0.00a
0.75L/ha	0.67±0.21a	0.17±0.17a	0.17±0.17a	0.50±0.22a	0.00±0.00a	0.00±0.00a
0.50 L/ha	0.83±0.31a	0.66±0.21a	0.33±0.21a	0.50±0.22a	0.33±0.21a	0.00±0.00a
62.5ml/ha Fipronil	0.50±0.22a	0.17±0.17a	0.00±0.00a	0.00±0.00a	0.17±0.17a	0.00±0.00a
Control (Unsprayed)	0.67±0.21a	1.50±0.22b	1.17±0.17b	1.33±0.21b	1.33±0.21b	1.17±0.31b
	P>0.10	P<0.0004	P<0.0009	P<0.004	P<0.0001	P<0.0001

Means within columns followed by the same letters are not significantly different ($P>0.05$), Tukey-Kramer Multiple comparison test.

Table 4.2.1.2: Efficacy of different rates of BC 639 fungal insecticides against *C. dilutus* nymphs per metre in transgenic (Bollgard II) cotton crops at the Australian Cotton Research Institute farm in Narrabri, 2006-07

Treatments	Pre-treatment counts	3 DAT	7 DAT	14 DAT	21 DAT	28 DAT
1L/ha	2.67±0.21a	2.17±0.17a	1.50±0.22a	0.00±0.00a	0.00±0.00a	0.00±0.00a
0.75L/ha	3.00±0.25a	1.17±0.31a	2.00±0.26a	0.17±0.17a	0.33±0.21a	0.00±0.00a
0.50 L/ha	2.67±0.21a	2.33±0.21a	1.83±0.40a	0.67±0.21a	0.50±0.22a	0.00±0.00a
62.5ml/ha Fipronil	3.33±0.21a	1.50±0.22a	0.83±0.17a	0.00±0.00a	0.33±0.21a	0.00±0.00a
Control (Unsprayed)	3.67±0.42a	4.17±0.54b	4.33±0.21b	3.17±0.31b	3.00±0.37b	2.17±0.31b
	P>0.09	P<0.0001	P<0.0001	P<0.0001	P<0.0001	P<0.0001

Means within columns followed by the same letters are not significantly different ($P>0.05$), Tukey-Kramer Multiple comparison test.

4.2.1b Efficacy of different rates of BC 639 and BC 667 on the survival of green mirids on commercial transgenic (Bollgard II) cotton crops

The results of the study showed that the fungal insecticides can invade green mirids killing them within 3-7 days. The number of green mirid adults and nymphs recorded on plots treated with different rates of BC 667 and BC 639 were the same as plots treated with half the label rate of Fipronil (Figure 4.2.1.1). The number of green mirid adults and nymphs per metre recorded in the unsprayed plot was significantly higher ($P<0.008$) than the plots treated with either fungus or half rate of Fipronil insecticide (Figure 4.2.1.1). Plots treated with Fipronil at half the label rate has the same number of green mirids per metre ($P>0.05$) as plots treated with different rates of BC667 and BC 639 fungi (Figure 4.2.1.1). Overall, approximately 2.5 and 2.2 times more green mirid adults and nymphs were recorded on the untreated plots than the fungus treated plots (Figure 4.2.1.1).

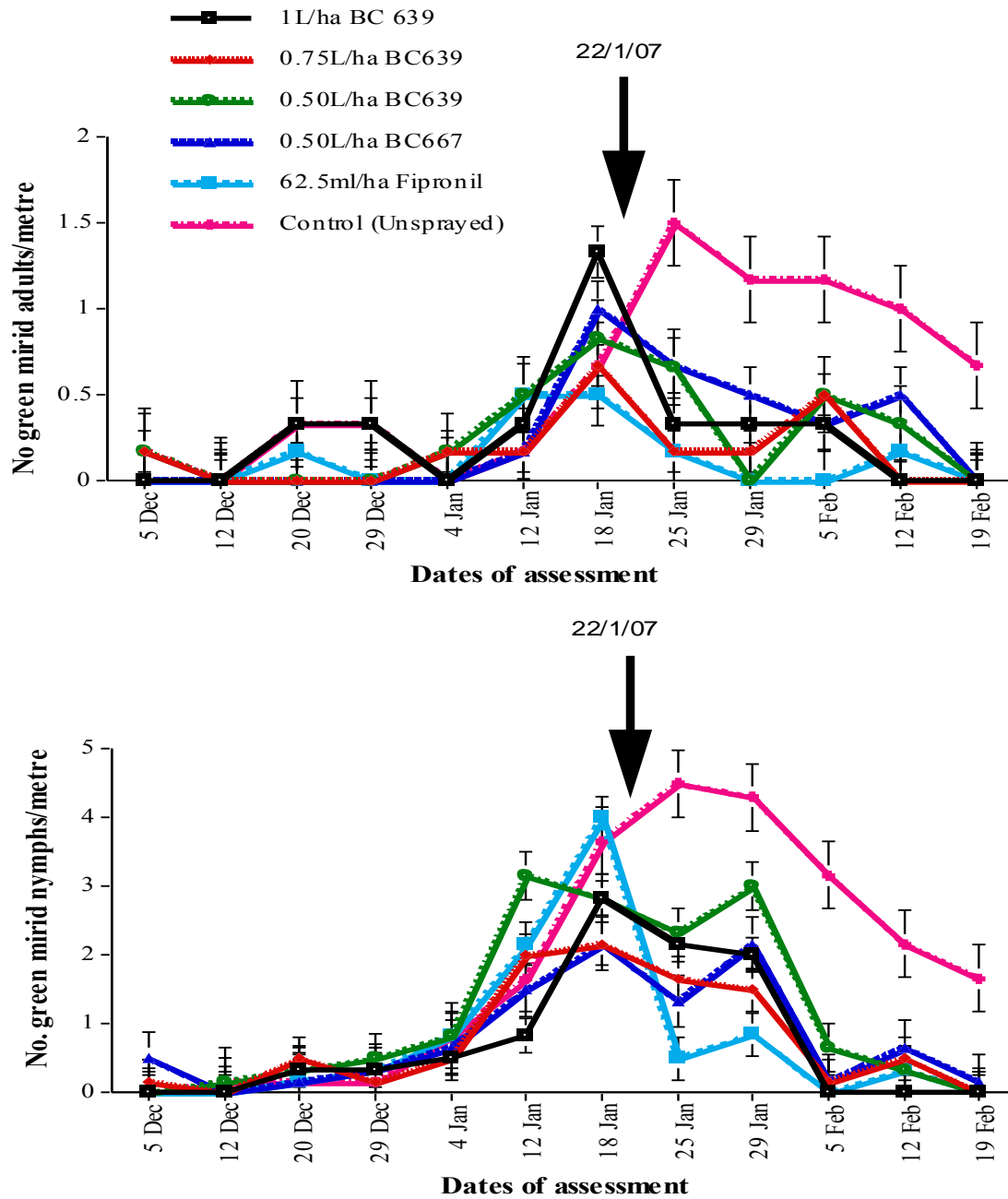


Figure 4.2.1.1 The efficacy of different rates of BC639 and BC 667 fungal insecticides against green mirid adults and nymphs in Bollgard cotton crops at ACRI in Narrabri, 2006-07.

4.2.2 Efficacy of different rates of BC 639 on the survival of beneficial insects on commercial transgenic (Bollgard II) cotton crops, 2006-07

4.2.2.1 Predatory beetles

The number of predatory beetles per metre identified in the study site is given in Table 4.3.3. The number of predatory beetles per metre is given in Table 4.2.2.1.1. No significant difference ($P>0.05$) was found in the number of predatory beetles per metre among treatment and control plots (Table 4.2.2.1.1).

Table 4.2.2.1.1: The number of predatory beetles per metre in commercial Bollgard II cotton crops treated with different rates BC 639 at ACRI, 2006-07.

Treatments	Pre-treatment counts	3 DAT	7 DAT	14 DAT	21 DAT	28 DAT
1L/ha	4.67±0.49a	6.50±0.43a	6.00±0.57a	9.50±0.43a	7.17±0.87a	7.50±0.76a
0.75L/ha	8.17±0.31a	7.17±0.60a	5.00±0.26a	8.17±0.17a	5.67±0.80a	7.17±0.54a
0.50 L/ha	7.50±0.43a	7.67±0.49a	6.17±0.60a	8.00±0.36a	6.67±0.88a	7.67±0.88a
62.5ml/ha Fipronil	6.67±0.71a	5.67±0.61a	6.17±0.54a	8.50±1.12a	5.67±0.80a	5.83±0.70a
Control (Unsprayed)	6.50±0.76a	8.00±0.52a	6.17±0.40a	8.67±1.05a	6.50±0.62a	6.67±0.49a
	P>0.28	P>0.05	P>0.47	P>0.72	P>0.59	P>0.42

Means within columns followed by the same letters are not significantly different ($P>0.05$), Tukey-Kramer Multiple comparison test.

4.2.2.2 Predatory bugs

The number of predatory bugs per metre identified in the study site is given in Table 4.3.3. The number of predatory bugs per metre is given in Table 4.2.2.2.1. No significant difference ($P>0.05$) in the number of predatory bugs were found among BC 639 treated plots and the unsprayed plots and control plots (Table 4.2.2.2.1). However, the number of predatory bugs per metre recorded in plots treated with Fipronil was consistently significantly lower ($P<0.004$ and $P<0.01$) at 7 and 14 DAT than the fungus-treated and unsprayed plots (Table 4.2.2.2.1). The number of predatory bugs per metre on plots treated with lower rate of BC 639 fungus at 3 to 28 DAT was not significantly different from the BC 639 higher rates and were more selective than Fipronil (Table 4.2.2.2.1).

Table 4.2.2.2.1: The number of predatory bugs per metre in commercial Bollgard II cotton crops treated with different rates BC 639 at ACRI, 2006-07.

Treatments	Pre-treatment counts	3 DAT	7 DAT	14 DAT	21 DAT	28 DAT
1L/ha	3.67±0.42a	3.67±0.99a	3.50±0.85a	3.50±0.85a	3.67±0.49a	5.17±0.48a
0.75L/ha	3.00±0.68a	3.17±0.60a	3.17±0.60a	3.50±0.43a	3.50±0.72a	5.33±0.56a
0.50 L/ha	2.17±0.70a	2.67±0.72a	3.67±0.56a	3.50±0.43a	3.50±0.67a	6.00±0.63a
62.5ml/ha Fipronil	3.00±0.63a	1.67±0.62a	0.67±0.21b	1.17±0.17b	2.00±0.26a	6.17±0.79a
Control (Unsprayed)	2.17±0.48a	3.50±0.43a	3.67±0.42a	3.50±0.43a	3.67±0.67a	7.17±0.48a
	P>0.32	P>0.25	P<0.004	P<0.01	P>0.26	P>0.19

Means within columns followed by the same letters are not significantly different ($P>0.05$), Tukey-Kramer Multiple comparison test.

4.2.2.3 Predatory lacewings

The number of predatory lacewings per metre identified in the study site is given in Table 4.3.3. No significant difference ($P>0.05$) in the number of predatory lacewings were found among treatment and control plots (Table 4.2.2.3.1). However, the number of predatory lacewings recorded in plots treated with Fipronil was consistently lower than the fungus-treated and unsprayed plots (Table 4.2.2.3.1).

Table 4.2.2.3.1: The number of predatory lacewings per metre in commercial Bollgard II cotton crops treated with different rates BC 639 at ACRI, 2006-07.

Treatments	Pre-treatment counts	3 DAT	7 DAT	14 DAT	21 DAT	28 DAT
1L/ha	0.50±0.50a	0.33±0.21a	0.67±0.33a	0.83±0.31a	1.50±0.34a	0.83±0.48a
0.75L/ha	0.50±0.22a	0.33±0.21a	0.67±0.21a	1.50±0.34a	1.50±0.22a	1.00±0.37a
0.50 L/ha	1.00±0.45a	0.67±0.21a	0.67±0.21a	1.00±0.26a	1.67±0.21a	0.83±0.17a
62.5ml/ha Fipronil	0.50±0.22a	0.17±0.17a	0.17±0.17a	0.50±0.22a	1.33±0.33a	0.50±0.22a
Control (Unsprayed)	0.33±0.21a	0.50±0.22a	0.83±0.31a	1.33±0.31a	1.83±0.31a	1.33±0.21a
	P>0.54	P>0.58	P>0.50	P>0.17	P>0.82	P>0.31

Means within columns followed by the same letters are not significantly different ($P>0.05$), Tukey-Kramer Multiple comparison test.

4.2.2.4 Spiders

The number of spiders per metre identified in the study site is given in Table 4.3.3. No significant difference ($P>0.05$) in the number of spiders were found among treatment and control plots (Table 4.2.2.4.1). However, the number of spiders per metre recorded in plots treated with Fipronil was consistently lower than the fungus-treated and unsprayed plots respectively (Table 4.2.2.4.1).

Table 4.2.2.4.1: The number of spiders per metre in commercial Bollgard II cotton crops treated with different rates BC 639 at ACRI, 2006-07.

Treatments	Pre-treatment counts	3 DAT	7 DAT	14 DAT	21 DAT	28 DAT
1L/ha	3.50±0.72a	3.83±0.65a	3.83±0.65a	3.00±0.45a	2.83±0.48a	3.67±0.33a
0.75L/ha	4.00±0.63a	4.00±0.37a	4.33±0.42a	3.17±0.43a	2.83±0.48a	4.00±0.78a
0.50 L/ha	3.67±0.56a	4.00±0.68a	4.50±0.67a	2.67±0.33a	3.83±0.48a	4.33±0.49a
62.5ml/ha Fipronil	3.33±0.42a	3.50±0.34a	3.50±0.43b	2.00±0.45a	2.83±0.54a	2.83±0.54a
Control (Unsprayed)	3.83±0.40a	3.67±0.33a	3.33±0.42a	3.83±0.40a	3.17±0.54a	5.00±0.58a
	P>0.89	P>0.93	P>0.45	P>0.06	P>0.58	P>0.11

Means within columns followed by the same letters are not significantly different ($P > 0.05$), Tukey-Kramer Multiple comparison test.

4.2.2.5 Effect of BC 639 on cotton yield

Significantly higher ($P < 0.05$) yields were harvested from synthetic (Fipronil) and fungus (BC 639) treated plots than the unsprayed plots (Table 4.2.2.5.1).

Table 4.2.2.5.1. Cotton yield (bales/acre) harvested from commercial cotton crops managed with fungal insecticides at Norwood near Moree, 2006 - 07.

Treatments	Yield (bales/acre)
1L/ha BC 639 + Horti oil	3.28 ± 0.11 a
0.75 L/ha BC 639 + Horti oil	3.35 ± 0.09 a
0.50 L/ha BC 639 + Horti oil	3.37 ± 0.19 a
62.5 ml/ha Fipronil	3.42 ± 0.13 a
Unsprayed (Control)	2.84 ± 0.05 b
Significant level	$P < 0.05$

Means within columns followed by the same letter are not significantly different ($P > 0.05$), Tukey-Kramer Multiple Comparison Tests.

Conclusions

The results of the study showed that BC 639 fungus controlled green mirid adults and nymphs on commercial cotton crops similar to Fipronil insecticide. Additionally, BC 639 did not have significant effect on predatory beetles, predatory bugs, predatory lacewings and spiders. In comparison to Fipronil insecticide, BC 639 at any rate is more selective on beneficial insects when applied to cotton plants. There is no yield loss when BC 639 was used to manage green mirids on the cotton plants.

4.3 Trials at Norwood near Moree in 2006-07

4.3.1 Efficacy of different rates of BC 639 on the survival of green mirid adults and nymphs

The number of green mirid adults and nymphs per metre recorded on plots treated with recommended rate of Fipronil insecticide, fungus and unsprayed (control) is given in Tables 4.3.1.1, 4.3.1.2, 4.3.1.3 and 4.3.1.4. The first spray application of the treatments occurred when green mirid numbers per metre in the treated plots ranged from 1.50 – 2.50 (adults) and 1.50 - 3.83 (nymphs) per metre (Tables 4.3.1.1, 4.3.1.2). The corrected mortalities of green mirid adults at 3 DAT recorded on plots treated with fungus ranged from 75.12 – 87.72 % compared with 100% recorded on the plots treated with Fipronil (Table 4.3.1.1). At 7 DAT, the corrected mortalities were 100, 83.1 and 42.7 for 1L/ha, 0.75L/ha and 0.5L/ha BC 639 fungus respectively (Table 4.3.1.1). The Fipronil treated plot recorded 100% control (Table 4.3.1.1).

The second treatment application was on 23 January 2007 (Table 4.3.1.2). The number of green mirid adults per metre in the fungus and Fipronil treated plots were not significantly different ($P>0.05$) but were significantly different from the unsprayed (control) plots (Table 4.3.1.2).

The number of green mirid nymphs in the first and second spray applications was the same on the fungus and Fipronil treated plots but were significantly different from the unsprayed plots (Tables 4.2.3.1.3 and 4.2.3.1.4).

Table 4.3.1.1 Efficacy of different rates of fungal insecticides against green mirid adults on Bollgard II cotton crops at Norwood near Moree, 2006-07 (1st spray).

Treatments	Pre-treatment counts (16/1/07)	3 days after treatment (19/1/07) (% mortality)	7 days after treatment (23/1/07) (% mortality)
1L/ha BC639	2.50 ± 0.56 a	0.17 ± 0.17 ab (87.7%)	0.00 ± 0.00 a (100)
750ml/ha BC639	2.50 ± 0.62 a	0.17 ± 0.17 ab (87.7%)	0.33 ± 0.21 ab (83.1)
500ml/ha BC639	1.50 ± 0.22 a	0.33 ± 0.21 ab (75.1%)	0.67 ± 0.33 ab (42.7)
62.5 ml/ha Fipronil	1.67 ± 0.49 a	0.00 ± 0.00 a (100%)	0.00 ± 0.00 a (100)
Unsprayed (Control)	1.50 ± 0.67 a	0.83 ± 0.17 b (0)	1.17 ± 0.40 b (0)
	P<0.43	P<0.002	P<0.02

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.3.1.2 Efficacy of different rates of fungal insecticides against green mirid adults on Bollgard II cotton crops at Norwood near Moree, 2006-07 (2nd spray).

Treatments	Pre-treatment counts (23/1/07)	3 days after treatment (26/1/07)	7 days after treatment (30/1/07)	14 days after treatment (6/2/07)	21 days after treatment (13/2/07)
1L/ha BC639	0.00 ± 0.00a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a
750ml/ha BC639	0.33 ± 0.21ab	0.17 ± 0.17 a	0.00 ± 0.00 a	0.17 ± 0.17 a	0.17 ± 0.17 a
500ml/ha BC639	0.67 ± 0.33ab	0.17 ± 0.17 a	0.00 ± 0.00 a	0.33 ± 0.21 a	0.00 ± 0.00 a
62.5 ml/ha Fipronil	0.00 ± 0.00a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.17 ± 0.17 a	0.00 ± 0.00 a
Unsprayed (Control)	1.17 ± 0.40b	1.33 ± 0.21 b	0.83 ± 0.33 b	1.17 ± 0.31 b	0.67 ± 0.21 b
	P<0.02	P<0.0001	P<0.01	P<0.001	P<0.002

Table 4.3.1.3 Efficacy of different rates of fungal insecticides against green mirid nymphs on Bollgard II cotton crops at Norwood near Moree, 2006-07 (1st spray).

Treatments	Pre-treatment counts (16/1/07)	3 days after treatment (19/1/07)	7 days after treatment (23/1/07)
1L/ha BC639	1.00 ± 0.26 a	0.33 ± 0.21 a	0.33 ± 0.21 a
750ml/ha BC639	2.50 ± 0.62 ab	0.67 ± 0.21 a	1.00 ± 0.37 ab
500ml/ha BC639	3.83 ± 0.31 b	0.83 ± 0.31 a	1.83 ± 0.42 b
62.5 ml/ha Fipronil	1.67 ± 0.49 ab	0.17 ± 0.17 a	0.17 ± 0.17 a
Uns sprayed (Control)	1.50 ± 0.67 a	2.50 ± 0.72 b	2.00 ± 0.21 b
	P<0.008	P<0.002	P<0.003

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.3.1.4 Efficacy of different rates of fungal insecticides against green mirid nymphs on Bollgard II cotton crops at Norwood near Moree, 2006-07 (2nd spray).

Treatments	Pre-treatment counts (23/1/07)	3 days after treatment (26/1/07)	7 days after treatment (30/1/07)	14 days after treatment (6/2/07)	21 days after treatment (13/2/07)
1L/ha BC639	0.33 ± 0.21 a	0.17 ± 0.17 a	0.17 ± 0.17 a	0.00 ± 0.00 a	0.00 ± 0.00 a
750ml/ha BC639	1.00 ± 0.37 ab	0.33 ± 0.21 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.17 ± 0.17 a
500ml/ha BC639	1.83 ± 0.42 b	0.17 ± 0.17 a	0.17 ± 0.17 a	0.17 ± 0.17 a	0.17 ± 0.17 a
62.5 ml/ha Fipronil	0.17 ± 0.17 a	0.33 ± 0.21 a	0.17 ± 0.17 a	0.17 ± 0.17 a	0.17 ± 0.17 a
Uns sprayed (Control)	2.00 ± 0.21 b	1.67 ± 0.33 a	1.50 ± 0.43 b	0.83 ± 0.17 b	0.83 ± 0.17 b
	P<0.003	P<0.0008	P<0.002	P<0.0008	P<0.007

4.3.2 Effect of BC 639 fungus on very small (1-2 instar) green vegetable bug (*Nezara viridula*)

The number of green vegetable bug nymphs per metre recorded on plots treated with different rates of BC 639 fungus and Fipronil 3 days after spray 1 was lower and not significantly different ($P>0.05$), but were significantly different ($P<0.006$) from the unsprayed plots (Table 4.3.2.1). At 7 DAT, the green vegetable bug numbers per metre in both treated and control plots were the same ($P<0.51$) (Table 4.3.2.1).

The second spray was applied on 23 Jan 2007 and at 3 DAT, the number of nymphs was increased on plots treated with the fungus and control plots whereas the Fipronil treated plots had no nymphs (Table 4.3.2.2). The increase in the number of nymphs on the fungus treated and control plots was due to nymphs hatching from eggs that were on the crop prior to the second spray and the conidia have not yet developed to kill the nymphs. In contrast, the highly persistent Fipronil insecticide could control the newly hatched nymphs.

However, at 7 DAT, the number of nymphs recorded on plots treated with the BC 639 was not significantly different from the insecticide treated plots ($P>0.05$) but were significantly different ($P<0.006$) from the unsprayed plots exception is the 0.5L/ha BC 639 treated plots. At 14 DAT the number of nymphs on the fungus and insecticide treated plots were the same and were significantly different ($P<0.002$) from the unsprayed (control plots (Table 4.3.2.2).

Table 4.3.2.1. Number of Green vegetable bug per metre on commercial cotton crops treated with different rates of BC639 fungal insecticides at Norwood near Moree, 2006-07 (1st spray).

Treatments	Pre-treatment counts (16/1/07)	3 days after treatment (19/1/07)	7 days after treatment (23/1/07)
1L/ha BC639	0.33 ± 0.21 a	0.00 ± 0.00 a	0.00 ± 0.00 a
750ml/ha BC639	0.67 ± 0.33 a	0.00 ± 0.00 a	0.17 ± 0.17 a
500ml/ha BC639	0.83 ± 0.54 a	0.17 ± 0.17 a	0.00 ± 0.00 a
62.5 ml/ha Fipronil	0.33 ± 0.21 a	0.00 ± 0.00 a	0.17 ± 0.17 a
Unsprayed (Control)	0.67 ± 0.33 a	0.67 ± 0.21 b	0.33 ± 0.21 a
	P<0.75	P<0.006	P<0.51

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.3.2.2 Number of Green vegetable bug per metre on commercial cotton crops treated with different rates of BC639 fungal insecticides at Norwood near Moree, 2006-07 (2nd spray).

Treatments	Pre-treatment counts (23/1/07)	3 days after treatment (26/1/07)	7 days after treatment (30/1/07)	14 days after treatment (6/2/07)	21 days after treatment (13/2/07)
1L/ha BC639	0.00 ± 0.00 a	0.83 ± 0.17 a	0.00 ± 0.00 a	0.33 ± 0.21 a	0.33 ± 0.21 a
750ml/ha BC639	0.17 ± 0.17 a	0.50 ± 0.22 a	0.33 ± 0.21 a	0.17 ± 0.17 a	0.17 ± 0.17 a
500ml/ha BC639	0.00 ± 0.00 a	0.50 ± 0.22 a	0.50 ± 0.22 ab	0.33 ± 0.21 a	0.50 ± 0.22 a
62.5 ml/ha Fipronil	0.17 ± 0.17 a	0.00 ± 0.00 b	0.00 ± 0.00 a	0.33 ± 0.21 a	0.33 ± 0.21 a
Unsprayed (Control)	0.33 ± 0.21 a	0.83 ± 0.17 a	0.67 ± 0.21 b	1.33 ± 0.21 b	1.67 ± 0.21 b
	P<0.51	P<0.01	P<0.04	P<0.002	P<0.002

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.3.3 Efficacy of BC 639 fungus against predatory beetles, bugs, lacewings and spiders in commercial cotton crops at Norwood near Moree, 2006-07

Beneficial insects identified from the treated plots were predominantly predators and these include predatory beetles, bugs, lacewings and spiders (Table 4.3.3).

Table 4.3.3. Predators of cotton pests sampled and identified from study sites from 2004-2009.

Order	Family	Species	Group
Coleoptera	Coccinellidae	<i>Coccinella transversalis</i> (Fabricius)	Predatory beetles
		<i>Diomus notescens</i> (Blackburn)	
	Melyridae	<i>Dicranolauis bellulus</i> (Guerin-Meneville)	
Hemiptera	Nabidae	<i>Nabis capsiformis</i> (Germar)	Predatory bugs
	Lygaeidae	<i>Geocoris lubra</i> (Kirkaldy)	
	Pentatomidae	<i>Cermatulus nasalis</i> (Westwood)	
		<i>Ochelia schellenbergii</i> (Guerin-Meneville)	
		<i>Coranus triabeatus</i> (Horvath)	
Neuroptera	Chrysopidae	<i>Chrysopa</i> spp.	Predatory lacewings
	Hemerobiidae	<i>Micromus tasmaniae</i> (walker)	
Araneida	Lycosidae	<i>Lycosa</i> spp.	spiders
	Oxyopidae	<i>Oxyopes</i> spp.	
	Salticidae	<i>Salticidae</i> spp.	
	Araneidae	<i>Araneus</i> spp.	

4.3.3.1 Predatory beetles on commercial cotton crops

The predominant predatory beetles identified from the study plots are given in Table 4.3.3. The results showed that the fungal insecticides are selective against predatory beetles which include *Coccinella transversalis*, *Diomus notescens* and *Dicranolauis bellulus* (Table 4.3.3.1.1 and 4.3.3.1.2). No significant difference ($P > 0.05$) was detected in the number of predatory beetles per metre in plots treated with BC 639 and the unsprayed (control) plots (Tables 4.3.3.1.1 and 4.3.3.1.2). The plots treated with Fipronil consistently had the lowest number of predatory beetles per metre and at 14 DAT the number of predatory beetles per metre on the insecticide treated plots was significantly different ($P < 0.008$) from the control but the difference was not significant ($P > 0.05$) from the plots treated with the fungus and the unsprayed (Table 4.3.3.1.2).

Table 4.3.3.1.1. Efficacy of different rates of BC639 fungal insecticides on the number of predatory beetles per metre on commercial cotton crops at Norwood near Moree, 2006-07 (1st spray).

Treatments	Pre-treatment counts (16/1/07)	3 days after treatment (19/1/07)	7 days after treatment (23/1/07)
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1L/ha BC639	4.67 ± 0.76 a	6.50 ± 1.46 a	8.00 ± 1.59 a
750ml/ha BC639	8.33 ± 2.49 a	7.17 ± 0.98 a	5.00 ± 0.82 a
500ml/ha BC639	7.50 ± 1.06 a	7.83 ± 0.91 a	9.17 ± 2.18 a
62.5 ml/ha Fipronil	6.00 ± 1.00 a	5.83 ± 1.85 a	9.33 ± 0.88 a
Unsprayed (Control)	5.00 ± 1.32 a	8.00 ± 0.73 a	8.33 ± 1.45 a
	P<0.36	P<0.66	P<0.17

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.3.3.2 Efficacy of different rates of BC639 fungal insecticides on the number of predatory beetles per metre on commercial cotton crops at Norwood near Moree, 2006-07 (2nd spray).

Treatments	Pre-treatment counts (23/1/07)	3 days after treatment (26/1/07)	7 days after treatment (30/1/07)	14 days after treatment (6/2/07)	21 days after treatment (13/2/07)
1L/ha	8.00 ± 1.59 a	6.17 ± 0.95 a	7.50 ± 2.23 a	4.17 ± 0.60 a	14.17 ± 3.20 a
BC639					
750ml/ha	5.00 ± 0.82 a	8.17 ± 1.17 a	7.00 ± 2.27 a	5.33 ± 0.72 ab	11.83 ± 2.15 a
BC639					
500ml/ha	9.17 ± 2.18 a	9.00 ± 2.13 a	7.83 ± 2.75 a	5.00 ± 0.26 ab	12.67 ± 2.26 a
BC639					
62.5 ml/ha	9.33 ± 0.88 a	8.00 ± 1.71 a	5.83 ± 1.56 a	3.33 ± 0.49 a	7.17 ± 1.05 a
Fipronil					
Unsprayed (Control)	8.33 ± 1.45 a	8.67 ± 1.76 a	5.67 ± 1.31 a	6.50 ± 0.56 b	11.50 ± 2.59 a
	P<0.17	P<0.60	P<0.88	P<0.008	P<0.33

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.3.3.2 Predatory bugs per metre

Predatory bugs identified from the study plots are given in Table 4.3.3. No significant difference was detected in the number of predatory bugs per metre recorded in plots treated with different rates of BC 639, fipronil and unsprayed (control) at 3 days after the first spray application (Table 4.3.3.2.1). However, at 7 DAT, the plots treated with Fipronil insecticide had significantly lower ($P<0.02$) numbers of predatory bugs per metre than any of the treatments (Table 4.3.3.2.1).

Table 4.3.3.2.1. Efficacy of different rates of BC639 fungal insecticides on the number of predatory bugs per metre on commercial cotton crops at Norwood near Moree, 2006-07 (1st spray).

Treatments	Pre-treatment counts (16/1/07)	3 days after treatment	7 days after treatment
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		(19/1/07)	(23/1/07)
1L/ha BC639	3.67 ± 1.20 a	3.67 ± 0.96 a	2.83 ± 0.87 ab
750ml/ha BC639	3.00 ± 0.52 a	3.33 ± 1.28 a	2.50 ± 0.22 ab
500ml/ha BC639	4.50 ± 0.62 a	4.33 ± 0.62 a	3.50 ± 0.56 ab
62.5 ml/ha Fipronil	3.00 ± 0.82 a	1.67 ± 0.67 a	1.67 ± 0.56 b
Unsprayed (Control)	2.17 ± 0.54 a	3.50 ± 0.56 a	5.17 ± 0.79 a
	P<0.30	P<0.20	P<0.02

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

At the 2nd spray application, the Fipronil treated plots had significantly lower number of predatory bugs at 3 and 14 DAT than the other treatments (Table 4.3.3.2.2). In general the plots treated with BC 639 fungus had the similar numbers of predatory bugs as the unsprayed (control) plots (Table 4.3.3.2.2).

Table 4.3.3.2.2. Efficacy of different rates of BC639 fungal insecticides on the number of predatory bugs per metre on commercial cotton crops at Norwood near Moree, 2006-07 (2nd spray).

Treatments	Pre-treatment counts (23/1/07)	3 days after treatment (26/1/07)	7 days after treatment (30/1/07)	14 days after treatment (6/2/07)	21 days after treatment (13/2/07)
1L/ha BC639	2.83 ± 0.87ab	2.17 ± 0.48ab	2.50 ± 0.72 a	3.33 ± 0.67 a	1.00 ± 0.26 a
750ml/ha BC639	2.50 ± 0.22ab	2.83 ± 0.48ab	2.83 ± 0.87 a	3.17 ± 0.48 a	1.50 ± 0.43 a
500ml/ha BC639	3.50 ± 0.56ab	3.17 ± 0.48 b	3.50 ± 0.76 a	3.17 ± 0.48 a	2.33 ± 0.33 a
62.5 ml/ha Fipronil	1.67 ± 0.56 b	0.83 ± 0.31 a	1.17 ± 0.54 a	0.83 ± 0.48 b	1.67 ± 0.62 a
Unsprayed (Control)	5.17 ± 0.79 a	3.33 ± 0.96 b	3.83 ± 0.48 a	3.67 ± 0.49 a	2.00 ± 0.52 a
	P<0.02	P<0.02	P<0.11	P<0.0005	P<0.69

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.3.3.3 Predatory lacewings per metre

The predominant predatory lacewings identified from the study plots were *Chrysopa* spp. and *Micromus tasmaniae* (Table 4.3.3). No significant differences in the number of predatory lacewings per metre were detected among the treated and control (unsprayed) plots in spray 1 and 2 except 14 DAT in spray 2 where the number of predatory insects in the unsprayed plot was significantly different ($P<0.0001$) than plots treated with conventional insecticides and 1L/ha and 0.75L/ha BC 639 (Tables 4.3.3.3.1 and 4.3.3.3.2). The number of predatory

lacewings recorded in plots treated with 0.5L/ha BC 639 were similar to the unsprayed plots in both sprays 1 and 2 (Tables 4.3.3.3.1 and 4.3.3.3.2)

Table 4.3.3.3.1. Efficacy of different rates of BC639 fungal insecticides on the number of *Chrysopa* spp. (predatory lacewings) per metre on commercial cotton crops at Norwood near Moree, 2006-07 (1st spray).

Treatments	Pre-treatment counts (16/1/07)	3 days after treatment (19/1/07)	7 days after treatment (23/1/07)
1L/ha BC639	0.50 ± 0.22 a	0.33 ± 0.21 a	0.83 ± 0.31 a
750ml/ha BC639	0.50 ± 0.22 a	0.33 ± 0.21 a	0.83 ± 0.17 a
500ml/ha BC639	0.67 ± 0.21 a	0.33 ± 0.21 a	1.17 ± 0.17 a
62.5 ml/ha Fipronil	0.50 ± 0.22 a	0.17 ± 0.17 a	0.33 ± 0.21 a
Unsprayed (Control)	0.33 ± 0.21 a	0.50 ± 0.22 a	1.00 ± 0.26 a
	P<0.84	P<0.85	P<0.13

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

Table 4.3.3.3.2. Efficacy of different rates of BC639 fungal insecticides on the number of *Chrysopa* spp. (predatory lacewings) per metre on commercial cotton crops at Norwood near Moree, 2006-07 (2nd spray).

Treatments	Pre-treatment counts (23/1/07)	3 days after treatment (26/1/07)	7 days after treatment (30/1/07)	14 days after treatment (6/2/07)	21 days after treatment (13/2/07)
1L/ha BC639	0.83 ± 0.31 a	0.67 ± 0.33 a	1.50 ± 0.76 a	0.50 ± 0.22 a	0.83 ± 0.40 a
750ml/ha BC639	0.83 ± 0.17 a	0.67 ± 0.21 a	0.83 ± 0.17 a	0.67 ± 0.21 a	1.00 ± 0.63 a
500ml/ha BC639	1.17 ± 0.17 a	0.83 ± 0.17 a	1.17 ± 0.31 a	0.83 ± 0.31 ab	1.00 ± 0.26 a
62.5 ml/ha Fipronil	0.33 ± 0.21 a	0.17 ± 0.17 a	0.50 ± 0.23 a	0.33 ± 0.21 a	0.50 ± 0.22 a
Unsprayed (Control)	1.00 ± 0.26 a	0.83 ± 0.31 a	1.33 ± 0.33 a	1.83 ± 0.31 b	1.33 ± 0.42 a
	P<0.13	P<0.45	P<0.33	P<0.001	P<0.73

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

4.3.3.4 Spiders per metre

Spiders identified from the study plots were *Lycosa* spp., *Oxyopes* spp., *Salticidae* spp., *Araneus* spp. (Table 4.3.3). Spiders were consistently the same in all treated plots throughout the study (Table 4.3.3.4.1 and 4.3.3.4.2).

Table 4.3.3.4.1. Efficacy of different rates of BC639 fungal insecticides on the number of spiders per metre on commercial cotton crops at Norwood near Moree, 2006-07 (1st spray).

Treatments	Pre-treatment counts (16/1/07)	3 days after treatment (19/1/07)	7 days after treatment (23/1/07)
1L/ha BC639	3.50 ± 0.99 a	3.50 ± 0.76 a	1.83 ± 0.31 a
750ml/ha BC639	4.00 ± 0.68 a	2.33 ± 0.21 a	2.83 ± 0.48 a
500ml/ha BC639	3.67 ± 1.02 a	4.00 ± 0.89 a	3.33 ± 0.49 a
62.5 ml/ha Fipronil	2.67 ± 0.33 a	2.33 ± 0.21 a	1.67 ± 0.21 a
Unsprayed (Control)	3.83 ± 0.65 a	3.67 ± 0.72 a	3.00 ± 0.37 a
	P<0.61	P<0.21	P<0.04

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.3.3.4.2. Efficacy of different rates of BC639 fungal insecticides on the number of spiders per metre on commercial cotton crops at Norwood near Moree, 2006-07 (2nd spray).

Treatments	Pre-treatment counts (23/1/07)	3 days after treatment (26/1/07)	7 days after treatment (30/1/07)	14 days after treatment (6/2/07)	21 days after treatment (13/2/07)
1L/ha BC639	1.83 ± 0.31 a	4.67 ± 1.59 a	3.00 ± 0.58 a	2.50 ± 0.62 a	3.67 ± 0.67 a
750ml/ha BC639	2.83 ± 0.48 a	3.83 ± 1.72 a	3.17 ± 0.70 a	2.83 ± 0.95 a	4.00 ± 0.89 a
500ml/ha BC639	3.33 ± 0.49 a	4.00 ± 1.34 a	3.00 ± 0.37 a	3.83 ± 0.75 a	4.17 ± 0.70 a
62.5 ml/ha Fipronil	1.67 ± 0.21 a	3.17 ± 0.48 a	1.83 ± 0.31 a	2.83 ± 0.48 a	2.83 ± 0.60 a
Unsprayed (Control)	3.00 ± 0.37 a	3.33 ± 1.17 a	3.83 ± 0.65 a	3.33 ± 0.33 a	5.00 ± 0.82 a
	P<0.04	P<0.91	P<0.22	P<0.68	P<0.25

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.3.3.5 Effect of BC 639 on cotton yield

Significantly higher ($P<0.0001$) cotton yields (bales/acre) were harvested from plots treated with different rates of BC 639 fungus and Fipronil than the unsprayed plots (Table 4.3.3.5.1). The cotton yield harvested from the Fipronil treated plots was not significantly different ($P>0.05$) from the BC 639 treated plots (Table 4.3.3.5.1).

Table 4.3.3.5.1. Effect of BC 639 on yields of cotton crops treated with BC 639 fungus and Fipronil insecticides against sucking pests on commercial cotton crops at Norwood in Moree, 2006-07

Treatments	Yields (bales/acre)
1 L/ha BC 639	4.18 ± 0.03 a
0.75L/ha BC 639	4.04 ± 0.22 a
0.50L/ha BC 639	3.94 ± 0.07 a
62.5ml/ha Fipronil	4.27 ± 0.10 a
Unsprayed (control)	2.80 ± 0.07 b
Significance level	P<0.0001

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Conclusions

The results of the study showed that BC 639 fungus controlled green mirid adults and nymphs as well as green vegetable bugs 1st and 2nd instar on commercial cotton crops similar to Fipronil insecticide. Additionally, BC 639 did not have significant effect on predatory beetles, lacewings and spiders but had minimal effect on predatory bugs. Compared to Fipronil insecticide, BC 639 at any rate is more selective on beneficial insects when applied to cotton plants. No yield loss was found when BC 639 was used to manage green mirids and green vegetable bugs on commercial cotton.

4.4 Trials at Goondiwindi - 2006-07

4.4.1 Efficacy of different rates of BC 639 and BC 667 on the survival of green mirids, green vegetable bugs and beneficial insects on commercial cotton crops

4.4.1.1 Effect of BC 639 on survival of green mirids

Application of BC 639 at 1, 0.50 and 0.25 L/ha reduced the number of green mirid adults and nymphs per metre and remained effective against the mirids up to 14 days after they were applied to cotton plants in commercial cotton fields (Tables 4.4.1.1.1 and 4.4.1.1.2).

Table 4.4.1.1.1 Efficacy of different rates of BC639 fungal insecticides on the number of *Creontiades dilutus* (Green mirids) per metre on commercial conventional cotton crops at Goondiwindi, 2006-07 (1st spray).

Treatments	Pre-spray counts	3 DAT	7 DAT	14 DAT
	31-1-2007			
1 L/ha BC 639	0.75 ± 0.25 a	0.25 ± 0.25 a	0.00 ± 0.00 a	0.00 ± 0.00 a
0.50 L/ha BC 639	0.75 ± 0.48 a	0.25 ± 0.25 a	0.00 ± 0.00 a	0.25 ± 0.25 a
0.25 L/ha BC 639	0.50 ± 0.29 a	0.50 ± 0.29 a	0.50 ±	0.25 ± 0.25 a

			0.29ab	
62.5ml/ha Fipronil	0.75 ± 0.48 a	0.25 ± 0.25 a	0.00 ± 0.00 a	0.50 ± 0.29 a
Unsprayed (Control)	0.75 ± 0.25 a	0.75 ± 0.48 a	1.25 ± 0.25 b	1.25 ± 0.25 b
	P<0.89	P<0.58	P<0.001	

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

Table 4.4.1.1.2. Efficacy of different rates of BC639 fungal insecticides on the number of *Creontiades dilutus* (Green mirids) per metre on commercial conventional cotton crops at Goondiwindi, 2006-07 (2nd spray).

Treatments	Pre-spray counts 25-2-07	3 DAT	7 DAT	14 DAT
1 L/ha BC 639	0.25 ± 0.25 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a
0.50 L/ha BC 639	0.50 ± 0.29 a	0.00 ± 0.00 a	0.25 ± 0.25ab	0.00 ± 0.00 a
0.25 L/ha BC 639	0.75 ± 0.48 a	0.25 ± 0.25 ab	0.75 ± 0.75ab	0.00 ± 0.00 a
62.5ml/ha Fipronil	0.50 ± 0.29 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a
Unsprayed (Control)	1.00 ± 0.41 a	0.75 ± 0.25 b	1.00 ± 0.41 b	0.75 ± 0.25 b
	P<0.53	P<0.04	P<0.05	P<0.001

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

4.4.1.2 Effect of BC 639 on survival of green vegetable bug (*Nezara viridula*)

Application of BC 639 at rates of 1.0, 0.50 and 0.25 L/ha controlled green vegetable bug at 3 and 7 DAT similar to half rate Fipronil applied at 62.5 ml/ha (Table 4.4.1.2.1). Application of the 1.0 and 0.50 L/ha rates of BC 639 reduced green vegetable bug survival and remained effective against the pest up to 14 days after treatment. The number of green vegetable bug per metre recorded on BC 639 applied at 0.25 L/ha rate and the Fipronil treated plots were the same as 1.0 and 0.50 L/ha rates but were not significantly different (P>0.05) from the unsprayed (control) plots (Table 4.4.1.2.1). All fungus and insecticide treatments were found to be effective against very small nymphs of the green vegetable bugs.

Table 4.4.1.2.1. Efficacy of different rates of BC639 fungal insecticides on the number of *Nezara viridula* (Green vegetable bug) per metre on commercial conventional cotton crops at Goondiwindi, 2006-07.

Treatments	Pre-spray counts 25-2-07	3 DAT	7 DAT	14 DAT
1 L/ha BC 639	5.25 ± 0.48 ab	2.25 ± 0.25 a	1.50 ± 0.50 a	1.00 ± 0.41 a
0.50 L/ha BC 639	6.25 ± 0.25 ab	2.50 ± 0.65 a	1.50 ± 0.65 a	1.00 ± 0.41 a
0.25 L/ha BC 639	6.25 ± 1.38 ab	3.25 ± 0.48 ab	1.75 ± 0.25 a	2.75 ± 0.48 ab
62.5ml/ha Fipronil	4.25 ± 0.85 a	2.00 ± 0.41 a	1.50 ± 0.65 a	1.50 ± 0.50 ab
Unsprayed	7.25 ± 0.85 b	4.50 ± 0.29 b	4.75 ± 1.11 b	3.00 ± 0.41 b

(Control)

P<0.13 P<0.01 P<0.008 P<0.09

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

4.4.1.3 Effect of BC 639 on survival of cotton aphids (*Aphis gossypii*)

Prophylactic application of 1, 0.5 and 0.25L/ha of fungus was effective at reducing the number of aphids per leaf on treated cotton plants at 7 and 14 DAT in the first spray application (Tables 4.4.1.3.1). The reduction of aphid numbers on cotton plants treated with the fungus was the same as plots treated with and Imidacloprid with Pulse penetrant but was significantly higher (P<0.0003 and 0.0001) than the unsprayed (control) plots at 7 and 14 DAT respectively (Table 4.4.1.3.1). After the second spray application, the aphid numbers per leaf was significantly reduced (P<0.0001) at 3 and 7 DAT on plots treated with 1L, 0.50 L/ha fungus and Imidacloprid with Pulse penetrant than 0.25 L/ha fungus and the unsprayed (control) (Table 4.4.1.3.2). The number of aphids per leaf recorded on the plots treated with 0.25 L/ha fungus was not significantly different (P>0.05) from the unsprayed (control) plot in spray 2 (Table 4.4.1.3.2). Overall aphid numbers per leaf on all treated plots increased significantly 14 DAT with 1L/ha treated plot recording the lowest (98 aphids/leaf) increment and the control the highest (290 aphids/leaf) (Table 4.4.1.3.2).

Table 4.4.1.3.1. Efficacy of different rates of BC639 fungal insecticides on the numbers of *Aphis gossypii* (cotton aphids) per metre on commercial conventional cotton crops at Goondiwindi, 2006-07 (1st spray application).

Treatments	Pre-spray counts	3 DAT	7 DAT	14 DAT
	31-1-2007			
1 L/ha BC 639	2.50 ± 0.29 a	1.75 ± 0.25 ab	0.25 ± 0.25 a	1.00 ± 0.41 a
0.50 L/ha BC 639	2.50 ± 0.69 a	2.00 ± 0.41 ab	0.25 ± 0.25 a	0.75 ± 0.25 a
0.25 L/ha BC 639	1.25 ± 0.25 a	2.50 ± 0.29 a	0.75 ± 0.25 a	0.50 ± 0.29 a
Imidacloprid + Pulse Penetrant (0.25L/ha + 0.2% v/v)	1.00 ± 0.29 a	0.75 ± 0.25 b	0.25 ± 0.25 a	2.00 ± 0.41 a
Unsprayed (Control)	1.50 ± 0.50 a	2.00 ± 0.41ab	2.75 ± 0.48 b	5.75 ± 0.48 b
Significant level	P<0.09	P<0.01	P<0.0003	P<0.0001

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

Table 4.4.1.3.2. Efficacy of different rates of BC639 fungal insecticides on the number of *Aphis gossypii* (cotton aphids) per metre on commercial conventional cotton crops at Goondiwindi, 2006- 07 (2nd spray application).

Treatments	Pre-spray	3 DAT	7 DAT	14 DAT
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	counts			
	25-2-2007			
1 L/ha BC 639	10.00 ± 0.41 a	1.25 ± 0.48 a	7.50 ± 0.65 a	98.75 ± 14.10 a
0.50 L/ha BC 639	11.25 ± 1.49 a	0.75 ± 0.25 a	6.50 ± 0.29 a	165.00 ± 11.97ab
0.25 L/ha BC 639	8.00 ± 0.82 a	7.50 ± 0.96 b	13.75 ± 2.39 b	170.00 ± 11.37 b
62.5ml/ha Fipronil	12.00 ± 2.04 a	1.25 ± 0.48 a	1.50 ± 0.65 a	117.50 ± 9.97 a
Unsprayed (Control)	11.25 ± 1.11 a	12.00 ± 2.00 b	15.00 ± 2.89 b	290.00 ± 12.36 b
Significant level	P<0.32	P<0.0001	P<0.001	P<0.0001

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.4.1.4 Efficacy of different rates of BC 639 fungal insecticides on beneficial insects

Beneficial insects identified from the treated plots were predominantly predators and these include predatory beetles, bugs, lacewings and spiders (Table 4.3.3).

3.4.1.4.1 Efficacy on predatory beetles

The predominant predatory beetles identified from the study plots are given in Table 4.3.3. The results showed that different rates of the fungus applied to cotton plants were selective against predatory beetles (Tables 4.4.1.4.1.1 and 4.3.1.4.1.2). No significant difference ($P>0.05$) was detected after the first spray application, in the number of predatory beetles per metre in plots treated with the fungus and the unsprayed (control) plots (Table 4.3.1.4.1.1). The plots treated with half label rate of Fipronil had the same number of predatory beetles per metre as the fungus and the unsprayed plots (Table 4.3.1.4.1.1). Similar results were obtained when the products were applied in the second treatment application (Table 4.3.1.4.1.2).

Table 4.4.1.4.1.1. Efficacy of different rates of BC639 fungal insecticides on the numbers of predatory beetles per metre on commercial conventional cotton crops at Goondiwindi, 2006-07 (1st spray).

Treatments	Pre-spray counts	3 DAT	7 DAT	14 DAT
	31-1-2007			
1 L/ha BC 639	0.00 ± 0.00 a	0.25 ± 0.25 a	0.25 ± 0.25 a	0.25 ± 0.25 a
0.50 L/ha BC 639	0.25 ± 0.25 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.25 ± 0.25 a
0.25 L/ha BC 639	0.00 ± 0.00 a	0.00 ± 0.00 a	0.25 ± 0.25 a	0.25 ± 1.25 a
62.5ml/ha Fipronil	0.25 ± 0.25 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.25 ± 0.25 a
Unsprayed (Control)	0.25 ± 0.25 a	0.50 ± 0.29 a	0.00 ± 0.00 a	0.25 ± 0.25 a
Significant level	P<0.72	P<0.26	P<0.61	P<0.99

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.4.1.4.1.2. Efficacy of different rates of BC639 fungal insecticides on the number of predatory beetles per metre on commercial conventional cotton crops at Goondiwindi, 2006-07 (2nd spray).

Treatments	Pre-spray counts	3 DAT	7 DAT	14 DAT
	25-2-2007			
1 L/ha BC 639	0.50 ± 0.29 a	0.75 ± 0.25 a	0.00 ± 0.00 a	0.00 ± 0.00 a
0.50 L/ha BC 639	0.50 ± 0.29 a	1.50 ± 0.29 a	0.00 ± 0.00 a	0.00 ± 0.00 a
0.25 L/ha BC 639	0.25 ± 0.25 a	1.50 ± 0.29 a	0.25 ± 0.25 a	0.00 ± 0.00 a
62.5ml/ha Fipronil	0.25 ± 0.25 a	0.50 ± 0.29 a	0.00 ± 0.00 a	0.00 ± 0.00 a
Unsprayed(Control)	0.25 ± 0.25 a	1.50 ± 0.50 a	0.25 ± 0.25 a	0.00 ± 0.00 a
Significant level	P<0.92	P<0.10		

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.4.1.4.2 Efficacy on predatory bugs

Predatory bugs identified from the study plots are given in Table 4.3.3. No significant difference was detected in the number of predatory bugs per metre recorded in plots treated with different rates of fungus, recommended rate of Fipronil and unsprayed (control) (Tables 4.4.1.4.2.1 and 4.4.14.2.2).

Table 4.4.1.4.2.1. Efficacy of different rates of BC639 fungal insecticides on the numbers of predatory bugs per metre on commercial conventional cotton crops at Getta Getta in Goondiwindi, 2006-07 (1st spray).

Treatments	Pre-spray counts	3 DAT	7 DAT	14 DAT
	31-1-2007			
1 L/ha BC 639	0.50 ± 0.29 a	0.50 ± 0.29 a	0.25 ± 0.25 a	0.75 ± 0.25 a
0.50 L/ha BC 639	0.25 ± 0.25 a	0.50 ± 0.29 a	0.25 ± 0.25 a	0.75 ± 0.25 a
0.25 L/ha BC 639	0.00 ± 0.00 a	0.75 ± 0.25 a	0.25 ± 0.25 a	0.75 ± 0.48 a
62.5ml/ha Fipronil	0.50 ± 0.29 a	0.25 ± 0.25 a	0.25 ± 0.25 a	0.25 ± 0.25 a
Unsprayed (Control)	1.25 ± 0.48 a	0.75 ± 0.48 a	0.50 ± 0.29 a	1.25 ± 0.25 a
Significant level	P<0.11	P<0.65	P<0.85	P<0.18

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.4.1.4.2.2. Efficacy of different rates of BC639 fungal insecticides on the number of predatory bugs per metre on commercial conventional cotton crops at Getta Getta in Goondiwindi, 2006-07 (2nd spray).

Treatments	Pre-spray counts	3 DAT	7 DAT	14 DAT
	25-2-2007			
1 L/ha BC 639	0.50 ± 0.29 a	0.50 ± 0.29 a	0.25 ± 0.25 a	0.75 ± 0.25 a
0.50 L/ha BC 639	0.25 ± 0.25 a	0.25 ± 0.25 a	0.50 ± 0.29 a	0.75 ± 0.48 a
0.25 L/ha BC 639	0.25 ± 0.25 a	0.25 ± 0.25 a	0.25 ± 0.25 a	1.00 ± 0.41 a
62.5ml/ha Fipronil	0.25 ± 0.25 a	0.50 ± 0.29 a	0.25 ± 0.25 a	0.75 ± 0.48 a
Unsprayed(Control)	0.50 ± 0.29 a	0.50 ± 0.29 a	0.50 ± 0.29 a	1.25 ± 0.25 a
Significant level	P<0.83	P<0.87	P<0.89	P<0.87

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.4.1.4.3 Efficacy on predatory lacewings

The predominant predatory lacewings identified from the study plots were *Chrysopa* spp. and *Micromus tasmaniae* (Table 4.3.3). After the first treatment application, the number of predatory lacewings per metre recorded on the unsprayed plots and plots treated with 1.0, 0.5 and 0.25L/ha fungus were significantly different ($P< 0.01$) from crops treated with Fipronil at 3 and 7 DAT (Table 4.4.1.4.3.1). At 14 DAT, no significant differences were detected among the treated and unsprayed plots (Table 4.4.1.4.3.1). At the second spray application, the number of predatory lacewings per metre recorded on plots treated with fungus was not significantly different ($P>0.05$) from the unsprayed plot at 3, 7 and 14 DAT (Table 4.4.1.4.3.2) indicating that the fungus does not have any negative effect on the predatory lacewings. In contrast, the number of predatory lacewings in the Fipronil treated plots was significantly lower ($P<0.0001$) at 3 DAT than the unsprayed and fungus treated plots (Table 4.4.1.4.3.2) indicating that Fipronil has a negative effect on lacewings. At 7 and 14 DAT, the number of predatory lacewings per metre on plots treated with Fipronil was the same as the fungus treated and the unsprayed plot (Table 4.4.1.4.3.2). This may be due to the fact that cotton was the only crop around during that time of the year, and adult lacewings might have migrated from the surrounding refuges into the study site.

Table 4.4.1.4.3.1. Efficacy of different rates of BC639 fungal insecticides on the numbers of predatory lacewings per metre on commercial conventional cotton crops at Goondiwindi, 2006-07 (1st spray).

Treatments	Pre-spray counts	3 DAT	7 DAT	14 DAT
	31-1-2007			
1 L/ha BC 639	4.25 ± 0.48 a	2.75 ± 0.25 a	1.50 ± 0.29ab	1.00 ± 0.41 a
0.50 L/ha BC 639	3.75 ± 0.48 a	2.75 ± 0.48 a	1.75 ± 0.25 a	1.25 ± 0.25 a
0.25 L/ha BC 639	3.25 ± 0.25 a	3.00 ± 0.41 a	2.00 ± 0.41 a	1.25 ± 0.48 a
62.5ml/ha Fipronil	5.00 ± 1.08 a	0.75 ± 0.48 b	0.25 ± 0.25 b	0.75 ± 0.48 a
Unsprayed (Control)	3.50 ± 1.04 a	3.25 ± 0.25 a	2.00 ± 0.41 a	1.75 ± 0.48 a
Significance level	P = 0.31	P = 0.008	P = 0.01	P = 0.62

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.4.1.4.3.2. Efficacy of different rates of BC639 fungal insecticides on the number of predatory lacewings per metre on commercial conventional cotton crops at Goondiwindi, 2006-07 (2nd spray).

Treatments	Pre-spray counts	3 DAT	7 DAT	14 DAT
	25-2-2007			
1 L/ha BC 639	3.00 ± 0.41 a	2.00 ± 0.41 bc	0.75 ± 0.25 a	3.25 ± 0.48 a
0.50 L/ha BC 639	3.75 ± 0.25 a	3.25 ± 0.25 ab	0.50 ± 0.29 a	2.50 ± 0.87 a
0.25 L/ha BC 639	4.75 ± 0.63 a	3.75 ± 0.25 a	0.75 ± 0.48 a	3.50 ± 1.04 a
62.5ml/ha Fipronil	2.75 ± 0.75 a	0.75 ± 0.25 c	0.25 ± 0.25 a	2.00 ± 0.71 a
Unsprayed(Control)	4.50 ± 0.50 a	4.00 ± 0.41 a	1.25 ± 0.48 a	2.75 ± 0.85 a
Significance level	P = 0.08	P = 0.0001	P = 0.09	P = 0.58

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.4.1.4.4 Efficacy on spiders

Spiders identified from the study plots were *Lycosa* spp., *Oxyopes* spp., *Salticidae* spp., *Araneus* spp. (Table 4.3.3). Spiders were consistently the same in all treated and control (unsprayed) plots throughout the study (Tables 4.4.1.4.4.1 and 4.4.1.4.4.2). The explanation given is that spiders hide in soil cracks and the lower stems not terminals of cotton plants and so usually escape direct contact chemical sprays.

Table 4.4.1.4.4.1. Efficacy of different rates of BC639 fungal insecticides on the numbers of spiders per metre on commercial conventional cotton crops at Goondiwindi, 2006-07 (1st spray).

Treatments	Pre-spray counts	3 DAT	7 DAT	14 DAT
	31-1-2007			
1 L/ha BC 639	5.00 ± 0.41 a	3.75 ± 0.63 a	5.00 ± 0.58 a	6.25 ± 0.85 a
0.50 L/ha BC 639	5.50 ± 0.65 a	4.00 ± 0.41 a	4.75 ± 0.85 a	5.00 ± 1.08 a
0.25 L/ha BC 639	6.00 ± 0.71 a	4.75 ± 0.85 a	4.25 ± 0.95 a	5.75 ± 0.95 a
62.5ml/ha Fipronil	4.50 ± 0.50 a	3.25 ± 0.48 a	3.75 ± 0.48 a	6.00 ± 0.58 a
Unsprayed (Control)	4.25 ± 0.75 a	3.50 ± 0.29 a	5.50 ± 0.65 a	6.50 ± 0.65 a
Significance level	P = 0.25	P = 0.34	P = 0.46	P = 0.65

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.4.1.4.4.2. Efficacy of different rates of BC639 fungal insecticides on the number of spiders per metre on commercial conventional cotton crops at Goondiwindi, 2006-07 (2nd spray).

Treatments	Pre-spray counts	3 DAT	7 DAT	14 DAT
	25-2-2007			
1 L/ha BC 639	3.50 ± 0.29 a	3.25 ± 0.48 a	4.75 ± 1.11 a	5.75 ± 1.03 a
0.50 L/ha BC 639	2.75 ± 0.63 a	4.75 ± 0.48 a	4.50 ± 0.29 a	5.25 ± 0.63 a
0.25 L/ha BC 639	4.25 ± 0.75 a	5.00 ± 0.41 a	4.50 ± 0.65 a	6.00 ± 0.71 a
62.5ml/ha Fipronil	2.00 ± 0.41 a	3.25 ± 0.48 a	4.75 ± 0.48 a	4.00 ± 0.41 a
Unsprayed(Control)	3.75 ± 0.48 a	3.75 ± 0.48 a	4.25 ± 0.75 a	5.50 ± 1.04 a
Significance level	P = 0.13	P = 0.04	P = 0.99	P = 0.53

Means between treatments within columns followed by the same letter are not significantly different ($P > 0.05$); Tukey-Kramer multiple comparison test.

Conclusions

Application of BC 639 controlled green mirids, green vegetable bugs and cotton aphids similar to Fipronil and Confidor used by the cotton industry to manage these pests. In addition, the BC 639 fungus at all rates of application was found to be more selective to predatory beetles, bugs, lacewings and spiders than the commercial insecticide Fipronil.

4.5 Trials at ACRI in Narrabri – 2007-08

4.5.1 Efficacy of BC 639 on the survival of green mirids, green vegetable bugs and non-target arthropods on commercial cotton crops and impact on yield

4.5.1.1 Efficacy of BC 639 on green mirids on commercial cotton crops at ACRI in Narrabri, 2007-08 (1st spray)

The number of green mirids per metre recorded at 3 to 14 days after first spray application on plots treated with different rates of BC 639 fungus and the recommended rate of Fipronil insecticide was significantly lower ($P < 0.0001$) than control (unsprayed) (Table 4.5.1.1.1). No significant difference was detected in the number of green mirids per metre recorded on plots treated with fungal insecticides and the recommended rate of Fipronil indicating that the fungus caused the same mortality to green mirids as Fipronil (Table 4.5.1.1.1).

Similar result was obtained after the second spray application with no significant difference ($P > 0.05$) detected in the number of green mirids per metre recorded on plots treated with fungal insecticides and the recommended rate of Fipronil indicating that the fungus caused similar mortalities as Fipronil (Table 4.5.1.1.2).

Table 4.5.1.1.1. Efficacy of different rates of BC639 fungal insecticides on the number of *Creontiades dilutus* (Green mirids) per metre on commercial cotton crops at ACRI in Narrabri, 2007-08 (1st spray).

Treatments	Pre-spray counts	3 DAT	7 DAT	14 DAT
		6 - 01-2008	10-01-2008	17-01-2008
	3/1/2008			
500ml/ha BC 639	2.00 ± 0.37 ab	0.67 ± 0.21 a	0.67 ± 0.33 a	0.67 ± 0.33 a
250ml/ha BC 639	1.67 ± 0.56 ab	0.67 ± 0.21 a	1.67 ± 0.33 a	1.67 ± 0.33 b
62.5ml/ha Fipronil	2.33 ± 0.21 a	0.33 ± 0.21 a	1.00 ± 0.58 a	0.33 ± 0.33 a
Uns sprayed (Control)	1.33 ± 0.21 b	2.33 ± 0.21 b	4.00 ± 1.16 b	3.33 ± 0.33 c
Significant level	P <0.01	P<0.0001	P<0.0001	P<0.0001

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.5.1.1.2. Efficacy of different rates of BC639 fungal insecticides on the number of *Creontiades dilutus* (Green mirids) per metre on commercial cotton crops at ACRI in Narrabri, 2007-08 (2nd spray).

Treatments	Pre- spray counts	3 DAT	7 DAT	14 DAT	21 DAT
		3-02-2008	7-02-2008	14-02-2008	21-02-2008
	30/1/2008				
500ml/ha BC 639	0.67 ± 0.21 ab	0.33 ± 0.21 a	0.33 ± 0.21 a	0.00 ± 0.00 a	0.00 ± 0.00 a
250ml/ha BC 639	2.00 ± 0.63 a	0.33 ± 0.21 a	0.33 ± 0.21 a	0.67 ± 0.21 a	0.33 ± 0.21 a
62.5ml/ha Fipronil	0.33 ± 0.21 b	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a
Uns sprayed (Control)	4.00 ± 0.37 c	3.00 ± 0.36 b	2.67 ± 0.21 b	2.33 ± 0.21 b	2.00 ± 0.37 b
Sig. level	P<0.0001	P<0.0001	P <0.0001	P < 0.0001	P <0.0001

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.5.1.2 Efficacy on green vegetable bug

The number of green vegetable bugs per metre recorded on plots treated with 500ml/ha BC 639 fungus was not significantly different ($P>0.05$) from Fipronil-treated plots at 3 to 21 DAT (Table 3.5.1.2.1). Application of 250ml/ha of BC 639 though was not significantly different ($P>0.05$) from the unsprayed plots, the number of green vegetable bugs per metre at 3, 7 and 14 DAT were 37.6, 30.9 and 35.6 per cent respectively less than the untreated plots (Table 4.5.1.2.1). At 14 and 21 DAT, the number of green vegetable bug per metre recorded on plots treated with 500ml/ha BC 639 was 33 and 45.4 per cent lower respectively than the Fipronil treated plots (Table 4.5.1.2.1). The performance of both the higher (500ml/ha) and lower (250ml/ha) rates of the fungus were similar.

Table 4.5.1.2.1. Efficacy of different rates of BC639 fungal insecticides on the number of *Nezara viridula* (Green vegetable bug) per metre recorded on commercial cotton crops at ACRI in Narrabri, 2007-08.

Treatments	Pre- spray	3 DAT	7 DAT	14 DAT	21 DAT
	30-01-2008	3-02-2008	7-02-2008	14-02-2008	21-02-2008
500ml/ha BC 639	0.17 ± 0.17 a	0.67 ± 0.21ab	1.17 ± 0.48 a	0.67 ± 0.33 a	1.00 ± 0.26 a
250ml/ha BC 639	0.67 ± 0.21 a	0.83 ± 0.40ab	1.50 ± 0.43ab	1.50 ± 0.43ab	1.00 ± 0.37 a
62.5ml/ha Fipronil	0.50 ± 0.22 a	0.17 ± 0.17 b	0.33 ± 0.21 a	1.00 ± 0.37ab	1.83 ± 0.17 ab
Unsprayed (Control)	0.00 ± 0.00 a	1.33 ± 0.33 a	2.17 ± 0.31 b	2.33 ± 0.56 b	2.67 ± 0.42 b
Sig leve	P<0.06	P<0.02	P<0.002	P<0.04	P<0.002

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.5.1.3 Efficacy of lower rates of BC 639 on the survival of beneficial insects on commercial cotton crops

4.5.1.3.1 Efficacy on predatory beetles

The predatory beetles identified from the study plots are given in Table 4.3.3 . The results showed that application of 0.50 and 0.25 L/ha BC 639 fungus to cotton plants were selective against predatory beetles (Table 4.5.1.3.1.1). No significant difference ($P>0.05$) was detected in the number of predatory beetles per metre in plots treated with different rates of BC 639 fungus and the unsprayed (control) plots (Table 4.5.1.3.1.1). However, plots treated with recommended rate of Fipronil insecticide had significantly lower rates of predatory beetles per metre at 7 DAT than the BC 639 fungus and unsprayed plots (Table 4.5.1.3.1.1).

Table 4.5.1.3.1.1. Efficacy of different rates of BC639 fungal insecticides on the number of predatory beetles per metre recorded on commercial cotton crops at ACRI in Narrabri, 2007-08.

Treatments	Pre-spray	3 DAT	7 DAT	14 DAT
	3-01-2008	6-01-2008	10-01-2008	17-01-2008
500ml/ha BC 639	0.50 ± 0.22 a	0.83 ± 0.17 a	1.67 ± 0.21 a	1.83 ± 0.31 a
250ml/ha BC 639	0.67 ± 0.21 ab	1.00 ± 0.26 a	1.83 ± 0.31 a	1.83 ± 0.31 a
62.5ml/ha Fipronil	2.00 ± 0.45 b	0.67 ± 0.21 a	0.83 ± 0.17 b	1.17 ± 0.31 a
Unsprayed (Control)	1.33 ± 0.42 ab	1.00 ± 0.26 a	1.67 ± 0.49 a	1.50 ± 0.22 a
Sig. level	P<0.02	P<0.70	P<0.12	P<0.33

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.5.1.3.2 Efficacy on predatory bugs

Predatory bugs identified from the study plots are given in Table 4.3.3. No significant difference was detected among treated and control plots (Table 4.5.1.3.2.1 and 4.5.1.3.2.2).

Table 4.5.1.3.2.1. Efficacy of different rates of BC639 fungal insecticides on the number of predatory bugs per metre on commercial cotton crops at ACRI in Narrabri, 2007-08 (1st spray).

Treatments	Pre-spray	3 DAT	7 DAT	14 DAT
	3-01-2008	6-01-2008	10-01-2008	17-01-2008
500ml/ha BC 639	0.00 ± 0.00 a	0.17 ± 0.17 a	0.50 ± 0.22 a	0.67 ± 0.21 a
250ml/ha BC 639	0.17 ± 0.17 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.67 ± 0.21 a
62.5ml/ha Fipronil	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.67 ± 0.21 a
Unsprayed (Control)	0.00 ± 0.00 a	0.00 ± 0.00 a	0.17 ± 0.17 a	0.83 ± 0.31 a
Sig. level	P<0.42	P<0.42	P<0.10	P<0.77

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.5.1.3.2.2. Efficacy of different rates of BC639 fungal insecticides on the number of predatory bugs per metre on commercial cotton crops at ACRI in Narrabri, 2007-08 (2nd spray).

Treatments	Pre- spray counts	3 DAT	7 DAT	14 DAT	21 DAT
500ml/ha BC 639	0.17 ± 0.17 a	0.50 ± 0.22 a	0.50 ± 0.22 a	0.33 ± 0.21 a	0.17 ± 0.17 a
250ml/ha BC 639	0.00 ± 0.00 a	0.33 ± 0.21 a	0.50 ± 0.22 a	0.33 ± 0.21 a	0.17 ± 0.17 a
62.5ml/ha Fipronil	0.50 ± 0.22 a	0.33 ± 0.21 a	0.17 ± 0.17 a	0.50 ± 0.22 a	0.17 ± 0.17 a
Unsprayed (Control)	0.33 ± 0.21 a	0.50 ± 0.31 a	0.67 ± 0.21 a	0.17 ± 0.17 a	0.17 ± 0.17 a
Sig. level	P<0.10	P<0.61	P<0.36	P<0.60	P<0.99

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.5.1.3.3 Efficacy on predatory lacewings

The predominant predatory lacewings identified from the study plots were *Chrysopa* spp. and *Micromus tasmaniae* (Table 4.3.3). No significant differences in the number of predatory lacewings per metre were detected among the treated and unsprayed plots (Tables 4.5.1.3.3.1 and 4.5.1.3.3.2). Though the plots treated with recommended rate of Fipronil had the lowest number of predatory lacewings than all the treatments tested, the difference was not significant (Tables 4.5.1.3.3.1 and 4.5.1.3.3.2).

Table 4.5.1.3.3.1. Efficacy of different rates of BC639 fungal insecticides on the number of predatory lacewings (*Chrysopa* spp.) per metre recorded on commercial cotton crops at ACRI in Narrabri, 2007-08 (1st spray).

Treatments	Pre-spray counts	3 DAT	7 DAT	14 DAT
	(3-1-2008)			
500ml/ha BC 639	1.50 ± 0.76 a	1.00 ± 0.26 a	1.00 ± 0.26 a	1.67 ± 0.33 a
250ml/ha BC 639	0.67 ± 0.33 a	1.00 ± 0.26 a	1.00 ± 0.26 a	2.50 ± 0.85 a
62.5ml/ha Fipronil	0.67 ± 0.21 a	0.67 ± 0.33 a	1.00 ± 0.26 a	1.17 ± 0.40 a
Unsprayed (Control)	1.00 ± 0.37 a	1.00 ± 0.37 a	0.50 ± 0.22 a	1.33 ± 0.48 a
Significance level	P<0.49	P<0.69	P<0.29	P<0.38

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

Table 4.5.1.3.3.2. Efficacy of different rates of BC639 fungal insecticides on the number of predatory lacewings (*Chrysopa* spp.) per metre recorded on commercial cotton crops at ACRI in Narrabri, 2007-08 (2nd spray).

Treatments	Pre-spray counts	3 DAT	7 DAT	14 DAT	21 DAT
	(31-1-2008)				
500ml/ha BC 639	1.33 ± 0.21 a	2.00 ± 0.26 a	1.00 ± 0.26 a	0.50 ± 0.22 a	1.00 ± 0.26 a
250ml/ha BC 639	1.83 ± 0.54 a	2.83 ± 0.40 a	1.17 ± 0.40 a	0.67 ± 0.33 a	1.00 ± 0.26 a
62.5ml/ha Fipronil	2.00 ± 0.52 a	2.17 ± 0.40 a	0.83 ± 0.17 a	0.50 ± 0.22 a	0.83 ± 0.17 a
Unsprayed (Control)	1.50 ± 0.34 a	2.33 ± 0.21 a	1.33 ± 0.33 a	0.83 ± 0.31 a	1.17 ± 0.17 a
Sig. level	P<0.13	P<0.23	P<0.47	P<0.83	P<0.79

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

4.5.1.3.4 Efficacy on spiders

Spiders identified from the study plots were *Lycosa* spp., *Oxyopes* spp., *Salticidae* spp., *Araneus* spp. (Table 4.3.3). The number of spiders per metre was consistently the same in the fungus treated and control (unsprayed) plots throughout the study (Table 4.5.1.3.4.1 and 4.5.1.3.4.2). The number of spiders per metre recorded in the Fipronil treated plots were significantly lower ($P < 0.02$) at 7 DAT in the first spray (Tables 4.5.1.3.4.1) and at 7 and 14 DAT in the second spray (Table 4.5.1.3.4.2).

Table 4.5.1.3.4.1. Efficacy of different rates of BC639 fungal insecticides on the number of spiders per metre recorded on commercial cotton crops at ACRI in Narrabri, 2007-08 (1st spray)

Treatments	Pre-spray counts	3 DAT	7 DAT	14 DAT
	(3-1-2008)			
500ml/ha BC 639	3.50 ± 1.18 a	2.83 ± 0.95 a	4.50 ± 0.34ab	4.17 ± 0.79 a
250ml/ha BC 639	2.00 ± 0.45 a	3.00 ± 0.63 a	5.00 ± 0.34 a	4.33 ± 0.92 a
62.5ml/ha Fipronil	2.50 ± 0.43 a	2.17 ± 0.40 a	2.83 ± 0.31 b	4.50 ± 0.76 a
Unsprayed (Control)	2.33 ± 0.33 a	2.33 ± 0.42 a	4.00 ± 0.52ab	3.83 ± 0.40 a
Significant level	$P < 0.51$	$P < 0.72$	$P < 0.02$	$P < 0.85$

Means between treatments within columns followed by the same letter are not significantly different ($P > 0.05$); Tukey-Kramer multiple comparison test.

Table 4.5.1.3.4.2. Efficacy of different rates of BC639 fungal insecticides on the number of spiders per metre recorded on commercial cotton crops at ACRI in Narrabri, 2007-08 (2nd spray)

Treatments	Pre- spray counts	3 DAT	7 DAT	14 DAT	21 DAT
	(30-1-2008)				
500ml/ha BC 639	6.17 ± 0.60 a	6.33 ± 0.49 a	4.50 ± 0.67ab	5.83 ± 1.05ab	4.00 ± 0.89 a
250ml/ha BC 639	4.00 ± 1.00 a	4.67 ± 0.80 a	6.00 ± 0.68 a	7.50 ± 0.89 a	5.67 ± 0.84 a
62.5ml/ha Fipronil	6.17 ± 0.91 a	4.50 ± 0.56 a	3.00 ± 0.78 b	3.67 ± 1.15 b	5.83 ± 0.60 a
Unsprayed (Control)	4.83 ± 1.08 a	4.83 ± 0.54 a	6.00 ± 0.45 a	7.67 ± 0.67 a	5.67 ± 0.76 a
Sig. level	$P < 0.18$	$P < 0.17$	$P < 0.02$	$P < 0.03$	$P < 0.21$

Means between treatments within columns followed by the same letter are not significantly different ($P > 0.05$); Tukey-Kramer multiple comparison test.

4.5.1.4 Efficacy of lower rates of BC 639 on the survival of non-target arthropods on commercial cotton crops

3.5.1.4.1 Efficacy against apple dimpling bug (*Campylomma liebknehti*)

Significantly lower ($P < 0.001$) number of apple dimpling bugs per metre were recorded on plots treated with the fungus and recommended rate of Fipronil than the unsprayed plots at 3, 7 and 14 DAT (Table 4.5.1.4.1.1). At 21 DAT, the number of apple dimpling bugs per metre on plots treated with 500 ml/ha was significantly lower ($P < 0.03$) but similar to the Fipronil treated plots (Table 4.5.1.4.1.1). The unsprayed plots and plots treated with 250 ml/ha BC 639 were not significantly different ($P > 0.05$). No significant difference ($P > 0.05$) was detected between Fipronil and fungal insecticide treated plots (Table 4.5.1.4.1.1).

Table 4.5.1.4.1.1. Efficacy of different rates of BC639 fungal insecticides on the number of *Campylomma liebknehti* (Apple dimpling bugs) per metre on commercial cotton crops at ACRI in Narrabri, 2007-08.

Treatments	Pre- spray counts	3 DAT	7 DAT	14 DAT	21 DAT
	30-01-08				
500ml/ha BC 639	13.33 ± 2.08a	1.83 ± 0.48a	1.50 ± 0.72 a	1.67 ± 0.33 a	2.33 ± 0.62a
250ml/ha BC 639	12.50 ± 3.15a	6.17 ± 1.62a	3.83 ± 0.40 a	3.83 ± 0.79 a	2.83 ± 0.31ab
62.5ml/ha Fipronil	8.67 ± 1.41a	4.00 ± 1.32a	2.67 ± 0.62 a	1.83 ± 0.54 a	2.17 ± 0.60a
Unsprayed (Control)	8.50 ± 2.85a	14.67 ± 3.35b	13.33 ± 3.05 b	7.17 ± 0.87 b	4.83 ± 0.65b
Sig. level	P<0.38	P<0.004	P<0.001	P<0.0001	P<0.03

Means between treatments within columns followed by the same letter are not significantly different ($P > 0.05$); Tukey-Kramer multiple comparison test.

4.5.1.5 Effect of BC 639 on cotton yield

Significantly higher ($P < 0.002$) yields were harvested from plots treated with recommended rate of Fipronil insecticide and 500 ml/ha BC 639 than the unsprayed plot and plots treated with 250ml/ha BC 639 (Table 4.5.1.5.1). The yields harvested from plots treated with 250 ml/ha BC 639 were not significantly different ($P > 0.05$) from the unsprayed plots (Table 4.5.1.5.1).

Table 4.5.1.5.1. Efficacy of different rates of BC639 fungal insecticides against sucking pests and effect on yield (bales per acre) on commercial cotton crops at ACRI in Narrabri, 2007-08 (1st spray).

Treatments	Yield (bales/acre)
500ml/ha BC 639	5.24 ± 0.08 a
250ml/ha BC 639	4.96 ± 0.09 b
62.5ml/ha Fipronil	5.25 ± 0.08 a
Unsprayed (Control)	4.88 ± 0.12 b

Significant level $P < 0.002$

Means between treatments within columns followed by the same letter are not significantly different ($P > 0.05$); Tukey-Kramer multiple comparison test.

Conclusion

Application of BC 639 controlled green mirids, green vegetable bugs and apple dimpling bugs similar to Fipronil, a commercial insecticide used by the cotton industry to manage these pests. In addition, the BC 639 fungus at all rates of application was found to be more selective to predatory beetles, bugs, lacewings and spiders than the commercial insecticide Fipronil. No yield loss was detected when BC 639 was used to manage these pests on commercial cotton crops.

4.6 Trials at Norwood near Moree in 2007-008

4.6.1 Efficacy of different rates of BC 639 on *Helicoverpa* spp. and beneficial insects on conventional cotton crops and sucking pests on Bollgard cotton crops, 2007-08.

4.6.1.1 Efficacy on *Helicoverpa* spp. eggs, very small and small (VS + S) and medium and large (M + L) larvae

(A) *Helicoverpa* eggs

The first spray application was applied at high *Helicoverpa* spp. egg pressure (Table 4.6.1.1A.1). After the first spray application, the number of *Helicoverpa* spp. eggs recorded on plots treated with BC 639 fungus was significantly lower than the unsprayed plots (Table 4.6.1.1A.1). The number of *Helicoverpa* eggs per metre recorded on the BC 639 treated plots were significantly lower than plots treated with Emamectin insecticide at 7 DAT but was not different at 3 and 14 DAT (Table 4.6.1.1A.1).

Helicoverpa spp. egg pressure during the second treatment application was very low (Table 4.6.1.1A.2). However, the number of *Helicoverpa* spp. eggs recorded on the BC 639 and Indoxacarb insecticide treated plots were the same and significantly lower than the unsprayed plots (Table 4.6.1.1A.2). No eggs were recorded on plots treated with 1.0 and 0.5L/ha BC 639 at 7 and 14 DAT (Table 4.6.1.1A.2).

Table 4.6.1.1A.1. Efficacy of different rates of BC639 fungal insecticides on the number of *Helicoverpa* spp. eggs per metre on commercial conventional cotton crops at Norwood in Moree, 2007-08 (1st spray application).

Treatments	Pre- spray counts	3 DAT 3-2-08	7 DAT 7-02-08	14 DAT 14-2-08
	30-01-08			
1L/ha BC 639	27.75 ± 2.36 a	8.25 ± 1.89 a	1.25 ± 0.25 a	0.75 ± 0.25 a
0.50L/ha BC 639	25.00 ± 2.48a	5.50 ± 2.22 a	1.50 ± 0.65 a	1.00 ± 0.41 a
0.25L/ha BC 639	17.75 ± 3.38a	6.00 ± 1.58 a	1.00 ± 0.41 a	0.50 ± 0.29 a

0.70L/ha Emamectin	17.00 ± 2.35a	13.75 ± 2.46 ab	9.75 ± 0.85 b	3.50 ± 1.66 ab
Unsprayed (Control)	26.25 ± 4.03 a	17.00 ± 2.80 b	14.50 ± 1.04 c	7.00 ± 1.96 b
Sig. level	P<0.07	P<0.005	P<0.0001	P<0.0001

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.6.1.1A.2. Efficacy of different rates of BC639 fungal insecticides on the number of *Helicoverpa* spp. eggs per metre on commercial conventional cotton crops at Norwood in Moree, 2007-08 (2nd spray application).

Treatments	Pre- spray counts	3 DAT 28-2-08	7 DAT 4-03-08	14 DAT 11-3-08
1L/ha BC 639	2.75 ± 0.48 a	0.50 ± 0.29 a	0.00 ± 0.00 a	0.00 ± 0.00 a
0.50L/ha BC 639	2.25 ± 0.48 a	1.00 ± 0.58 a	0.00 ± 0.00 a	0.00 ± 0.00 a
0.25L/ha BC 639	2.25 ± 0.63 a	0.75 ± 0.25 a	0.00 ± 0.00 a	0.25 ± 0.29 a
0.85L/ha Indoxacarb	2.00 ± 0.41 a	1.50 ± 0.65 a	0.00 ± 0.00 a	0.50 ± 0.29 a
Unsprayed (Control)	1.50 ± 0.50 a	3.75 ± 0.48 b	2.00 ± 0.41 b	1.25 ± 0.25 b
Sig. level	P<0.17	P<0.002	P<0.0001	P<0.001

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

(B) *Helicoverpa* very small and small larvae

The first and second treatment applications coincided with *Helicoverpa* egg hatch. The wind speed during the application of 1.0L/ha BC 639 rate suddenly increased to 20 km/hour half way through the application causing the treatment to drift onto the unsprayed plot which was located adjacent to the treatment. In addition, the experimental site received 25mm rainfall at 3 days after the first spray application. These might have resulted in the low number of VS+S larvae recorded on the plots especially the unsprayed plots. Despite the low number of VS+S larvae recorded in all plots, the plots treated with BC 639 and conventional insecticides had significantly lower number of *Helicoverpa* spp. VS+S larvae than the unsprayed plots (Tables 4.6.1.1B.1 and 4.6.1.1B.2). The number of *Helicoverpa* VS+S larvae recorded on the BC 639 and conventional insecticide treated plots were below the recommended threshold of 2 larvae per metre used to manage these pests on conventional cotton crops.

Table 4.6.1.1B.1. Efficacy of different rates of BC639 fungal insecticides on the number of *Helicoverpa* spp. very small and small (VS+S) larvae per metre on commercial conventional cotton crops at Norwood in Moree, 2007-08 (1st spray application).

Treatments	Pre- spray counts 30-01-08	3 DAT 3-2-08	7 DAT 7-02-08	14 DAT 14-2-08
1L/ha BC 639	2.50 ± 0.29 a	1.25 ± 0.25 a	0.75 ± 0.25 a	1.50 ± 0.29 a
0.50L/ha BC 639	2.75 ± 0.63 a	1.25 ± 0.25 a	1.00 ± 0.41 a	1.25 ± 0.25 a
0.25L/ha BC 639	1.25 ± 0.25 a	1.75 ± 0.48 a	1.75 ± 0.25 a	1.75 ± 0.48 a
0.70L/ha Emamectin	2.00 ± 0.41 a	1.50 ± 0.29 a	1.00 ± 0.41 a	1.00 ± 0.41 a
Unsprayed (Control)	1.50 ± 0.50 a	2.75 ± 0.25 a	3.50 ± 0.65 b	5.00 ± 1.96 b
Sig. level	P<0.089	P<0.05	P<0.002	P<0.0001

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.6.1.1B.2. Efficacy of different rates of BC639 fungal insecticides on the number of *Helicoverpa* spp. very small and small (VS+S) larvae per metre on commercial conventional cotton crops at Norwood in Moree, 2007-08 (2nd spray application).

Treatments	Pre- spray counts 25-02-08	3 DAT 28-2-08	7 DAT 4-03-08	14 DAT 11-3-08
1L/ha BC 639	1.50 ± 0.50 a	0.25 ± 0.25 a	0.00 ± 0.00 a	0.00 ± 0.00 a
0.50L/ha BC 639	1.75 ± 0.48 a	0.50 ± 0.29 a	0.25 ± 0.25 a	0.00 ± 0.00 a
0.25L/ha BC 639	2.00 ± 0.58 a	0.75 ± 0.25 a	0.50 ± 0.29 a	0.25 ± 0.25 a
0.85L/ha Indoxacarb	1.25 ± 0.48 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a
Unsprayed (Control)	2.50 ± 1.04 a	2.75 ± 0.48 b	3.00 ± 0.71 b	2.00 ± 0.58 b
Sig. level	P<0.77	P<0.0003	P<0.0005	P<0.001

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

(C) *Helicoverpa* medium and large larvae

The number of *Helicoverpa* spp. medium and large larvae recorded on plots treated with BC 639 rates after the first treatment application were similar to the conventional insecticide treated plots but were significantly lower than the unsprayed plots at (Table 4.6.1.1C.1). The number of M+L larvae on plots treated with 1.0 and 0.5L/ha BC 639 ranged between 0.50-0.75 per metre at 3 and 7 DAT and this was lower than the recommended threshold of 1.0 per metre. However, the 0.25L/ha BC 639 rate had 2.50 per metre which was above the recommended threshold. At 14 DAT, the number of M+L larvae per metre on 1.0, 0.50 and 0.25L/ha BC 639 treated plots were 1.25, 1.50 and 2.25 respectively compared with 1.00 on the conventional treated plots (Table 4.6.1.1C.1). These numbers were higher than the

recommended *Helicoverpa* M+L larval thresholds for managing *Helicoverpa* spp. M+L larvae on conventional cotton crops.

After the second treatment application, the number of M+L larvae per metre on BC 639 treated plots were similar to the conventional treated plots and numbers were below recommended *Helicoverpa* M+L larval threshold for conventional cotton crops (Table 4.6.1.1C.2). The unsprayed plots had the highest number of M+L larvae per metre (3.50 - 3.75 per metre) (Table 4.6.1.1C.2).

Table 4.6.1.1C.1. Efficacy of different rates of BC639 fungal insecticides on the number of *Helicoverpa* spp. medium and large (M+L) larvae per metre on commercial conventional cotton crops at Norwood in Moree, 2007-08 (1st spray application).

Treatments	Pre- spray counts 30-01-08	3 DAT 3-2-08	7 DAT 7-02-08	14 DAT 14-2-08
1L/ha BC 639	1.25 ± 0.25 a	0.75 ± 0.25 a	0.50 ± 0.29 a	1.25 ± 0.25 a
0.50L/ha BC 639	1.00 ± 0.41 a	0.75 ± 0.48 a	0.50 ± 0.29 a	1.50 ± 0.29 a
0.25L/ha BC 639	2.00 ± 0.41 a	2.50 ± 0.29 a	2.50 ± 0.50 a	2.25 ± 0.63 a
0.70L/ha	1.00 ± 0.41 a	0.50 ± 0.29 a	0.50 ± 0.29 a	1.00 ± 0.41 a
Emamectin				
Unsprayed (Control)	2.00 ± 0.25 a	4.25 ± 0.75 b	4.00 ± 0.41 b	4.25 ± 0.63 b
Sig. level	P<0.069	P<0.0005	P<0.0001	P<0.003

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

Table 4.6.1.1C.2. Efficacy of different rates of BC639 fungal insecticides on the number of *Helicoverpa* spp. medium and large (M+L) larvae per metre on commercial conventional cotton crops at Norwood in Moree, 2007-08 (2nd spray application).

Treatments	Pre- spray counts 25-02-08	3 DAT 28-2-08	7 DAT 4-03-08	14 DAT 11-3-08
1L/ha BC 639	0.50 ± 0.29 a	0.50 ± 0.29 a	0.25 ± 0.25 a	0.00 ± 0.00 a
0.50L/ha BC 639	0.75 ± 0.48 a	1.25 ± 0.25 a	0.25 ± 0.25 a	0.00 ± 0.00 a
0.25L/ha BC 639	1.50 ± 0.29 a	1.75 ± 0.25 a	0.75 ± 0.25 a	0.25 ± 0.25 a
0.85L/ha	0.25 ± 0.25 a	0.75 ± 0.48 a	0.00 ± 0.00 a	0.25 ± 0.25 a
Indoxacarb				
Unsprayed (Control)	1.75 ± 0.25 a	3.50 ± 0.29 b	3.75 ± 0.48 b	3.75 ± 0.85 b
Sig. level	P<0.04	P<0.0003	P<0.0001	P<0.0002

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

4.6.1.2 Efficacy of BC 639 against beneficial insects in conventional cotton, Norwood 2007-08

4.6.1.2.1 Predatory beetles

The predominant predatory beetles identified from the study plots are given in Table 4.3.3. No significant differences were found among treatments after the first spray application, exception was at 14 DAT where the number of predatory beetles per metre found on the unsprayed plot (3.25 per metre) was significantly different from the fungus and the insecticide treated plots (Table 4.6.1.2.1.1).

Similarly, no significant differences were recorded in the number of predatory beetles per metre among treatments after the second spray application (Table 4.6.1.2.1.2).

Table 4.6.1.2.1.1. Efficacy of different rates of BC639 fungal insecticides on the number of predatory beetles per metre on commercial conventional cotton crops at Norwood in Moree, 2007-08 (1st spray application).

Treatments	Pre- spray counts 30-01-08	3 DAT 3-2-08	7 DAT 7-02-08	14 DAT 14-2-08
1L/ha BC 639	0.00 ± 0.00 a	0.25 ± 0.25 a	0.50 ± 0.29 a	1.00 ± 0.41 a
0.50L/ha BC 639	0.25 ± 0.25 a	0.00 ± 0.48 a	0.75 ± 0.48 a	1.25 ± 0.48 a
0.25L/ha BC 639	0.00 ± 0.00 a	0.00 ± 0.29 a	1.00 ± 0.58 a	1.50 ± 0.65 a
0.70L/ha	0.25 ± 0.25 a	0.00 ± 0.29 a	0.50 ± 0.29 a	1.00 ± 0.41 a
Emamectin				
Unsprayed (Control)	0.25 ± 0.25 a	0.50 ± 0.29 a	1.25 ± 0.48 a	3.25 ± 0.25 b
Sig. level	P<0.72	P<0.16	P<0.32	P<0.001

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

Table 4.6.1.2.1.2 Efficacy of different rates of BC639 fungal insecticides on the number of predatory beetles per metre on commercial conventional cotton crops at Norwood in Moree, 2007-08 (2nd spray application).

Treatments	Pre- spray counts 25-02-08	3 DAT 28-2-08	7 DAT 4-03-08	14 DAT 11-3-08
1L/ha BC 639	0.50 ± 0.29 a	0.25 ± 0.25 a	0.00 ± 0.00 a	0.75 ± 0.25 a
0.50L/ha BC 639	0.50 ± 0.29 a	0.50 ± 0.29 a	0.00 ± 0.00 a	0.50 ± 0.29 a
0.25L/ha BC 639	0.25 ± 0.25 a	0.25 ± 0.25 a	0.25 ± 0.25 a	0.50 ± 0.29 a
0.85L/ha	0.25 ± 0.25 a	0.25 ± 0.25 a	0.00 ± 0.00 a	0.50 ± 0.29 a
Indoxacarb				
Unsprayed (Control)	1.00 ± 0.41 a	0.75 ± 0.25 a	0.25 ± 0.25 a	1.50 ± 0.29 a

Sig. level P<0.14 P<0.63 P<0.61 P<0.63

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

4.6.1.2.2 Predatory bugs

The predominant predatory bugs identified from the study plots are given (Table 4.3.3). No significant differences were found among the unsprayed plots, fungus and insecticide treated plots after the treatment applications (Table 4.6.1.2.2.1 and 4.6.1.2.2.2).

Table 4.6.1.2.2.1. Efficacy of different rates of BC639 fungal insecticides on the number of predatory bugs per metre on commercial conventional cotton crops at Norwood in Moree, 2007-08 (1st spray application).

Treatments	Pre- spray counts 30-01-08	3 DAT 3-2-08	7 DAT 7-02-08	14 DAT 14-2-08
1L/ha BC 639	1.00 ± 0.41 a	0.50 ± 0.29 a	0.25 ± 0.25 a	0.75 ± 0.48 a
0.50L/ha BC 639	1.25 ± 0.25 a	0.50 ± 0.29 a	0.25 ± 0.25 a	0.75 ± 0.25 a
0.25L/ha BC 639	1.00 ± 0.41 a	0.75 ± 0.25 a	0.25 ± 0.25 a	0.75 ± 0.25 a
0.70L/ha Emamectin	1.00 ± 0.41 a	0.25 ± 0.25 a	0.25 ± 0.25 a	0.25 ± 0.25 a
Unsprayed (Control)	1.75 ± 0.25 a	0.75 ± 0.25 a	0.50 ± 0.29 a	1.25 ± 0.25 a
Sig. level	P<0.59	P<0.53	P<0.45	P<0.22

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

Table 4.6.1.2.2.2 Efficacy of different rates of BC639 fungal insecticides on the number of predatory bugs per metre on commercial conventional cotton crops at Norwood in Moree, 2007-08 (2nd spray application).

Treatments	Pre- spray counts 25-02-08	3 DAT 28-2-08	7 DAT 4-03-08	14 DAT 11-3-08
1L/ha BC 639	0.50 ± 0.29 a	0.50 ± 0.29 a	0.25 ± 0.25 a	0.75 ± 0.25 a
0.50L/ha BC 639	0.25 ± 0.25 a	0.25 ± 0.25 a	0.50 ± 0.25 a	0.75 ± 0.25 a
0.25L/ha BC 639	0.25 ± 0.25 a	0.25 ± 0.25 a	0.25 ± 0.25 a	1.00 ± 0.41 a
0.85L/ha Indoxacarb	0.50 ± 0.29 a	0.25 ± 0.25 a	0.25 ± 0.25 a	0.75 ± 0.25 a
Unsprayed (Control)	0.50 ± 0.29 a	0.50 ± 0.29 a	0.50 ± 0.29 a	1.25 ± 0.25 a
Sig. level	P<0.72	P<0.61	P<0.61	P<0.58

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.6.1.2.3 Predatory lacewings

The predominant predatory lacewings identified from the study plots were *Chrysopa* spp. and *Micromus tasmaniae* (Table 4.3.3). No significant differences were found among fungus treated plots and the unsprayed plots after the first and second treatment applications (Table 4.6.1.2.3.1 and 4.6.1.2.3.2). The conventional insecticide treated plots consistently recorded the lowest number of predatory lacewings per metre (about 50% lower than the fungus treated plots) throughout the study. However, it was only at 3DAT of the first spray that the difference between the insecticides treated plots were significant (Table 4.6.1.2.3.1).

Table 4.6.1.2.3.1. Efficacy of different rates of BC639 fungal insecticides on the number of predatory lacewings per metre on commercial conventional cotton crops at Norwood in Moree, 2007-08 (1st spray application).

Treatments	Pre- spray counts 30-01-08	3 DAT 3-2-08	7 DAT 7-02-08	14 DAT 14-2-08
1L/ha BC 639	4.25 ± 0.75 a	2.25 ± 0.25 ab	0.50 ± 0.29 a	1.00 ± 0.41 a
0.50L/ha BC 639	3.75 ± 1.11 a	3.25 ± 0.25 a	0.75 ± 0.25 a	1.50 ± 0.50 a
0.25L/ha BC 639	3.25 ± 0.48 a	3.00 ± 0.41 a	1.25 ± 0.25 a	1.50 ± 0.29 a
0.70L/ha	5.00 ± 0.82 a	0.75 ± 0.25 b	0.25 ± 0.25 a	0.75 ± 0.25 a
Emamectin				
Unsprayed (Control)	3.50 ± 0.65 a	3.25 ± 0.48 a	1.50 ± 0.50 a	2.00 ± 0.41 a
Sig. level	P<0.47	P<0.001	P<0.02	P<0.20

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.6.1.2.3.2 Efficacy of different rates of BC639 fungal insecticides on the number of predatory lacewings per metre on commercial conventional cotton crops at Norwood in Moree, 2007-08 (2nd spray application).

Treatments	Pre- spray counts 25-02-08	3 DAT 28-2-08	7 DAT 4-03-08	14 DAT 11-3-08
1L/ha BC 639	3.00 ± 0.41 a	1.25 ± 0.25 a	0.50 ± 0.29 a	3.25 ± 0.25 a
0.50L/ha BC 639	2.75 ± 0.25 a	1.50 ± 0.29 a	0.75 ± 0.25 a	3.50 ± 0.65 a
0.25L/ha BC 639	4.25 ± 0.48 a	1.75 ± 0.48 a	0.75 ± 0.25 a	3.50 ± 0.50 a
0.85L/ha	2.25 ± 0.25 a	0.75 ± 0.25 a	0.25 ± 0.25 a	2.50 ± 0.87 a
Indoxacarb				
Unsprayed (Control)	4.25 ± 0.75 a	2.25 ± 0.25 a	1.25 ± 0.48 a	2.75 ± 0.48 a
Sig. level	P<0.04	P<0.02	P<0.10	P<0.71

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.6.1.2.4 Spiders

The predominant spiders identified from the study plots are given Table 4.3.3. No significant differences were found among the unsprayed plots, fungus and insecticide treated plots after the treatment applications (Table 4.6.1.2.4.1 and 4.6.1.2.4.2).

Table 4.6.1.2.4.1. Efficacy of different rates of BC639 fungal insecticides on the number of spiders per metre on commercial conventional cotton crops at Norwood in Moree, 2007-08 (1st spray application).

Treatments	Pre- spray counts 30-01-08	3 DAT 3-2-08	7 DAT 7-02-08	14 DAT 14-2-08
1L/ha BC 639	5.20 ± 0.75 a	5.00 ± 0.58 a	5.00 ± 0.71 a	6.25 ± 0.75 a
0.50L/ha BC 639	5.50 ± 29 a	4.00 ± 0.41 a	4.75 ± 0.48 a	5.00 ± 0.91 a
0.25L/ha BC 639	5.50 ± 0.50 a	5.50 ± 0.29 a	4.25 ± 0.25 a	5.75 ± 1.55 a
0.70L/ha Emamectin	5.75 ± 0.85 a	3.25 ± 0.63 a	3.75 ± 1.03 a	6.00 ± 0.91 a
Unsprayed (Control)	6.00 ± 0.91 a	4.00 ± 0.91 a	5.25 ± 0.25 a	6.50 ± 0.65 a
Sig. level	P<0.95	P<0.06	P<0.28	P<0.81

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.6.1.2.4.2 Efficacy of different rates of BC639 fungal insecticides on the number of spiders per metre on commercial conventional cotton crops at Norwood in Moree, 2007-08 (2nd spray application).

Treatments	Pre- spray counts 25-02-08	3 DAT 28-2-08	7 DAT 4-03-08	14 DAT 11-3-08
1L/ha BC 639	4.75 ± 0.25 a	2.75 ± 0.48 a	4.75 ± 0.25 a	5.25 ± 1.03 a
0.50L/ha BC 639	3.25 ± 0.25 a	3.75 ± 0.29 a	4.50 ± 0.65 a	6.25 ± 0.75 a
0.25L/ha BC 639	3.75 ± 0.48 a	4.25 ± 0.63 a	4.50 ± 1.19 a	6.00 ± 1.47 a
0.85L/ha Indoxacarb	3.75 ± 0.63 a	2.00 ± 0.41 a	3.75 ± 0.63 a	4.00 ± 0.82 a
Unsprayed (Control)	3.50 ± 0.29 a	3.75 ± 0.48 a	4.25 ± 0.75 a	5.50 ± 1.04 a
Sig. level	P<0.13	P<0.07	P<0.93	P<0.37

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Conclusion

Application of BC 639 reduced the number of *Helicoverpa* spp. eggs and also controlled *Helicoverpa* spp. very small, medium and large larvae on conventional cotton crops similar to Emamectin and Indoxacarb insecticides. The BC 639 had minimal effect on predatory beetles after the first spray application but no negative effect was detected after the second spray. In addition, BC 639 spray did not have any negative effect on predatory bugs, predatory lacewings and spiders when applied to the conventional cotton crops. Emamectin also reduced predatory beetle numbers per metre after the first spray application but no reduction in the predatory beetle numbers per metre was detected after the second spray application.

4.7 Trials at Norwood near Moree on commercial Bollgard cotton crops, 2007-08

4.7.1 Efficacy against green mirids in Bollgard cotton crops, Norwood, 2007-08

The number of green mirids per metre found on BC 639 treated plots were similar to the insecticide treated plots but significantly lower than the unsprayed plots except 0.25L/ha BC 639 treated plots which were not significantly different from the unsprayed plot at 3 days after the first spray (Tables 4.7.1.1 and 4.7.1.2). Application of 1.0, 0.50 and 0.25L/ha BC 639 controlled the mirids similar to Fipronil (Tables 4.7.1.1 and 4.7.1.2).

Table 4.7.1.1. Efficacy of different rates of BC639 fungal insecticides on the number of green mirids per metre on commercial Bollgard cotton crops at Norwood in Moree, 2007-08 (1st spray application).

Treatments	Pre- spray counts 14-1-08	3 DAT 17-1-08	7 DAT 21-1-08	14 DAT 28-1-08
1L/ha BC 639	1.75 ± 0.25 a	0.50 ± 0.29 a	0.00 ± 0.00 a	0.25 ± 0.25 a
0.50L/ha BC 639	2.25 ± 0.63 a	0.50 ± 0.29 a	0.25 ± 0.25 a	0.25 ± 0.25 a
0.25L/ha BC 639	1.75 ± 0.50 a	0.75 ± 0.25 ab	0.50 ± 0.29 a	0.50 ± 0.29 a
62.5 ml/ha Fipronil	1.50 ± 0.29 a	0.50 ± 0.29 a	0.00 ± 0.00 a	0.00 ± 0.00 a
Unsprayed (Control)	1.50 ± 0.29 a	2.00 ± 0.41 b	2.75 ± 0.48 b	2.50 ± 0.29 b
Sig. level	P<0.68	P<0.02	P<0.28	P<0.81

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.7.1.2 Efficacy of different rates of BC639 fungal insecticides on the number of green mirids per metre on commercial Bollgard cotton crops at Norwood in Moree, 2007-08 (2nd spray application).

Treatments	Pre- spray counts 25-02-08	3 DAT 28-2-08	7 DAT 4-03-08	14 DAT 11-3-08
1L/ha BC 639	0.75 ± 0.48 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a
0.50L/ha BC 639	1.00 ± 0.41 a	0.25 ± 0.25 a	0.00 ± 0.00 a	0.25 ± 0.25 a
0.25L/ha BC 639	1.25 ± 0.48 a	0.75 ± 0.48 a	0.25 ± 0.25 a	0.50 ± 0.29 a
62.5 mL/ha Fipronil	0.75 ± 0.25 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a
Unsprayed (Control)	2.00 ± 0.41 a	2.25 ± 0.48 b	3.00 ± 0.41 b	2.50 ± 0.29 b
Sig. level	P>0.08	P<0.001	P<0.0001	P<0.0001

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.7.2 Efficacy of BC 639 against apple dimpling bugs in Bollgard cotton crops, Norwood 2007-08

The number of apple dimpling bug per metre found on BC 639 treated plots was similar to the insecticide treated plots but significantly lower than the unsprayed plots (Tables 4.7.2.1 and 4.7.2.2). Thus application of 1.0, 0.50 and 0.25L/ha BC 639 controlled apple dimpling bugs similar to Fipronil (Tables 3.7.2.1 and 3.7.2.2).

Table 4.7.2.1. Efficacy of different rates of BC639 fungal insecticides on the number of apple dimpling bugs per metre on commercial conventional cotton crops at Norwood in Moree, 2007-08 (1st spray application).

Treatments	Pre- spray counts 14-1-08	3 DAT 17-1-08	7 DAT 21-1-08	14 DAT 28-1-08
1L/ha BC 639	9.25 ± 0.86 a	3.25 ± 0.48 a	1.50 ± 0.29 a	3.75 ± 1.11 a
0.50L/ha BC 639	9.25 ± 1.25 a	3.50 ± 0.65 a	2.00 ± 0.41 a	4.25 ± 0.75 a
0.25L/ha BC 639	5.75 ± 0.48 a	5.75 ± 0.75 a	3.25 ± 1.03 a	5.75 ± 0.75 a
62.5 ml/ha Fipronil	7.50 ± 0.87 a	2.25 ± 0.75 a	0.75 ± 0.25 a	3.00 ± 0.71 a
Unsprayed (Control)	10.50 ± 1.19 a	9.50 ± 0.96 b	9.75 ± 1.25 b	8.75 ± 0.48 b
Sig. level	P<0.04	P<0.0001	P<0.28	P<0.81

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.7.2.2 Efficacy of different rates of BC639 fungal insecticides on the number of apple dimpling bugs per metre on commercial conventional cotton crops at Norwood in Moree, 2007-08 (2nd spray application).

Treatments	Pre- spray counts 25-02-08	3 DAT 28-2-08	7 DAT 4-03-08	14 DAT 11-3-08
1L/ha BC 639	8.25 ± 0.25 a	2.25 ± 0.25 a	2.25 ± 0.48 a	0.50 ± 0.50 a
0.50L/ha BC 639	7.00 ± 0.70 a	2.75 ± 0.48 a	2.75 ± 0.25 a	1.50 ± 0.29 a
0.25L/ha BC 639	7.25 ± 0.48 a	3.50 ± 0.87 a	3.75 ± 0.48 a	2.00 ± 0.71 a
62.5 ml/ha Fipronil	6.50 ± 0.29 a	2.50 ± 0.50 a	2.25 ± 0.48 a	0.75 ± 0.25 a
Unsprayed (Control)	8.50 ± 0.65 a	7.00 ± 0.71 b	7.50 ± 0.65 b	5.75 ± 0.48 b
Sig. level	P>0.04	P<0.001	P<0.0001	P<0.0001

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.7.3 Efficacy of BC 639 against green vegetable bugs in Bollgard cotton crops, Norwood, 2007-08

After the first treatment application, no significant differences were found in the number of green vegetable bugs per metre between the BC 639, Fipronil and unsprayed plots at 3 DAT (Table 4.7.3.1). However at 7 and 14 DAT, the number of green vegetable bugs per metre found on plots treated with BC 639 rates were similar to Fipronil treated plots but significantly different from the unsprayed plots except the 0.25L/ha BC 639 rate that were not different from the unsprayed plots at 7 and 14 DAT (Table 4.7.3.1).

After the second treatment application, the number of green vegetable bugs recorded on all the BC 639 rates and Fipronil plots were significantly different from the unsprayed plots except the 0.25L/ha BC 639 rate (Table 4.7.3.2). However, at 7 and 14 DAT, the number of green vegetable bugs on the fungus and Fipronil treated plots were significantly different from the unsprayed plots (Table 4.7.3.2) indicating the BC 639 rates controlled green vegetable bugs similar to Fipronil insecticides.

Table 4.7.3.1. Efficacy of different rates of BC639 fungal insecticides on the number of green vegetable bugs per metre on commercial conventional cotton crops at Norwood in Moree, 2007-08 (1st spray application).

Treatments	Pre- spray counts 14-1-08	3 DAT 17-1-08	7 DAT 21-1-08	14 DAT 28-1-08
1L/ha BC 639	2.25 ± 0.25 a	1.75 ± 0.25 a	1.00 ± 0.41 a	1.25 ± 0.25 a
0.50L/ha BC 639	1.50 ± 0.29 a	1.75 ± 0.48 a	1.00 ± 0.41 a	1.50 ± 0.29 a
0.25L/ha BC 639	1.00 ± 0.41 a	2.50 ± 0.29 a	3.25 ± 0.48 b	3.00 ± 0.41 ab
62.5 ml/ha Fipronil	1.50 ± 0.29 a	1.75 ± 0.48 a	0.75 ± 0.25 a	1.25 ± 0.25 a
Unsprayed (Control)	1.00 ± 0.41 a	2.50 ± 0.29 a	3.75 ± 0.25 b	4.50 ± 1.04 b
Sig. level	P>0.06	P<0.26	P<0.0001	P<0.005

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.7.3.2 Efficacy of different rates of BC639 fungal insecticides on the number of green vegetable bugs per metre on commercial conventional cotton crops at Norwood in Moree, 2007-08 (2nd spray application).

Treatments	Pre- spray counts 25-02-08	3 DAT 28-2-08	7 DAT 4-03-08	14 DAT 11-3-08
1L/ha BC 639	5.25 ± 1.03 a	2.25 ± 0.25 a	0.75 ± 0.25 a	0.50 ± 0.29 a
0.50L/ha BC 639	6.25 ± 0.85 a	2.50 ± 0.29 a	1.00 ± 0.41 a	0.75 ± 0.25 a
0.25L/ha BC 639	6.25 ± 0.75 a	3.25 ± 0.25 ab	1.75 ± 0.48 a	1.75 ± 0.48 a
62.5ml/ha Fipronil	4.25 ± 0.48 a	2.50 ± 1.50 a	0.75 ± 0.25 a	0.75 ± 0.25 a
Unsprayed (Control)	8.00 ± 0.41 a	5.75 ± 0.48 b	5.25 ± 0.48 b	5.50 ± 0.87 b
Sig. level	$P>0.03$	$P<0.02$	$P<0.0001$	$P<0.0001$

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Conclusion

Application of BC 639 to Bollgard cotton crops controlled green mirids, green vegetable bugs and apple dimpling bugs similar to Fipronil, a commercial insecticide used by the cotton industry to manage these pests. Application of 0.25L/ha BC 639, however, did not control green vegetable bugs.

4.8 Trials at Getta Getta in Goondiwindi – 2007-08

4.8.1 Efficacy of different rates of BC 639 on oviposition of *Helicoverpa* spp. and the survival of green mirids, beneficial insects and non-target arthropods on commercial cotton crops

4.8.1.1 Efficacy of different rates of BC 639 on oviposition of *Helicoverpa* spp.

The number of *Helicoverpa* spp. eggs per metre recorded on plots treated with 1.0L/ha and 0.50L/ha of BC 639 were significantly lower ($P<0.003$) than the unsprayed (control) plots at 7 and 14 DAT (Table 4.8.1.1.1). No significant difference in the number of eggs per metre was recorded on plots treated with 0.25L/ha BC 639 and recommended rate of Fipronil and the 1.0 and 0.50 BC 639 treated plots (Table 4.8.1.1.1). However, the number of eggs recorded on the 0.25L/ha BC 639 and Fipronil treated plots were not significantly different ($P>0.05$) from the unsprayed plots exception was 0.25L/ha BC 639 at 14 DAT (Table 4.8.1.1.1). Overall, about 4 times less eggs were recorded on the fungus treated plots than the unsprayed plots (Table 4.8.1.1.1).

Table 4.8.1.1.1. Efficacy of different rates of BC639 fungal insecticides on the number of *Helicoverpa* spp. eggs per metre on commercial cotton crops at Getta Getta in Goondiwindi, 2007-08.

Treatments	Pre-spray counts 14/1/08	3 DAT	7 DAT	14 DAT
1 L/ha BC 639	10.00 ± 2.65 a	6.00 ± 0.58 a	2.33 ± 0.67 a	1.00 ± 0.58 a
500ml/ha BC 639	3.67 ± 1.76 a	3.33 ± 1.86 a	4.33 ± 0.88 a	0.67 ± 0.33 a
250ml/ha BC 639	4.67 ± 0.88 a	6.33 ± 0.67 a	5.33 ± 0.88ab	2.33 ± 0.33 a
62.5ml/ha Fipronil	5.33 ± 0.33 a	6.67 ± 0.88 a	6.33 ± 0.33ab	3.00 ± 0.58 ab
Unsprayed (Control)	7.00 ± 2.89 a	8.00 ± 1.53 a	8.33 ± 0.33 b	5.33 ± 0.88 b
Significant level	P<0.34	P<0.25	P<0.003	P<0.003

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.8.1.2 Efficacy of different rates of BC 639 on the survival of green mirids

Significantly lower ($P<0.001$) number of green mirids per metre was found on plots treated with different rates of BC 639 fungus and recommended rate of Fipronil insecticide than control (unsprayed) (Tables 4.8.1.2.1 and 4.8.1.2.2). The number of green mirids per metre recorded on plots treated with fungal insecticides and Fipronil was not significantly different ($P>0.05$) throughout the study exception was 250ml/ha BC 639 rate at 7 DAT in spray 1 (Tables 4.8.1.2.1 and 4.8.1.2.2). In the second spray application, application of the fungal insecticides at 250 ml/ha did not cause any significant difference in the number of green mirids per metre at 3 DAT in comparison to the control (Table 4.8.1.2.2). However, significant differences between the 250ml/ha BC 639 rate and the unsprayed plot was detected at 7-21 DAT in the second spray (Table 4.8.1.2.2). Overall, no significant differences were found in the number of green mirids per metre in plots treated with 1.0 and 0.50 L/ha fungus and the recommended Fipronil treated plots (Tables 4.8.1.2.1 and 4.8.1.2.2).

Table 4.8.1.2.1. Efficacy of different rates of BC639 fungal insecticides on the number of *Creontiades dilutus* (Green mirids) per metre on commercial cotton crops at Getta Getta in Goondiwindi, 2007-08 (1st spray).

Treatments	Pre-spray counts 14/1/08	3 DAT	7 DAT	14 DAT
1 L/ha BC 639	2.67 ± 0.33 a	0.33 ± 0.33 a	0.00 ± 0.00 a	1.00 ± 0.58 a
500ml/ha BC 639	3.00 ± 0.58 a	0.33 ± 0.33 a	0.33 ± 0.33 a	1.00 ± 0.58 a
250ml/ha BC 639	2.33 ± 0.88 a	1.00 ± 0.58 ab	1.67 ± 0.33 b	1.00 ± 0.58 a
62.5ml/ha Fipronil	2.00 ± 0.58 a	0.00 ± 0.00 a	0.00 ± 0.00 a	2.00 ± 0.33 ab
Unsprayed (Control)	2.00 ± 0.58 a	3.00 ± 0.58 b	3.33 ± 0.33 c	3.67 ± 0.67 b
Significant level	P<0.59	P<0.01	P<0.0001	P<0.005

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.8.1.2.2. Efficacy of different rates of BC639 and BC667 fungal insecticides on the number of *Creontiades dilutus* (Green mirids) per metre on commercial cotton crops at Getta Getta in Goondiwindi, 2007-08 (2nd spray).

Treatments	Pre- spray counts 4/2/08	3 DAT	7 DAT	14 DAT	21 DAT
1 L/ha BC 639	2.33 ± 0.33 a	0.33 ± 0.33 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a
500ml/ha BC 639	2.00 ± 0.58ab	0.67 ± 0.33 a	0.33 ± 0.33 a	0.00 ± 0.00 a	0.00 ± 0.00 a
250ml/ha BC 639	2.67 ± 0.67ab	1.67 ± 0.33 ab	0.67 ± 0.33 a	0.00 ± 0.00 a	0.67 ± 0.33 a
62.5ml/ha Fipronil	1.67 ± 0.33 a	0.67 ± 0.33 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a
Unsprayed (Control)	3.67 ± 0.33 b	3.00 ± 0.58 b	3.00 ± 0.58 b	3.00 ± 0.58 b	3.00 ± 0.33 b
Sig. level	P<0.15	P<0.002	P<0.001	P<0.0001	P<0.0004

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.8.1.3 Efficacy of different rates of BC 639 on the survival of beneficial insects on commercial cotton

4.8.1.3.1 Efficacy on predatory beetles

The predatory beetles identified from the study plots are given in table 4.3.3. The results showed that application of 1.0, 0.50 and 0.25 L/ha BC 639 to cotton plants was selective against predatory beetles (Tables 4.8.1.3.1.1 and 4.8.1.3.1.2). No significant difference ($P>0.05$) was detected in the number of predatory beetles per metre in plots treated with BC 639 rates and the unsprayed (control) plots (Tables 4.8.1.3.1.1 and 4.8.1.3.1.2).

Table 4.8.1.3.1.1. Efficacy of different rates of BC639 and BC667 fungal insecticides on the number of predatory beetles per metre on commercial cotton crops at Getta Getta in Goondiwindi, 2007-08 (1st spray)

Treatments	Pre-spray counts 14/1/08	3 DAT	7 DAT	14 DAT
1 L/ha BC 639	1.00 ± 0.58 a	0.67 ± 0.33 a	0.67 ± 0.33 a	0.67 ± 0.33 a
500ml/ha BC 639	1.33 ± 0.33 a	1.00 ± 0.33 a	0.67 ± 0.33 a	1.33 ± 0.33 a
250ml/ha BC 639	1.00 ± 0.58 a	0.67 ± 0.33 a	0.67 ± 0.33 a	1.33 ± 0.33 a
62.5ml/ha Fipronil	1.00 ± 0.58 a	0.33 ± 0.33 a	0.00 ± 0.00 a	0.33 ± 0.33 a

Unsprayed (Control)	1.33 ± 0.58 a	1.33 ± 0.33 a	1.33 ± 0.33 a	1.67 ± 0.58 a
Significant difference	P<0.46	P<0.23	P<0.13	P< 0.15

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.8.1.3.1.2. Efficacy of different rates of BC639 and BC667 fungal insecticides on the number of predatory beetles per metre on commercial cotton crops at Getta Getta in Goondiwindi, 2007-08 (2nd spray)

Treatments	Pre- spray counts 4/2/08	3 DAT	7 DAT	14 DAT	21 DAT
1 L/ha BC 639	1.67 ± 0.33 a	1.00 ± 0.58 a	0.67 ± 0.33 a	0.00 ± 0.00 a	0.00 ± 0.00 a
500ml/ha BC 639	1.33 ± 0.33 a	0.67 ± 0.67 a	1.00 ± 0.58 a	0.33 ± 0.33 a	0.33 ± 0.33 a
250ml/ha BC 639	1.33 ± 0.33 a	1.00 ± 0.58 a	1.00 ± 0.58 a	0.33 ± 0.33 a	0.00 ± 0.00 a
62.5ml/ha Fipronil	1.33 ± 0.33 a	0.33 ± 0.33 a	0.33 ± 0.33 a	0.00 ± 0.00 a	0.00 ± 0.00 a
Unsprayed (Control)	1.67 ± 0.33 a	1.67 ± 0.88 a	1.00 ± 0.58 a	0.67 ± 0.33 a	0.33 ± 0.33 a
Sig. level	P<0.90	P<0.69	P<0.76	P<0.23	P<0.46

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.8.1.3.2 Efficacy on predatory bugs

Predatory bugs identified from the study plots are given in table 4.3.3. The number of predatory bugs per metre was the same in plots treated with fungus and the unsprayed plots (Tables 4.8.1.3.2.1 and 4.8.1.3.2.2). Fipronil treated plots consistently recorded lower numbers of predatory bugs but were not significantly different ($P>0.05$) from the fungus and the unsprayed plots (Tables 4.8.1.3.2.1 and 4.8.1.3.2.2).

Table 4.8.1.3.2.1. Efficacy of different rates of BC639 and BC667 fungal insecticides on the number of predatory bugs per metre on commercial cotton crops at Getta Getta in Goondiwindi, 2007-08 (1st spray)

Treatments	Pre-spray counts 14/1/08	3 DAT	7 DAT	14 DAT
1 L/ha BC 639	1.00 ± 0.58 a	0.67 ± 0.33 a	1.33 ± 0.33 a	1.33 ± 0.67 a
500ml/ha BC 639	0.67 ± 0.33 a	0.67 ± 0.67 a	1.67 ± 0.33 a	1.33 ± 0.33 a
250ml/ha BC 639	1.00 ± 0.58 a	1.33 ± 0.33 a	2.33 ± 0.33 a	1.33 ± 0.67 a
62.5ml/ha Fipronil	0.67 ± 0.67 a	0.33 ± 0.33 a	0.33 ± 0.33 a	0.67 ± 0.33 a

Unsprayed (Control)	0.67 ± 0.33 a	1.33 ± 0.33 a	1.33 ± 0.33 a	1.00 ± 0.58 a
Significant level	P<0.74	P<0.40	P<0.04	P<0.98

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.8.1.3.2.2. Efficacy of different rates of BC639 and BC667 fungal insecticides on the number of predatory bugs per metre on commercial cotton crops at Getta Getta in Goondiwindi, 2007-08 (2nd spray)

Treatments	Pre- spray counts 4/2/08	3 DAT	7 DAT	14 DAT	21 DAT
1 L/ha BC 639	1.33 ± 0.67 a	2.33 ± 0.88 a	0.67 ± 0.33 a	0.67 ± 0.33 a	0.33 ± 0.33 a
500ml/ha BC 639	1.33 ± 0.33 a	2.33 ± 0.88 a	0.67 ± 0.33 a	1.00 ± 0.58 a	0.33 ± 0.33 a
250ml/ha BC 639	1.33 ± 0.33 a	2.67 ± 0.67 a	0.67 ± 0.58 a	1.33 ± 0.33 a	0.67 ± 0.33 a
62.5ml/ha Fipronil	1.33 ± 0.33 a	2.00 ± 0.58 a	1.00 ± 0.58 a	0.33 ± 0.33 a	0.67 ± 0.33 a
Unsprayed (Control)	1.00 ± 0.58 a	2.33 ± 0.88 a	1.00 ± 0.58 a	1.33 ± 0.33 a	0.67 ± 0.33 a
Sig. level	P<0.94	P<0.98	P<0.96	P<0.28	P<0.85

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.8.1.3.3 Efficacy on predatory lacewings

The predominant predatory lacewings identified from the study plots were *Chrysopa* spp. and *Micromus tasmaniae* (Table 4.3.3). In the first spray application, plots treated with 1L/ha BC 639 and recommended rate of Fipronil had the lowest number of predatory lacewings per metre at 3, 7 and 14 DAT but the differences were not significantly different from 500 and 250ml/ha BC 639 and the unsprayed except at 3 DAT (Table 4.8.1.3.3.1). In contrast, plots treated with 500 and 250 ml/ha BC 639 had the same number of predatory lacewings as the unsprayed plots (Tables 4.8.1.3.3.1 and 4.8.1.3.3.2). In the second spray application, no significant differences in the number of predatory lacewings per metre were detected among plots treated with fungus and the unsprayed plots (Table 4.8.1.3.3.2).

Table 4.8.1.3.3.1. Efficacy of different rates of BC639 and BC667 fungal insecticides on the number of predatory lacewings per metre on commercial cotton crops at Getta Getta in Goondiwindi, 2007-08 (1st spray)

Treatments	Pre-spray counts 14/1/08	3 DAT	7 DAT	14 DAT
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1 L/ha BC 639	0.67 ± 0.33 a	0.33 ± 0.33 ab	0.33 ± 0.33 a	0.67 ± 0.33 a
500ml/ha BC 639	0.33 ± 0.33 a	1.67 ± 0.33 a	1.00 ± 0.58 a	1.33 ± 0.33 a
250ml/ha BC 639	0.33 ± 0.33 a	1.67 ± 0.33 a	1.33 ± 0.33 a	1.33 ± 0.33 a
62.5ml/ha Fipronil	0.67 ± 0.58 a	0.00 ± 0.00 b	0.33 ± 0.33 a	0.33 ± 0.33 a
Unsprayed (Control)	1.00 ± 0.58 a	1.67 ± 0.33 a	1.00 ± 0.58 a	1.67 ± 0.33 a
Significant level	P<0.23	P<0.01	P<0.19	P<0.09

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.8.1.3.3.2. Efficacy of different rates of BC639 and BC667 fungal insecticides on the number of predatory lacewings per metre on commercial cotton crops at Getta Getta in Goondiwindi, 2007-08 (2nd spray)

Treatments	Pre- spray counts 4/2/08	3 DAT	7 DAT	14 DAT	21 DAT
1 L/ha BC 639	0.67 ± 0.33 a	0.33 ± 0.33 a	1.00 ± 0.58 a	1.00 ± 0.58 a	0.67 ± 0.33 a
500ml/ha BC 639	1.33 ± 0.33 a	0.33 ± 0.33 a	1.67 ± 0.33 a	1.67 ± 0.88 a	2.00 ± 1.00 a
250ml/ha BC 639	1.33 ± 0.67 a	0.67 ± 0.33 a	1.67 ± 0.67 a	1.67 ± 0.33 a	1.67 ± 0.33 a
62.5ml/ha Fipronil	0.33 ± 0.33 a	0.00 ± 0.00 a	0.33 ± 0.33 a	1.00 ± 0.58 a	1.33 ± 0.33 a
Unsprayed (Control)	1.67 ± 0.67 a	1.00 ± 0.58 a	1.67 ± 0.58 a	1.67 ± 0.33 a	1.33 ± 0.33 a
Sig. level	P<0.17	P<0.14	P<0.35	P<0.63	P<0.39

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.8.1.3.4 bEfficacy on predatory spiders

Spiders identified from the study plots were *Lycosa* spp., *Oxyopes* spp., *Salticidae* spp., *Araneus* spp. (Table 4.3.3). Spiders numbers per metre were consistently the same in all the fungus treated and control (unsprayed) plots throughout the study (Tables 4.8.1.3.4.1 and 4.8.1.3.4.2). However, spider numbers recorded in the Fipronil treated plots was significantly lower ($P<0.01$) at 7 DAT (Table 4.8.1.3.4.1). No significant difference in the number of spiders per metre ($P>0.05$) was detected among treatments after the second treatment application (Table 4.8.1.3.4.2).

Table 4.8.1.3.4.1. Efficacy of different rates of BC639 and BC667 fungal insecticides on the number of spiders per metre on commercial cotton crops at Getta Getta in Goondiwindi, 2007-08 (1st spray)

Treatments	Pre-spray counts	3 DAT	7 DAT	14 DAT
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	14/1/08			
1 L/ha BC 639	3.00 ± 0.58 a	2.00 ± 1.00 a	4.33 ± 0.33 a	3.67 ± 0.33 a
500ml/ha BC 639	1.67 ± 0.67 a	2.33 ± 0.67 a	4.33 ± 0.33 a	2.67 ± 0.88 a
250ml/ha BC 639	2.33 ± 0.67 a	3.33 ± 0.67 a	5.00 ± 0.58 a	3.00 ± 0.58 a
62.5ml/ha Fipronil	3.00 ± 0.58 a	1.33 ± 0.33 a	1.67 ± 0.33 b	2.33 ± 0.88 a
Unsprayed (Control)	1.67 ± 0.33 a	2.00 ± 1.00 a	5.00 ± 0.58 a	3.00 ± 0.58 a
Significant level	P<0.41	P<0.60	P<0.01	P<0.75

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.8.1.3.4.2. Efficacy of different rates of BC639 and BC667 fungal insecticides on the number of spiders per metre on commercial cotton crops at Getta Getta in Goondiwindi, 2007-08 (2nd spray)

Treatments	Pre- spray counts	3 DAT	7 DAT	14 DAT	21 DAT
	4/2/08				
1 L/ha BC 639	2.67 ± 0.67 a	2.67 ± 0.33 a	3.33 ± 0.67 a	5.00 ± 1.73 a	4.67 ± 0.33 a
500ml/ha BC 639	3.00 ± 0.58 a	2.67 ± 0.67 a	3.00 ± 0.58 a	4.00 ± 1.16 a	4.00 ± 0.58 a
250ml/ha BC 639	3.67 ± 0.33 a	3.00 ± 1.00 a	2.67 ± 0.33 a	4.33 ± 0.88 a	4.33 ± 0.33 a
62.5ml/ha Fipronil	2.33 ± 0.88 a	2.00 ± 0.58 a	1.33 ± 0.33 a	3.00 ± 0.58 a	4.00 ± 0.58 a
Unsprayed (Control)	3.00 ± 0.58 a	3.33 ± 0.88 a	3.33 ± 0.67 a	5.33 ± 0.33 a	4.67 ± 0.33 a
Sig. level	P<0.69	P<0.82	P<0.20	P<0.45	P<0.57

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.8.1.4 Efficacy of different rates of BC 639 and BC 667 on the survival of other non-target organisms

4.8.1.4.1 Efficacy of different rates of BC 639 and BC 667 on the survival of apple dimpling bug

Significantly lower ($P<0.001$) number of apple dimpling bugs (ADB) per metre were recorded on plots treated with BC 639 fungus compared with the unsprayed plot except 0.25L/ha BC 639 treated plots where ADB numbers per metre were not significantly different ($P>0.05$) from the unsprayed plots at 14 days after the first treatment application (Table 4.8.1.4.1.1 and 4.8.1.4.1.2). No significant difference ($P>0.05$) was detected between plots treated with the BC 639 fungus and Fipronil (Table 4.8.1.4.1.1 and 4.8.1.4.1.2). The number of ADBs in the BC 639 and Fipronil treated plots though were consistently lower than the unsprayed plots, at no time were the insect exterminated by the treatments. Rather, the

numbers continue to build up at 14 DAT (Table 4.8.1.4.1.1 and 4.8.1.4.1.2). Thus, the BC 639 fungus can be used by growers to suppress ADB numbers in cotton crops where high ADB numbers are resulting pin square damage.

Table 4.8.1.4.1.1. Efficacy of different rates of BC639 and BC667 fungal insecticides on the number of *Campylomma liebknechti* (Apple dimpling bug) adults per metre on commercial cotton crops at Getta Getta in Goondiwindi, 2007-08 (1st spray).

Treatments	Pre-spray counts 14/1/08	3 DAT	7 DAT	14 DAT
1 L/ha BC 639	19.67 ± 2.73 a	1.67 ± 0.67 a	1.67 ± 1.53 a	8.00 ± 1.00 a
500ml/ha BC 639	14.00 ± 3.51 a	4.33 ± 1.86 a	2.00 ± 1.00 a	11.67 ± 2.91 a
250ml/ha BC 639	10.33 ± 2.91 a	5.67 ± 0.88 a	2.33 ± 1.53 a	18.67 ± 1.33 ab
62.5ml/ha Fipronil	17.33 ± 2.40 a	1.00 ± 0.58 a	2.00 ± 1.00 a	7.33 ± 1.45 a
Unsprayed (Control)	20.33 ± 3.33 a	15.33 ± 2.67 b	12.33 ± 3.79 b	22.00 ± 5.51 b
Significant level	P<0.22	P<0.001	P<0.001	P<0.01

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

Table 4.8.1.4.1.2. Efficacy of different rates of BC639 and BC667 fungal insecticides on the number of *Campylomma liebknechti* (Apple dimpling bug) adults per metre on commercial cotton crops at Getta Getta in Goondiwindi, 2007-08 (2nd spray).

Treatments	Pre- spray counts 4/2/08	3 DAT	7 DAT	14 DAT	21 DAT
1 L/ha BC 639	11.33 ± 0.67 a	0.67 ± 0.33 a	1.00 ± 0.58 a	3.67 ± 1.20 a	1.33 ± 0.33 a
500ml/ha BC 639	12.33 ± 0.58 a	1.00 ± 0.58 a	1.67 ± 0.33 a	3.67 ± 1.33 a	2.00 ± 0.58 a
250ml/ha BC 639	11.67 ± 0.33 a	2.00 ± 1.00 a	2.33 ± 0.33 a	6.67 ± 0.33 a	3.67 ± 0.88 a
62.5ml/ha Fipronil	10.67 ± 0.88 a	0.33 ± 0.33 a	1.00 ± 0.58 a	4.33 ± 0.33 a	1.67 ± 0.88 a
Unsprayed (Control)	13.00 ± 0.58 a	11.33 ± 1.86b	8.33 ± 0.33 b	14.00 ± 1.16b	9.33 ± 0.67 b
Sig. level	P<0.87	P<0.0001	P<0.0001	P<0.0002	P<0.0004

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

Conclusion

Application of BC 639 reduced the number of *Helicoverpa* spp. eggs on the commercial cotton crops and controlled green mirids and apple dimpling bugs similar to Fipronil, a commercial insecticide used by the cotton industry to manage these pests. In addition, the

BC 639 fungus at all rates of application was found to be more selective to predatory beetles, bugs, lacewings and spiders than the commercial insecticide Fipronil.

4.9 Trials at Australian Cotton Research Institute in Narrabri – 2008-09

4.9.1 Efficacy of different rates of BC 639 on the survival of *Helicoverpa* spp., green mirids, beneficial insects and non-target arthropods on commercial Bollgard cotton crops

4.9.1.1 Efficacy of different rates of BC 639 on survival of *Helicoverpa* spp. eggs

The number of *Helicoverpa* spp. eggs per metre recorded on plots treated with different rates of BC 639 was significantly lower than the unsprayed plots at 3, 7 and 14 DAT exception was the 25ml/ha treated plots which had egg numbers per metre not significantly different from the unsprayed plots at 3 DAT (Table 4.9.1.1.1). The number of *Helicoverpa* spp. eggs per metre recorded on plots treated with Fipronil was consistently higher than the fungus treated plots but the difference was not significant ($P>0.05$) (Table 4.9.1.1.1). Overall, plots treated with BC 639 fungus has lower eggs per metre than the Fipronil and the unsprayed plots (Table 4.9.1.1.1) indicating that BC 639 may be suppressing *Helicoverpa* egg lay on treated plants.

Table 4.9.1.1.1. Efficacy of different rates of BC639 fungal insecticides on the number of *Helicoverpa* spp. eggs per metre on commercial cotton crops at ACRI in Narrabri, 2008-09.

Treatments	Pre-spray counts 8/1/08	3 DAT	7 DAT	14 DAT
750ml/ha BC 639	15.13 ± 1.69 a	6.25 ± 0.96 a	2.75 ± 0.73 a	0.88 ± 0.35 a
500ml/ha BC 639	14.86 ± 1.62 a	7.63 ± 0.53 a	2.13 ± 0.52 a	0.75 ± 0.25 a
250ml/ha BC 639	12.63 ± 1.12 a	7.00 ± 1.00 ab	3.00 ± 0.57 a	1.75 ± 0.53 a
62.5ml/ha Fipronil	14.88 ± 1.33 a	5.63 ± 1.05 a	5.50 ± 0.71a	2.38 ± 0.36 a
Unsprayed (Control)	13.50 ± 1.78 a	11.00 ± 1.02 b	8.13 ± 1.32 b	6.38 ± 0.71 b
Significant level	P<0.63	P<0.006	P<0.0001	P<0.0001

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.9.1.2 Efficacy of different rates of BC 639 on the survival of green mirids

Significantly lower ($P<0.001$) number of green mirids per metre was found on plots treated with different rates of BC 639 and half label rate of Fipronil insecticide than control (unsprayed) (Tables 4.9.1.2.1 and 4.9.1.2.2). At the first spray application, the number of green mirids per metre recorded on plots treated with BC 639 fungus and recommended rate of Fipronil was significantly different ($P<0.0001$) at 3 and 7 DAT but was not significantly different ($P<0.35$) at 14 DAT (Table 4.9.1.2.1).

Table 4.9.1.2.1. Efficacy of different rates of BC639 fungal insecticides on the number of *Creontiades dilutus* (Green mirids) per metre on commercial cotton crops at ACRI in Narrabri, 2008-09 (1st spray)

Treatments	Pre-spray counts	3 DAT	7 DAT	14 DAT
	8/1/09			
750ml/ha BC 639	1.00 ± 0.19 a	1.63 ± 0.26 a	0.50 ± 0.19 a	1.25 ± 0.16 a
500ml/ha BC 639	1.13 ± 0.30 a	1.50 ± 0.27 a	0.63 ± 0.18 a	1.00 ± 0.19 a
250ml/ha BC 639	1.00 ± 0.19 a	1.75 ± 0.31 a	0.75 ± 0.16 a	1.13 ± 0.13 a
62.5ml/ha Fipronil	1.13 ± 0.23 a	0.38 ± 0.18 b	0.38 ± 0.18 a	0.88 ± 0.13 a
Unsprayed (Control)	0.88 ± 0.13 a	2.50 ± 0.27 a	1.25 ± 0.16 b	1.38 ± 0.26 a
Significant level	P<0.86	P<0.0001	P<0.001	P<0.35

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

In the second spray application, plots treated with different rates of BC 639 and Fipronil had significantly lower ($P<0.0001$) numbers of green mirids per metre than the unsprayed plot at 3, 7, 14 and 21 DAT (Table 4.9.1.2.2). No significant differences were found in the number of green mirids per metre recorded in plots treated with the BC 639 and fipronil (Table 4.9.1.2.2) indicating that the BC 639 fungus caused similar efficacy as Fipronil.

Table 4.9.1.2.2. Efficacy of different rates of BC639 fungal insecticides on the number of *Creontiades dilutus* (green mirids) per metre on commercial cotton crops at ACRI in Narrabri, 2008-09 (2nd spray)

Treatments	Pre-spray counts	3 DAT	7 DAT	14 DAT	21 DAT
	22/1/09				
750ml/ha BC 639	1.25 ± 0.16 a	0.38 ± 0.18 a	0.25 ± 0.19 a	0.00 ± 0.00 a	0.00 ± 0.00 a
500ml/ha BC 639	1.00 ± 0.19 a	0.25 ± 0.16 a	0.38 ± 0.18 a	0.13 ± 0.13 a	0.00 ± 0.00 a
250ml/ha BC 639	1.13 ± 0.13 a	0.63 ± 0.18 a	0.50 ± 0.16 a	0.13 ± 0.13 a	0.13 ± 0.13 a
62.5ml/ha Fipronil	0.88 ± 0.13 a	0.13 ± 0.13 a	0.13 ± 0.18 a	0.13 ± 0.13 a	0.00 ± 0.00 a
Unsprayed (Control)	1.38 ± 0.26 a	1.25 ± 0.16 b	1.13 ± 0.16 b	0.75 ± 0.25 b	0.63 ± 0.18 b
Sig. level	P<0.35	P<0.0001	P<0.001	P<0.001	P<0.001

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.9.1.3 Efficacy of different rates of BC 639 on the survival of *Campylomma liebknechti* (Apple dimpling bug)

In the first spray application, the number of apple dimpling bugs per metre recorded on plots treated with BC 639 fungus was not significantly different from fipronil treated plots at 3, 7 and 14 DAT exception was plots treated with 250ml/ha BC 639 at 3 DAT (Table 4.9.1.3.1). Plots treated with BC 639 fungus had fewer apple dimple bugs than the unsprayed plots indicating that higher rates of BC 639 fungus controls apple dimpling bugs (Table 4.9.1.3.1).

Similar results were achieved in the second spray application (Table 4.9.1.3.2). The number of apple dimpling bugs on plots treated with different rates of BC 639 and Fipronil insecticide were significantly lower than the unsprayed plots, exception was plots treated with 250ml/ha BC 639 which was not different at 3DAT (Table 4.9.1.3.2). The number of apple dimpling bugs per metre on plots treated with varying rates of BC 639 was the same as Fipronil treated plots (Table 4.9.1.3.2)

Table 4.9.1.3.1. Efficacy of different rates of BC639 fungal insecticides on the number of *Campylomma liebknechti* (Apple dimpling bug) per metre on commercial cotton crops at ACRI in Narrabri, 2008-09 (1st spray)

Treatments	Pre-spray counts 8/1/09	3 DAT	7 DAT	14 DAT
750ml/ha BC 639	9.50 ± 1.36 a	3.75 ± 0.59 a	1.88 ± 0.35 a	7.63 ± 0.16 a
500ml/ha BC 639	9.00 ± 1.17 a	3.50 ± 0.73 a	1.25 ± 0.31 a	5.75 ± 0.19 a
250ml/ha BC 639	6.75 ± 1.11 a	7.00 ± 0.91 b	3.13 ± 0.58 a	7.88 ± 0.13 a
62.5ml/ha Fipronil	7.63 ± 0.98 a	1.25 ± 0.41 a	0.50 ± 0.19 a	5.38 ± 0.13 a
Unsprayed (Control)	6.38 ± 1.27 a	7.38 ± 0.82 b	5.63 ± 0.82 b	11.75 ± 0.26 b
Significant level	P<0.27	P<0.001	P<0.0001	P<0.0001

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

Table 4.9.1.3.2. Efficacy of different rates of BC639 fungal insecticides on the number of *Campylomma liebknechti* (Apple dimpling bug) per metre on commercial cotton crops at ACRI in Narrabri, 2008-09 (2nd spray)

Treatments	Pre-spray counts 22/1/09	3 DAT	7 DAT	14 DAT	21 DAT
750ml/ha BC 639	7.63 ± 0.16 a	5.13 ± 0.79 a	2.88 ± 0.23 a	1.38 ± 0.32 a	0.50 ± 0.19 a
500ml/ha BC 639	5.75 ± 0.19 a	5.00 ± 0.76 a	2.75 ± 0.25 a	2.13 ± 0.48 a	1.25 ± 0.41 a

250ml/ha BC 639	7.88 ± 0.13 a	6.75 ± 0.45 a	4.38 ± 0.38ab	2.38 ± 0.46 a	1.75 ± 0.31 a
62.5ml/ha Fipronil	5.38 ± 0.13 a	0.75 ± 0.25 b	1.63 ± 0.32 a	1.38 ± 0.26 a	0.75 ± 0.16 a
Unsprayed (Control)	11.75 ± 0.26b	7.13 ± 0.55 a	5.13 ± 1.06 b	4.63 ± 0.76 b	4.00 ± 0.46 b
Sig. level	P<0.0001	P<0.001	P<0.001	P<0.0004	P<0.001

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.9.1.4 Efficacy of different rates of BC 639 and BC 667 on the survival of beneficial insects on commercial cotton

4.9.1.4.1 Efficacy on predatory beetles

The predatory beetles identified from the study plots are given in Table 4.3.3. The results showed that application of 0.75, 0.50 and 0.25 L/ha BC 639 to cotton plants was selective against predatory beetles (Tables 4.9.1.4.1.1 and 4.9.1.4.1.2). No significant difference ($P>0.05$) in the number of predatory beetles per metre was detected among BC 639 treated and control (unsprayed) plots after the first and second spray applications (Tables 4.9.1.4.1.1 and 4.9.1.4.1.2). Plots treated with Fipronil consistently had lower number of predatory beetles per metre throughout the study but this was not significantly different from the BC 639 and unsprayed plots after the first spray application (Table 4.9.1.4.1.1). However, after the second spray application, the number of predatory beetles per metre recorded on the Fipronil treated plots was significantly lower at 3 and 7 DAT (Table 4.9.1.4.1.2).

Table 4.9.1.4.1.1. Efficacy of different rates of BC639 fungal insecticides on the number of predatory beetles per metre on commercial cotton crops at ACRI in Narrabri, 2008-09 (1st spray)

Treatments	Pre-spray counts 8/1/09	3 DAT	7 DAT	14 DAT
750ml/ha BC 639	3.13 ± 0.67 a	3.00 ± 0.48 a	1.88 ± 0.48 a	1.75 ± 0.45 a
500ml/ha BC 639	3.13 ± 0.35 a	3.75 ± 0.65 a	1.63 ± 0.32 a	2.38 ± 0.60 a
250ml/ha BC 639	2.50 ± 0.33 a	3.50 ± 0.63 a	2.50 ± 0.50 a	2.13 ± 0.30 a
62.5ml/ha Fipronil	3.25 ± 0.49 a	2.88 ± 0.52 a	1.63 ± 0.50 a	2.25 ± 0.49 a
Unsprayed (Control)	4.00 ± 0.63 a	4.00 ± 0.33 a	2.13 ± 0.40 a	3.88 ± 0.79 a
Significant level	P>0.35	P>0.56	P>0.47	P>0.07

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.9.1.4.1.2. Efficacy of different rates of BC639 fungal insecticides on the number of predatory beetles per metre on commercial cotton crops at ACRI in Narrabri, 2008-09 (2nd spray)

Treatments	Pre-spray counts 22/1/09	3 DAT	7 DAT	14 DAT	21 DAT
750ml/ha BC 639	1.75 ± 0.45 a	3.00 ± 0.42 a	2.88 ± 0.52 a	2.38 ± 0.65 a	2.25 ± 0.31 a
500ml/ha BC 639	2.38 ± 0.60 a	3.13 ± 0.40 a	3.00 ± 0.27 a	3.50 ± 0.82 a	2.20 ± 0.30 a
250ml/ha BC 639	2.13 ± 0.30 a	3.13 ± 0.52 a	3.50 ± 0.38 a	2.88 ± 0.77 a	2.70 ± 0.33 a
62.5ml/ha Fipronil	2.25 ± 0.49 a	1.00 ± 0.19 b	1.50 ± 0.42 b	1.88 ± 0.52 a	1.45 ± 0.26 a
Unsprayed (Control)	3.88 ± 0.79 a	3.13 ± 0.40 a	3.13 ± 0.44 a	3.88 ± 0.30 a	2.00 ± 0.19 a
Sig. level	P>0.07	P<0.002	P<0.01	P>0.14	P>0.09

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

3.9.1.4.2 Efficacy on predatory bugs

Predatory bugs identified from the study plots are given in Table 4.3.3. No significant difference ($P>0.05$) in the number of predatory bugs per metre was found on plots treated with BC 639, Fipronil and the control after two treatment applications (Tables 4.9.1.4.2.1 and 4.9.1.4.2.2).

Table 4.9.1.4.2.1. Efficacy of different rates of BC639 fungal insecticides on the number of predatory bugs per metre on commercial cotton crops at ACRI in Narrabri, 2008-09 (1st spray)

Treatments	Pre-spray counts 8/1/09	3 DAT	7 DAT	14 DAT
750ml/ha BC 639	0.38 ± 0.18 a	0.63 ± 0.18 a	0.63 ± 0.18 a	2.63 ± 0.50 a
500ml/ha BC 639	0.00 ± 0.00 a	0.38 ± 0.18 a	0.75 ± 0.16 a	3.63 ± 0.42 a
250ml/ha BC 639	0.00 ± 0.00 a	0.50 ± 0.19 a	0.63 ± 0.18 a	2.75 ± 0.68 a
62.5ml/ha Fipronil	0.00 ± 0.00 a	0.25 ± 0.16 a	0.38 ± 0.18 a	3.88 ± 0.72 a
Unsprayed (Control)	0.25 ± 0.16 a	0.38 ± 0.18 a	0.63 ± 0.18 a	2.13 ± 0.44 a
Significant level	P>0.03	P>0.22	P>0.26	P>0.07

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.9.1.4.2.2. Efficacy of different rates of BC639 fungal insecticides on the number of predatory bugs per metre on commercial cotton crops at ACRI in Narrabri, 2008-09 (2nd spray)

Treatments	Pre-spray counts 22/1/09	3 DAT	7 DAT	14 DAT	21 DAT
750ml/ha BC 639	2.63 ± 0.50 a	1.88 ± 0.55 a	1.63 ± 0.26 a	1.50 ± 0.19 a	0.75 ± 0.16 a
500ml/ha BC 639	3.63 ± 0.42 a	2.75 ± 0.41 a	1.25 ± 0.25 a	2.25 ± 0.16 a	1.25 ± 0.31 a
250ml/ha BC 639	2.75 ± 0.68 a	1.63 ± 0.46 a	1.13 ± 0.30 a	2.00 ± 0.42 a	1.00 ± 0.27 a
62.5ml/ha Fipronil	3.88 ± 0.72 a	2.63 ± 0.32 b	1.38 ± 0.32 a	1.38 ± 0.26 a	0.75 ± 0.16 a
Unsprayed (Control)	2.13 ± 0.44 a	2.00 ± 0.54 a	1.38 ± 0.26 a	1.50 ± 0.19 a	1.00 ± 0.19 a
Sig. level	$P>0.07$	$P>0.32$	$P>0.80$	$P>0.14$	$P>0.08$

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

4.9.1.4.3 Efficacy on predatory lacewings

The predominant predatory lacewings identified from the study plots were *Chrysopa* spp. and *Micromus tasmaniae* (Table 4.3.3). Plots treated with BC 639 had the same number of predatory lacewings as plots treated with recommended rate of Fipronil at 3 to 14 DAT (Table 4.9.1.4.3.1). However, the number of predatory lacewings recorded on the BC 639 treated plots were not significantly different ($P>0.05$) from the unsprayed plots (Table 4.9.1.4.3.1). In contrast, plots treated with Fipronil had fewer ($P<0.03$) number of predatory lacewings than the unsprayed plots (Tables 4.9.1.4.3.1). In the second spray application, no significant differences in the number of predatory lacewings per metre were detected among plots treated with fungus and the unsprayed plots (Table 4.9.1.4.3.2). In contrast, plots treated with fipronil had fewer lacewings per metre than both BC 639 and unsprayed plots (Table 4.9.1.4.3.2) indicating that BC 639 is more selective against predatory lacewings than Fipronil.

Table 4.9.1.4.3.1. Efficacy of different rates of BC639 fungal insecticides on the number of predatory lacewings per metre on commercial cotton crops at ACRI in Narrabri, 2008-09 (1st spray)

Treatments	Pre-spray counts	3 DAT	7 DAT	14 DAT (22/1/09)
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	8/1/09				
750ml/ha BC 639	1.13 ± 0.40 a	2.50 ± 0.57 ab	3.25 ± 0.68 a	1.50 ± 0.38 ab	
500ml/ha BC 639	1.38 ± 0.32 a	2.00 ± 0.33 ab	2.75 ± 0.71 a	2.13 ± 0.58 ab	
250ml/ha BC 639	1.38 ± 0.26 a	3.00 ± 0.91 ab	2.50 ± 0.50 a	3.38 ± 0.71 ab	
62.5ml/ha Fipronil	1.25 ± 0.16 a	0.88 ± 0.30 b	2.50 ± 0.66 a	1.00 ± 0.42 b	
Unsprayed (Control)	1.63 ± 0.38 a	3.88 ± 0.64 a	3.00 ± 0.63 a	3.50 ± 0.68 a	
Significant level	P>0.81	P<0.03	P>0.92	P<0.02	

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

Table 4.9.1.4.3.2. Efficacy of different rates of BC639 fungal insecticides on the number of predatory lacewings per metre on commercial cotton crops at ACRI in Narrabri, 2008-09 (2nd spray)

Treatments	Pre-spray counts 22/1/09	3 DAT	7 DAT	14 DAT	21 DAT
750ml/ha BC 639	1.50 ± 0.38ab	3.63 ± 0.57 a	3.38 ± 0.42 a	1.75 ± 0.31 a	1.38 ± 0.32 a
500ml/ha BC 639	2.13 ± 0.58ab	4.13 ± 0.48 a	3.13 ± 0.69 a	1.75 ± 0.25 a	1.63 ± 0.38 a
250ml/ha BC 639	3.38 ± 0.71ab	3.75 ± 0.62 a	3.38 ± 0.38 a	2.00 ± 0.63 a	1.75 ± 0.16 a
62.5ml/ha Fipronil	1.00 ± 0.42 b	1.75 ± 0.45 b	1.63 ± 0.38 b	0.75 ± 0.31 b	0.75 ± 0.25 b
Unsprayed (Control)	3.50 ± 0.68 a	4.13 ± 0.48 a	3.75 ± 0.41 a	2.63 ± 0.53 a	1.88 ± 0.55 a
Sig. level	P<0.02	P<0.03	P<0.03	P<0.01	P>0.26

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

4.9.1.4.4 Efficacy on predatory spiders

Spiders identified from the study plots were *Lycosa* spp., *Oxyopes* spp., *Salticidae* spp., *Araneus* spp. (Table 4.3.3). Spiders numbers per metre were consistently the same in all the BC 639 fungus treated and control (unsprayed) plots throughout the study (Tables 4.9.1.4.4.1 and 4.9.1.4.4.2). The number of spiders per metre recorded on plots treated with Fipronil was also the same as the BC 639 treated and the unsprayed plots indicating that none of the treatments had any significant effect on spiders (Tables 4.9.1.4.4.1 and 4.9.1.4.4.2).

Table 4.9.1.4.4.1. Efficacy of different rates of BC639 fungal insecticides on the number of spiders per metre on commercial cotton crops at ACRI in Narrabri, 2008-09 (1st spray)

Treatments	Pre-spray counts 8/1/09	3 DAT	7 DAT	14 DAT (22/1/09)
750ml/ha BC 639	3.00 ± 0.38 a	5.88 ± 0.52 a	2.88 ± 0.40 a	4.00 ± 0.63 a
500ml/ha BC 639	2.63 ± 0.42 a	4.63 ± 0.50 a	2.50 ± 0.42 a	3.63 ± 0.73 a
250ml/ha BC 639	2.50 ± 0.38 a	4.88 ± 0.69 a	2.75 ± 0.53 a	5.13 ± 0.64 a
62.5ml/ha Fipronil	3.00 ± 0.71 a	3.25 ± 0.45 a	2.50 ± 0.42 a	3.13 ± 0.69 a
Unsprayed (Control)	4.00 ± 0.60 a	4.63 ± 0.98 a	2.63 ± 0.26 a	4.38 ± 0.96 a
Significant level	P>0.27	P>0.10	P>0.96	P>0.05

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

Table 4.9.1.4.4.2. Efficacy of different rates of BC639 fungal insecticides on the number of spiders per metre on commercial cotton crops at ACRI in Narrabri, 2008-09 (2nd spray)

Treatments	Pre-spray counts 22/1/09	3 DAT	7 DAT	14 DAT	21 DAT
750ml/ha BC 639	4.00 ± 0.63ab	3.25 ± 0.80 a	4.00 ± 0.50 a	4.00 ± 0.85 a	7.50 ± 1.57 a
500ml/ha BC 639	3.63 ± 0.73ab	2.75 ± 0.41 a	4.88 ± 0.69 a	4.63 ± 0.82 a	6.50 ± 1.32 a
250ml/ha BC 639	5.13 ± 0.64 a	4.13 ± 0.85 a	5.63 ± 1.74 a	5.38 ± 0.63 a	10.25 ± 0.56 a
62.5ml/ha Fipronil	3.13 ± 0.69 b	4.38 ± 0.32 a	3.63 ± 0.82 a	5.00 ± 0.63 a	9.75 ± 0.68 a
Unsprayed (Control)	4.38 ± 0.96 a	5.00 ± 0.87 a	4.63 ± 0.91 a	4.63 ± 0.65 a	10.75 ± 1.05 a
Sig. level	P>0.05	P>0.09	P>0.59	P>0.79	P>0.08

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

Conclusion

Application of BC 6 39 reduced the number of *Helicoverpa* spp. eggs on the commercial cotton crops and controlled green mirids and apple dimpling bugs similar to Fipronil. In addition, the BC 639 fungus at all rates of application was found to be more selective to predatory beetles, bugs, lacewings and spiders than the commercial insecticide Fipronil

4.10 BC 639 Aerial application trials at Mirrabooka in Narrabri, 2008-09

4.10.1 Efficacy of aerial application of BC 639 on the survival of green mirids and beneficial insects on commercial Bollgard cotton crops, 2008-09

4.10.1.1 Efficacy against green mirids

Significantly lower ($P < 0.001$) number of green mirids per metre was found on plots treated with 500ml/ha BC 639 and Fipronil insecticide than control (unsprayed) (Table 4.10.1.1.1). At the first spray application, the number of green mirids per metre recorded on plots treated with BC 639 and Fipronil was significantly different ($P < 0.0003$) at both 3 DAT and ($P < 0.005$) at 7 DAT (Table 4.10.1.1.1). After the second spray application, the number of mirids per metre found on BC 639 plots at 3 and 7 DAT were the same as the Fipronil treated plots and significantly lower than the unsprayed plots at 3 and 7 DAT (Table 4.10.1.1.1).

Table 4.10.1.1.1. Application of BC639 fungal insecticides by aircraft on the survival of green mirids on commercial cotton crops at Mirrabooka in Narrabri, 2008-09

Treatments	Pre-spray counts - 1 st spray 23/1/09	3 DAT	7 DAT (Pre-spray) - 2 nd spray	3 DAT	7 DAT
500ml/ha BC 639	8.50 ± 0.65 a	6.00 ± 0.41 a	7.25 ± 0.48 a	2.00 ± 0.71 a	0.50 ± 0.29 a
62.5ml/ha Fipronil	3.75 ± 0.63 b	1.00 ± 0.41 b	1.25 ± 0.48 b	0.50 ± 1.84 a	0.25 ± 0.25 a
Unsprayed (Control)	5.50 ± 0.65 b	9.00 ± 1.08 c	12.25 ± 2.50c	8.75 ± 0.75 b	8.00 ± 1.23 b
Sig. level	$P < 0.002$	$P < 0.0003$	$P < 0.005$	$P < 0.0001$	$P < 0.0001$

Means between treatments within columns followed by the same letter are not significantly different ($P > 0.05$); Tukey-Kramer multiple comparison test.

4.10.1.2 Efficacy against apple dimpling bugs

No Significant difference in the number of apple dimpling bugs per metre was found on plots treated with BC 639 and the unsprayed plots at 3 DAT (1st spray) and 7 DAT (2nd spray) (Table 4.10.1.2.1). However, the number of apple dimpling bugs per metre was the same on the BC 639 and Fipronil treated plots at 7 DAT (1st spray) and 3 DAT (2nd spray) (Table 4.10.1.2.1). Thus the results showed that BC 639 can be used to suppress apple dimpling bug numbers to prevent cotton pin-head damage at high apple dimpling bug pressure without exterminating them. This is important in cotton crop management because apple dimpling bugs can act as pest and a predator of other cotton pests in a cotton crop.

Table 4.10.1.2.1. Application of BC639 fungal insecticides by aircraft on the survival of apple dimpling bugs on commercial cotton crops at Mirrabooka in Narrabri, 2008-09

Treatments	Pre-spray counts - 1 st spray 23/1/09	3 DAT	7 DAT (Pre-spray) - 2 nd spray	3 DAT	7 DAT
500ml/ha BC 639	6.75 ± 1.38 a	7.75 ± 1.18 a	5.25 ± 0.48 a	6.00 ± 0.82 a	7.50 ± 0.87 a
62.5ml/ha Fipronil	5.25 ± 0.85 a	2.50 ± 0.65 b	2.25 ± 0.94 a	2.50 ± 0.96 a	3.25 ± 0.85 b
Unsprayed (Control)	6.75 ± 0.85 a	12.50 ± 1.19 a	13.00 ± 1.68b	10.50 ± 0.50b	10.50 ± 1.71 a
Sig. level	P>0.65	P<0.004	P<0.001	P<0.002	P<0.02

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

4.10.1.3 Efficacy of aerial application of BC 639 on the survival of beneficial insects on commercial cotton crops

4.10.1.3.1 Efficacy of aerial application against predatory beetles

The predatory beetles identified from the study plots are given in Table 4.3.3. No significant difference in the number of predatory beetles per metre was detected among BC 639 treated and unsprayed plots after the first and second spray applications (Table 4.10.1.3.1.1). The results showed that aerial application of 0.50 L/ha BC 639 to cotton plants was selective against predatory beetles (Tables 4.10.1.3.1.1). The plots treated with Fipronil though had the same number of predatory beetles per metre as BC 639 treated plots, the number of predatory beetles recorded in plots treated with Fipronil was significantly lower (P< 0.005) than the unsprayed plots at 3 DAT but after the second spray application (Table 4.10.1.3.1.1). This indicated that BC 639 was more selective on predatory beetles than Fipronil.

Table 4.10.1.3.1.1. Application of BC639 fungal insecticides by aircraft on the survival of predatory beetles on commercial cotton crops at Mirrabooka in Narrabri, 2008-09

Treatments	Pre-spray counts - 1 st spray 23/1/09	3 DAT	7 DAT (Pre-spray) - 2 nd spray	3 DAT	7 DAT
500ml/ha BC 639	3.25 ± 0.48 a	7.00 ± 1.23 a	9.00 ± 0.58 a	8.00 ± 0.91ab	7.75 ± 0.63 a
62.5ml/ha Fipronil	6.00 ± 1.47 a	6.75 ± 1.11 a	10.25 ± 0.75a	4.75 ± 0.48 a	5.50 ± 1.56 a
Unsprayed	2.75 ± 1.03 a	9.00 ± 1.78 a	10.25	12.00 ±	9.50 ± 1.71 a

(Control)			±0.85a	1.73b	
Sig. level	P>0.24	P>0.59	P>0.49	P<0.005	P>0.70

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

4.10.1.3.2 Efficacy of aerial application against predatory bugs

Predatory bugs identified from the study plots are given in Table 4.3.3. No significant difference (P>0.05) in the number of predatory bugs per metre was found on BC 639 and Fipronil treated and control plots after two treatment applications (Tables 4.10.1.3.2.1).

Table 4.10.1.3.2.1. Application of BC639 fungal insecticides by aircraft on the survival of predatory bugs on commercial cotton crops at Mirrabooka in Narrabri, 2008-09

Treatments	Pre-spray counts - 1 st spray 23/1/09	3 DAT	7 DAT (Pre-spray) - 2 nd spray	3 DAT	7 DAT
500ml/ha BC 639	0.25 ± 0.25 a	1.25 ± 0.25 a	3.50 ± 0.65 a	3.50 ± 0.87 a	2.25 ± 0.63 a
62.5ml/ha Fipronil	0.50 ± 0.29 a	1.25 ± 0.48 a	2.25 ± 0.48 a	1.25 ± 0.48 a	0.75 ± 0.25 a
Unsprayed (Control)	2.75 ± 0.29 a	1.75 ± 0.48 a	4.25 ± 1.60 a	3.75 ± 0.63 a	3.00 ± 0.41 a
Sig. level	P>0.77	P>0.70	P>0.37	P>0.09	P>0.04

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

4.10.1.3.3 Efficacy of aerial application of BC 639 against predatory lacewings

The predominant predatory lacewings identified from the study plots were *Chrysopa* spp. and *Micromus tasmaniae* (Table 4.3.3). Plots treated with BC 639 had the same number of predatory lacewings as plots treated with Fipronil and the unsprayed plots (Table 4.10.1.3.3.1).

Table 4.10.1.3.3.1. Application of BC639 fungal insecticides by aircraft on the survival of predatory lacewings on commercial cotton crops at Mirrabooka in Narrabri, 2008-09

Treatments	Pre-spray counts - 1 st spray 23/1/09	3 DAT	7 DAT (Pre-spray) - 2 nd spray	3 DAT	7 DAT
500ml/ha	0.25 ± 0.25 a	0.75 ± 0.48 a	0.75 ± 0.48	0.50 ± 0.29 a	1.00 ± 0.41 a

BC 639			a		
62.5ml/ha	1.00 ± 0.41 a	0.75 ± 0.48 a	0.75 ± 0.48	0.25 ± 0.25 a	1.25 ± 0.25 a
Fipronil			a		
Unsprayed (Control)	0.75 ± 0.25 a	1.25 ± 0.25 a	1.25 ± 0.25	0.75 ± 0.25 a	0.25 ± 0.25 a
Sig. level	P>0.63	P>0.10	P>0.63	P>0.42	P>0.10

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

4.10.1.3.4 Efficacy of aerial application of BC 639 against spiders

Spiders identified from the study plots were *Lycosa* spp., *Oxyopes* spp., *Salticidae* spp., *Araneus* spp. (Table 4.3.3). Spiders numbers per metre were consistently the same in all the BC 639 treated and control (unsprayed) plots throughout the study (Tables 4.10.1.3.4.1). The number of spiders per metre recorded on plots treated with Fipronil was also the same as the BC 639 treated and the unsprayed plots except at 3 DAT (1st spray) where the number of spiders per metre on the Fipronil treated plots was significantly lower (P<0.001) than both the BC 639 – treated and the unsprayed plots (Tables 4.10.1.3.4.1).

Table 4.10.1.3.4.1. Application of BC639 fungal insecticides by aircraft on the survival of spiders on commercial cotton crops at Mirrabooka in Narrabri, 2008-09

Treatments	Pre-spray counts - 1 st spray 23/1/09	3 DAT	7 DAT (Pre-spray) - 2 nd spray	3 DAT	7 DAT
500ml/ha BC 639	4.00 ± 0.41 a	6.75 ± 0.75 a	5.75 ± 0.85 a	7.75 ± 1.65 a	6.00 ± 0.82 a
62.5ml/ha Fipronil	4.75 ± 1.11 a	3.50 ± 1.04 b	3.75 ± 0.75 a	7.75 ± 1.97 a	3.00 ± 0.58 a
Unsprayed (Control)	3.50 ± 0.29 a	9.00 ± 1.23 a	4.50 ± 0.95 a	8.50 ± 0.87 a	8.25 ± 1.84 a
Sig. level	P>0.46	P<0.001	P>0.32	P>0.94	P>0.09

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

Conclusion

Aerial application of BC 6 39 controlled green mirids and apple dimpling bugs similar to Fipronil. In addition, the BC 639 fungus at all rates of application was found to have no effect and more selective to predatory beetles, bugs, lacewings and spiders than the commercial insecticide Fipronil

4.11 Trials against *Bemisia tabaci* (silverleaf whitefly) at the Australian Cotton Research Institute (ACRI) in Narrabri, 2008- 2009.

4.11.1 Efficacy of BC 639 on the survival of *Bemisia tabaci* (Silverleaf whitefly) on commercial cotton crops at ACRI in Narrabri

The *B. tabaci* strains present in the study site were predominantly the b-biotype. The number of *B. tabaci* adults per leaf recorded on plots treated with BC 639 and unsprayed plots were the same ($P>0.05$) at 3 DAT but were significantly lower on BC 639 treated plots at 7, 14 and 21 DAT (Table 4.11.1.1). At 3 DAT, BC 639 caused 60% mortality of SLW adults (Table 4.11.1.1). Mortality to SLW adults decreased at 7 DAT to 31.2% but increased to 67.2 and 68.8% DAT at 14 and 21 DAT (Table 4.11.1.1).

Similarly, the number of SLW nymphs treated with BC 639 was the same as the unsprayed plot 3 days after treatment (Table 4.11.1.2). However at 7, 14 and 21 DAT, the number of SLW nymphs recorded on BC 639 treated plots were significantly lower ($P<0.0001$) than the unsprayed plots (Table 4.11.1.2). Mortality caused by BC 639 to SLW nymphs increased from 10.5% at 3 DAT to 54.6, 62.3 and 51.7 % at 7, 14 and 21 DAT over the control (Table 4.11.1.2) indicating that BC 639 fungus controlled SLW adults 7 to 21 days after treatment.

Table 4.11.1.1. Effect of BC 639 entomopathogenic fungi on *B. tabaci* adults per leaf on commercial cotton crops at ACRI in Narrabri, 26 February to 19 March 2009.

Treatments	Pre-treatment	3 DAT	7 DAT	14 DAT	21 DAT
	26/2/2009	1/3/2009	5/3/2009	12/3/2009	19/3/2009
0.5L/ha BC 639	3.17 ± 0.24 a	3.97 ± 0.43 a	5.07 ± 0.55 a	5.87 ± 0.61a	3.10 ± 0.40 a
Unsprayed (control)	3.77 ± 0.44 a	9.93 ± 0.84 b	7.37 ± 0.76 b	17.87 ±1.68b	9.93 ± 0.79 b
Level of significance	$P > 0.49$	$P < 0.0001$	$P < 0.005$	$P < 0.0001$	$P < 0.0001$

Means between treatments within columns followed by the same letter are not significantly different ($P>0.05$); Tukey-Kramer multiple comparison test.

Table 4.11.1.2. Effect of BC 639 entomopathogenic fungi on *B. tabaci* nymphs per leaf on commercial cotton crops at ACRI in Narrabri, 26 February to 19 March 2009.

Treatments	Pre-treatment	3 DAT	7 DAT	14 DAT	21 DAT
	26/2/2009	1/3/2009	5/3/2009	12/3/2009	19/3/2009
0.5L/ha BC 639	17.67 ±1.53a	19.80 ±1.93a	9.27 ±1.14a	9.60 ±0.84a	14.53 ±0.93a
Unsprayed	15.60 ±1.64a	22.13 ±2.19a	20.40 ±1.85b	25.47 ±1.96b	30.07 ±4.84b

(control)
 Level of significance of P > 0.16 P > 0.58 P < 0.0001 P < 0.0001 P < 0.001

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

Conclusion

Application of BC 639 at 0.50L/ha was found to control silverleaf whitefly adults and nymphs on commercial cotton crops.

4.12 Trials against *Bemisia tabaci* (silverleaf whitefly) at Merah North in WeeWaa, 2008-2009

4.12.1 Comparison of efficacy of BC 639 entomopathogenic fungi on the survival of *Bemisia tabaci* (silverleaf whitefly) on commercial cotton crops

The *B. tabaci* strains present in the study site predominantly the b-biotype. The mortality of *B. tabaci* adults recorded on plots treated with BC 639 at 3 DAT was 36.9 per cent compared to the unsprayed plot which had 31.6 per cent increase in the number of SLW adults per metre (Table 4.12.1.1). At 7DAT, the mortality caused by BC 639 increased from 36.9 to 76.8 per cent whereas the unsprayed plots had an increase of 31.6 per cent of SLW adults (Table 4.12.1.1). At 14 DAT, BC 639 treated plots recorded 75.0 per cent mortality over the pre-treatment counts compared to the unsprayed plot that had a decline of 4.9 per cent (Table 4.12.1.1). The corrected mortalities of SLW adults caused by BC 639 were 53.6, 77.1 and 74.6 per cent at 3, 7 and 14 DAT respectively (Table 4.12.1.1).

The number of SLW nymphs per metre recorded on plots treated with BC 639 was significantly lower at 3 DAT (P<0.003), 7 DAT (P<0.0001) and 14 DAT (P<0.0001) (Table 4.12.1.2). When the mortalities of SLW nymphs were corrected relative to the control mortalities, BC 639 caused 24, 85.2 and 55.8 per cent mortalities at 3, 7 and 14 DAT respectively (Table 4.12.1.2).

Table 4.12.1.1. Effect of BC 639 entomopathogenic fungi on *B. tabaci* adults per leaf on commercial cotton crops at Merah North near WeeWaa, 24 March to 7 April 2009.

Treatments	Pre-treatment	3 DAT	7 DAT	14 DAT
	24/3/2009	27/3/2009	31/3/2009	7/4/2009
0.5L/ha BC 639	51.20 ± 3.94 a	32.33 ± 4.39 a	11.87 ± 1.32 a	12.80 ± 0.91 a
Unsprayed (control)	52.97 ± 4.53 a	69.70 ± 3.94 b	65.17 ± 2.83 b	50.40 ± 2.57 b
Level of significance	P > 0.90	P < 0.0001	P < 0.0001	P < 0.002

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

Table 4.12.1.2. Effect of BC 639 entomopathogenic fungi on *B. tabaci* nymphs per leaf on commercial cotton crops at Merah North near WeeWaa, 24 March to 7 April 2009.

Treatments	Pre-treatment	3 DAT	7 DAT	14 DAT
	24/3/2009	27/3/2009	31/3/2009	7/4/2009
0.5L/ha BC 639	72.13 ± 2.39 a	52.93 ± 2.64 a	25.00 ± 2.40 a	116.00 ± 5.90 a
Unsprayed (control)	75.83 ± 4.99 a	69.63 ± 4.45 b	169.03 ± 6.98 b	275.03 ± 12.35 b
Level of significance	P > 0.05	P < 0.003	P < 0.0001	P < 0.0001

Means between treatments within columns followed by the same letter are not significantly different ($P > 0.05$); Tukey-Kramer multiple comparison test

4.12.2 Comparison of the efficacy of entomopathogenic fungi (BC 639 and BC 667) and conventional insecticides on the survival of *Bemisia tabaci* (silverleaf whitefly) on commercial cotton crops at Merah north near WeeWaa.

The *B. tabaci* strains present at the study site was predominantly b-biotype. The mortality of *B. tabaci* adults recorded on plots treated with BC 639 was 34.6% at 3 DAT compared with 39.2% in plots treated with Pyriproxyfen. The unsprayed plots recorded an increase of 12.1% (Table 4.12.2.1). At 7 and 14 DAT, the mortalities recorded on the BC 639 treated plots were 29.5 and 54.9% compared to 18.7 and 53.3 % on the Pyriproxyfen treated plots. The unsprayed plots had 35.7% increment in SLW adult numbers at 7 DAT and a decline of 12.1% at 14 DAT (Table 4.12.2.1). The results showed that BC 639 controlled SLW adults similar to the commercial insecticide (Pyriproxyfen).

The mortality of nymphs in plots treated with BC 639 at 3 DAT was 70.5% compared with 3.5% to the slow acting Pyriproxyfen insecticide. The unsprayed plots recorded an increase of 28% of SLW nymphs (Table 4.12.2.2). At 7 and 14 DAT, the BC 639 treated plots recorded 55.6 and 63.7% mortalities in SLW nymphs whereas the pyriproxyfen treated plots had 47.2 and 43.8% mortalities. The unsprayed plot had a decline of 8% at 7DAT due to natural mortalities but had a higher increase of 94.8% of SLW nymphs at 14 DAT (Table 4.12.2.2). The results of the study showed that BC 639 controlled SLW nymphs significantly better than the commercial synthetic insecticide.

Table 4.12.2.1. Efficacy of BC 639 entomopathogenic fungi and conventional insecticides on *B. tabaci* adults per leaf on commercial cotton crops at Merah-North near WeeWaa, 22 March to 5 April 2009.

Treatments	Pre-treatment	3 DAT	7 DAT	14 DAT
	22/3/2009	25/3/2009	29/3/2009	5/4/2009
0.5L/ha BC 639	25.50 ± 1.51 a	16.67 ± 1.60 a (% mortality) (34.6%)	17.97 ± 1.49 a (% mortality) (29.5%)	11.50 ± 1.39 a (% mortality) (54.9%)

0.50 L/ha Pyriproxyfen	25.20 ± 1.52 a	15.33 ± 1.44 a	20.50 ± 1.46 ab	11.77 ± 1.45 a
		(39.2%)	(18.7%)	(53.3%)
Unsprayed (control)	22.30 ± 1.33 a	25.00 ± 1.44 b	30.27 ± 1.56 b	19.60 ± 1.44 b
		(-12.1%)	(-35.7%)	(12.1%)
Level of significance	P > 0.17	P < 0.0001	P < 0.0001	P < 0.0001

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test.

Table 4.12.2.2. Efficacy of BC 639 entomopathogenic fungi and conventional insecticides on *B. tabaci* nymphs per leaf on commercial cotton crops at Merah-North near WeeWaa, 22 March to 5 April 2009.

Treatments	Pre-treatment	3 DAT	7 DAT	14 DAT
	22/3/2009	25/3/2009	29/3/2009	5/4/2009
0.5L/ha BC 639	29.50 ± 1.39 a	8.70 ± 1.37 a	13.70 ± 1.37 a	10.70 ± 1.37 a
		(70.5%)	(55.6%)	(63.7%)
0.50 L/ha Pyriproxyfen	29.77 ± 1.45 a	28.73 ± 1.45 b	15.73 ± 1.45 b	16.73 ± 1.45 b
		(3.5%)	(47.2%)	(43.8%)
Unsprayed (control)	21.60 ± 1.44 b	25.60 ± 1.44 b	19.87 ± 1.45 b	42.07 ± 1.51 c
		(-18.5%)	(8.0%)	(-94.8%) increase
Level of significance	P < 0.0001	P < 0.0001	P < 0.006	P < 0.0001

Means between treatments within columns followed by the same letter are not significantly different (P>0.05); Tukey-Kramer multiple comparison test

Conclusion

Application of 0.50L/ha BC 639 controlled silverleaf whitefly adults and nymphs on commercial cotton crops better than 0.50L/ha Admiral (Pyriproxyfen). Mortality caused by BC 639 to silverleaf whitefly nymphs ranged from 55.6 to 70.5% and that of Admiral from 3.5 to 43.8%.

4.13.0 Trials at Morella in Goondiwindi, 2009-10

4.13.1 Efficacy of BC 639 against green mirids and silverleaf whiteflies on Bollgard cotton crops at Goondiwindi, 2009-10

4.13.1.1 Efficacy against green mirid adults and nymphs

Significantly lower ($P < 0.0001$) green mirid adults and nymphs were found on plots treated with BC 639 and Fipronil than the unsprayed plots (Figures 3.13.1.1.1 and 3.13.1.1.2). No significant differences ($P > 0.05$) were found between BC 639 and Fipronil treated plots indicating that BC 639 controlled the green mirids similar to Fipronil, the commercial insecticides used in the cotton industry to manage green mirids.

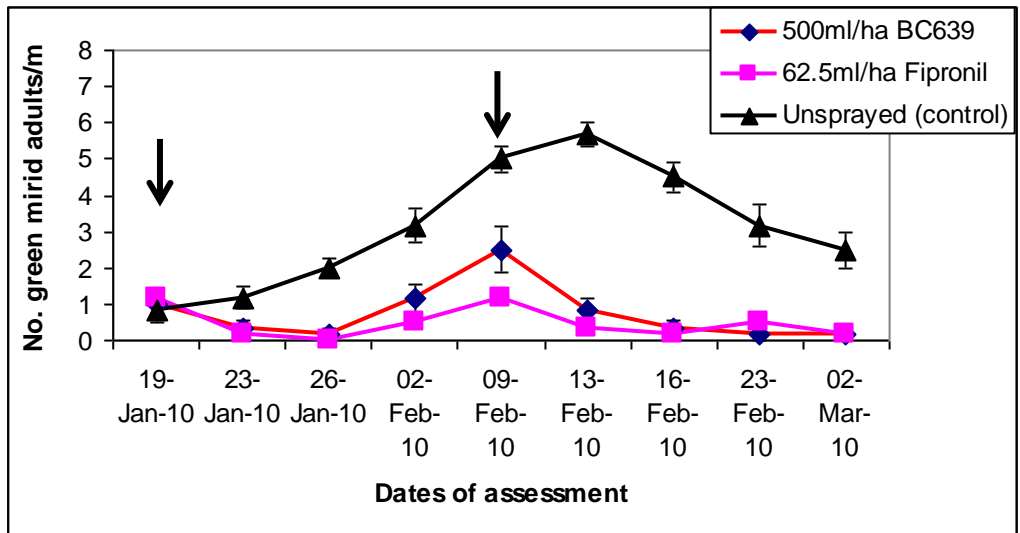


Figure 4.13.1.1.1. Comparison of efficacy of BC 639 entomopathogenic fungi and conventional insecticides against green mirid adults on commercial cotton crops at Goondiwindi 2009-2010.

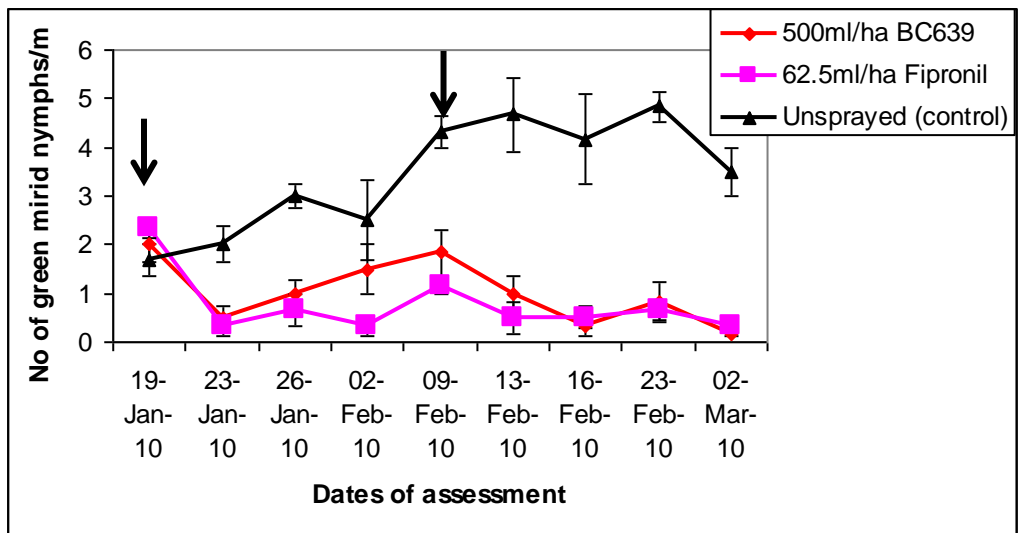


Figure 4.13.1.1.2. Comparison of efficacy of BC 639 entomopathogenic fungi and conventional insecticides against green mirid nymphs on commercial cotton crops at Goondiwindi 2009-2010.

4.13.1.2 Efficacy against silverleaf whitefly adults and nymphs

Application of BC 639 controlled silverleaf whitefly adults significantly better ($P < 0.001$) than Admiral (Pyriproxyfen) 4 to 7 days after the first spray (Figure 3.13.1.2.1). However, the

number of silver leaf whitefly adults per leaf on the BC 639 treated plots increased at 14 DAT and a second spray was applied to both the BC 639 and Admiral plots that reduced the number of silverleaf whitefly adults from 6 to 2 per leaf similar to Admiral treated plots (Figure 3.13.1.2.1). Similar results were achieved when BC 639 was used against silver leaf whitefly nymphs (Figure 3.13.1.2.2). Overall, BC 639 controlled silverleaf whitefly adults similar to Admiral (Pyriproxyfen) the commercial insecticide used to control whiteflies on cotton.

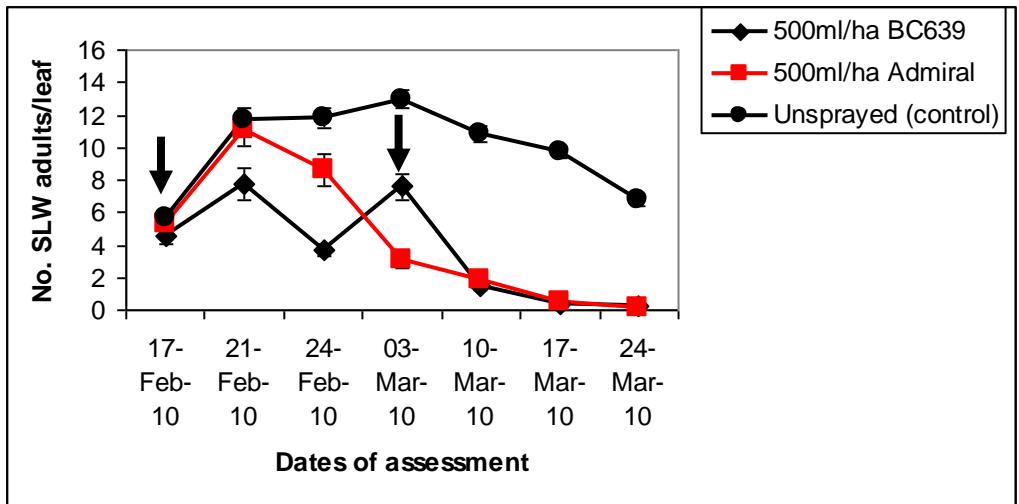


Figure 4.13.1.2.1. Comparison of efficacy of BC 639 entomopathogenic fungi and conventional insecticides against silverleaf whitefly adults on commercial cotton crops at Goondiwindi 2009-2010.

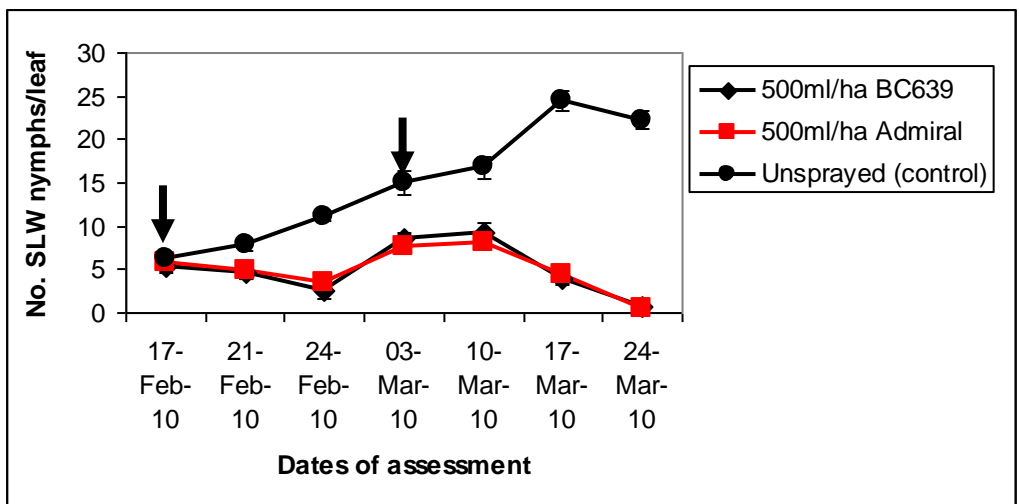


Figure 4.13.1.2.2. Comparison of efficacy of BC 639 entomopathogenic fungi and conventional insecticides against silverleaf whitefly nymphs on commercial cotton crops at Goondiwindi 2009-2010.

Conclusion

Application of 500ml/ha BC 639 controlled green mirids similar to Fipronil. In addition, the application of BC 639 fungus at 500ml/ha controlled silverleaf whitefly adults and nymphs similar to Admiral at 500ml/ha.

3.14.0 Trials at Australian Cotton Research Institute (ACRI) in Narrabri, 2009-10

3.14.1 Efficacy of BC 639 against silverleaf whiteflies on Bollgard cotton crops at ACRI in Narrabri 2009-10

4.14.1.1 Efficacy against silverleaf whitefly adults and nymphs

Trials were conducted at low silverleaf whitefly adults and nymphs pressure. Application of 500, 250 and 125 ml/ha rates of BC 639 fungus controlled silverleaf whitefly adults and nymphs on commercial cotton crops similar to 500 ml/ha Admiral (Pyriproxyfen) commercial insecticide (Figures 4.14.1.1.1 and 4.14.1.1.2). Thus, no significant differences ($P>0.05$) in the number of silverleaf whitefly adults and nymphs were found on plots treated with 125, 250 and 500 ml/ha BC 639 and Admiral (Pyriproxyfen) treated plots (Figures 4.14.1.1.1 and 4.14.1.1.2) indicating that at low SLW pressure BC 639 rate as low as 125 ml/ha can be used to manage whitefly adults and nymphs on commercial cotton crops. In relation to the unsprayed plots, 500ml/ha BC 639 rate caused SLW adult mortalities of 76.4, 80.0 and 81.0 % and SLW nymphs 72.2, 90.8 and 94.3 % at 14, 21 and 28 DAT (Figures 4.14.1.1.1 and 4.14.1.1.2). At 14, 21 and 28 DAT, the 250ml/ha BC 639 rate caused SLW adult mortalities of 68.9, 78.9 and 72.9 and SLW nymphs 67.8, 81.5, 87.7% whereas the 125ml/ha BC 639 rate caused 70.2, 71.7 and 82.6 % (SLW adults) and 70.1, 69.2 and 73.5% (SLW nymphs). In comparison, 500ml/ha Admiral (Pyriproxyfen) caused 87.5, 82.6 and 75.7 % mortality of SLW adults and 73.0, 90.1 and 94.3% mortality of SLW nymphs ((Figures 4.14.1.1.1 and 4.14.1.1.2) indicating no difference in SLW control between the commercial insecticide and BC 639 fungus.

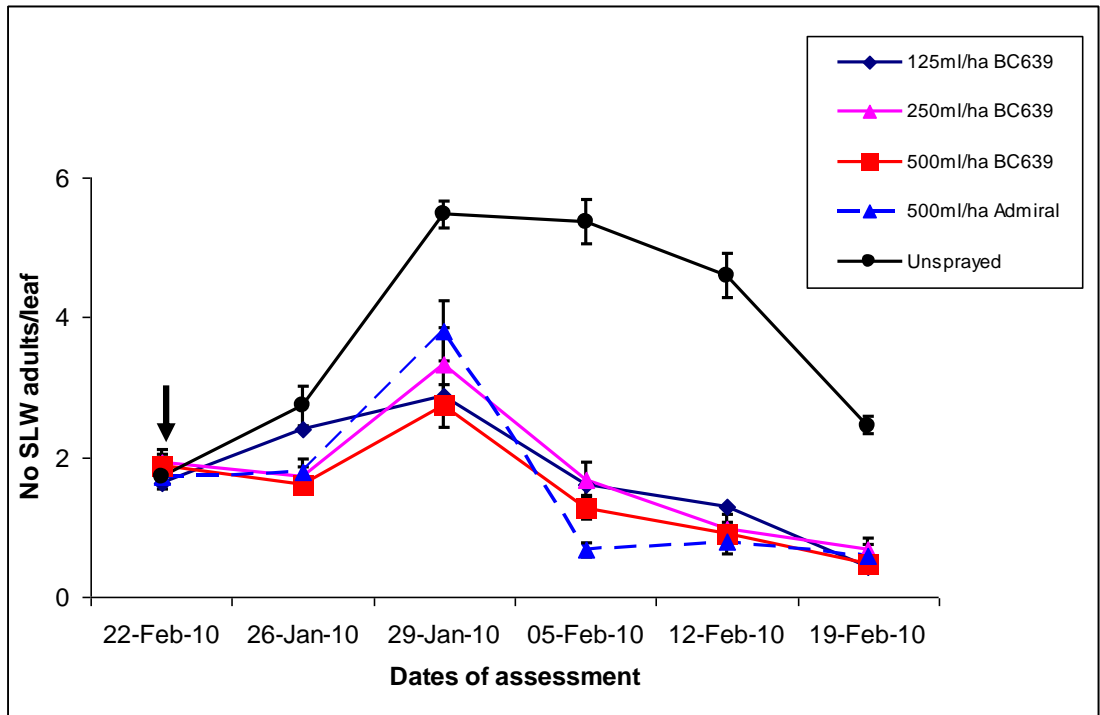


Figure 4.14.1.1.1 Comparison of efficacy of BC 639 entomopathogenic fungi and conventional insecticides against silverleaf whitefly adults on commercial cotton crops at ACRI in Narrabri, 2009-2010.

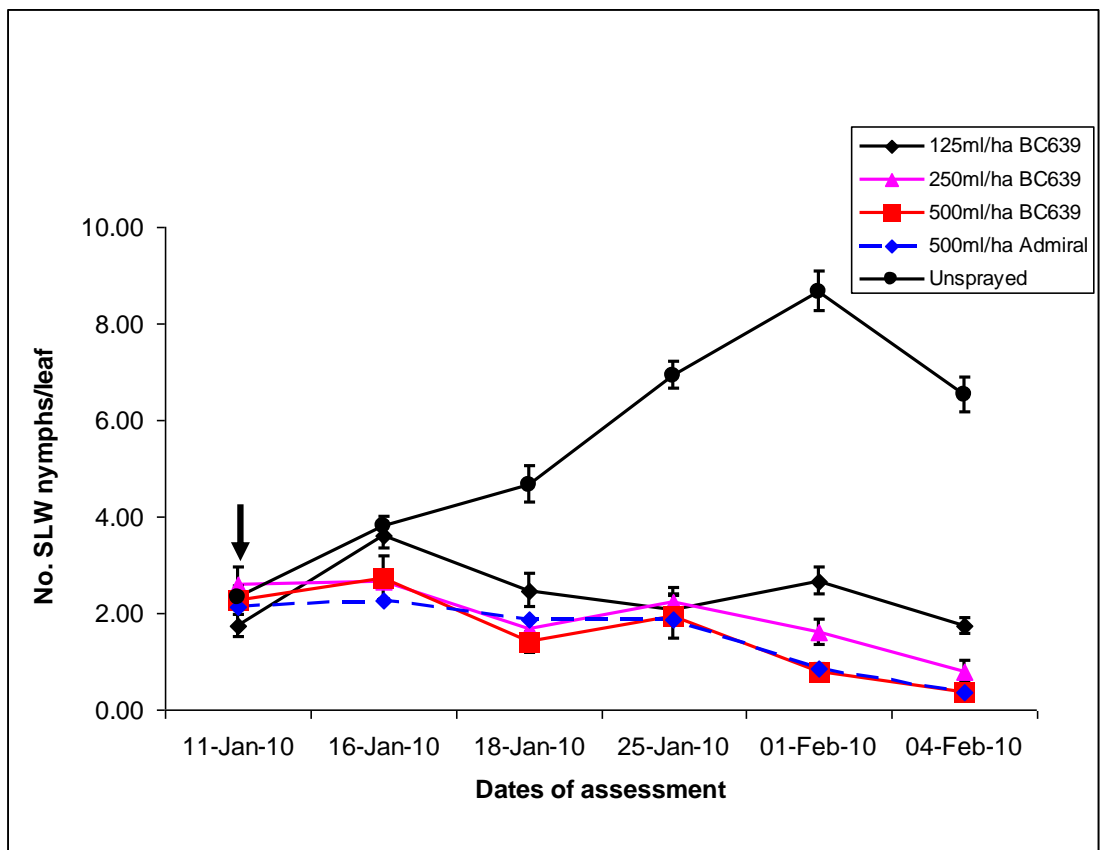




Figure 4.14.1.1.2 Comparison of efficacy of BC 639 entomopathogenic fungi and conventional insecticides against silverleaf whitefly nymphs on commercial cotton crops at ACRI in Narrabri, 2009-2010.

Conclusion

Application of 500, 250 and 125 ml/ha rates of BC 639 fungus controlled silverleaf whitefly adults and nymphs on commercial cotton crops similar to 500 ml/ha Admiral (Pyriproxyfen) commercial insecticide indicating that at low SLW pressure BC 639 rate as low as 125 ml/ha can be used to manage whitefly adults and nymphs on commercial cotton crops. In terms of mortalities relative to the unsprayed (control) treatment, application of 500ml/ha BC 639 can cause SLW adult mortalities ranging from 76.4 to 81.0 % and SLW nymphs 72.2 to 94.3% compared to Admiral 73 to 94.1% (SLW adults) and 73 to 94.3% (SLW nymphs).

Outcomes

5. Describe how the project's outputs will contribute to the planned outcomes identified in the project application. Describe the planned outcomes achieved to date.

The project has developed two entomopathogens (*Beauveria* sp. and *Aspergillus* sp.) for use as biopesticides against Helicoverpa and sucking pests including silverleaf whiteflies in cotton and other agricultural crops. The optimum rate and use pattern of these biopesticides have been identified and documented in the project report. The biopesticides developed in the project, when registered with APVMA can be used as benign alternatives to synthetic insecticides to minimize synthetic insecticide risk to the environment and human health as well as pest resistance. The use of the entomopathogens will enhance IPM in the cotton industry and reduce synthetic insecticide use against sucking pests on both conventional and transgenic cotton crops.

6. Please describe any:-

a) technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.);

The project identified and developed two fungal isolates BC 639 and BC 667 for commercialization in the cotton industry to control green mirids, Helicoverpa and possibly aphids. Each of the 2 products has been formulated in Horticultural oil. Both BC 639 and BC 667 are efficacious against green mirids and *Helicoverpa* spp. Lower rates of 0.25L/ha of BC 667 and BC639 have been tested in this project and found to be efficacious against cotton pests at low pest pressure situations. The optimum rate of 500ml/ha of either BC 639 and BC 667 was efficacious against green mirids and Helicoverpa very small and small larvae. In terms of commercial production and economics, BC 639 was found to produce more spores in culture than BC667. However, there are more regulatory problems associated with the

registration of BC639 than BC667. Hence, research effort has now being focussed back onto BC667 and DAT 511 in a new CRDC project to get the products registered. The commercial partner for the products is still Becker Underwood Pty Ltd. In the new project DAN1101C, Becker Underwood Pty Ltd has decided to undertake spore manufacturing role with a commercialization role to be given to a new commercial partner to be identified.

b) other information developed from research (eg discoveries in methodology, equipment design, etc.); and

New skills to improve viability and vigour into fungal isolates have been developed in the project. These skills will be passed on to junior scientists who may be employed to understudy Dr Mensah in the IPM program.

c) required changes to the Intellectual Property register.

CRDC project DAN 179C was completed in 2007. During the period of study in project DAN 179C, Dr Mensah found *Helicoverpa* spp. eggs infected with fungus in the adjacent pigeon pea refuge crop at Yarral. The fungus was identified as *Cladosporium* spp. The *Cladosporium* fungus was given to Prof. Peter Gregg's PhD student Mr Habibullah Bahar under NSW DII's Material Transfer Agreement with UNE. The student was to determine the efficacy of the fungus against *Helicoverpa* spp. eggs, larvae and key predatory insects on cotton. The student's results have shown that the *Cladosporium* fungus is efficacious against *Helicoverpa* spp. eggs and very small and small larvae but selective on red and blue beetles and green lacewings. CRDC should own part of the IP as funding body to the project.

In project 03DAN001, the Intellectual Property owned by Becker Underwood Pty Ltd (22%), CRDC (32%) and NSW Department of Industry and Investment (43%).

Conclusion

7. Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. What are the take home messages?

The project has set up a platform for the development and commercialization of two entomopathogens (BC 667- *Beauveria* sp. and DAT 500 – *Metarhizium* sp) for biological control of *Helicoverpa* and sucking pests in the cotton industry. The commercialization of these two biopesticides will contribute economically to the cotton industry through enhancement of biological control and IPM to reduce pesticide use and pest control costs. This is because the Bt toxin in the Bt cotton crops is not effective against sucking pests and growers still use synthetic insecticides to control mirids, aphids, green vegetable bugs and silver leaf whiteflies.

The new biopesticides being developed are environmentally-friendly and are effective against sucking pests. The biopesticides may be less expensive than synthetic insecticides and offer potential for cheaper alternatives.

Additionally, the biopesticides can also be used as adjuvants of synthetic insecticides enabling cotton growers to reduce label rates of the expensive new synthetic insecticides by 50% without sacrificing insecticide efficacy, resistance and cotton yield. Reducing the rates of the expensive insecticides will result in substantial savings in pest control on both Bollgard and conventional cotton crops. Also, adoption of new selective and IPM friendly biopesticides will assist in prolonging the life of the new synthetic insecticides by reducing selection pressure for resistance.

8.0 Extension Opportunities

8.1 Detail a plan for the activities or other steps that may be taken:

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

Dr Robert Mensah has collaborated with the Commercial partners to assist in the manufacture of the fungal insecticide products. When the product is registered with APVMA, Dr Mensah will work within the MyBMP extension team and also selected growers and consultants to educate the industry in product use pattern. Grower advisory publications will also be produced in collaboration with the extension staff in the My BMP program and published in cotton tales, spotlight, CRC and CRDC websites. Dr Mensah will educate the extension staff to enable them have first hand knowledge of how to use the biopesticide products.

8.2 *for the future presentation and dissemination of the project outcomes.*

Research data of the project outcomes will be compiled in tabular and graphical format and published in the Australian Cotton Grower and also Spotlight for growers to access information. All project information will be given to the extension focus group for pest management within the MyBMP program. Dr Robert Mensah plans to go on "Pest Management Road show" to communicate the results of the project to cotton growers when the products are registered.

8.3 *For future research.*

The future research will concentrate on improving the efficacy and spore production of BC667 (*Beauveria* sp.) and DAT 511 (*Metarhizium* sp.) to expedite commercialization of these two fungi. In addition, the impact of the new fungal insecticides on *Helicoverpa* pupae, soil pests as well as non-target organisms such

as key predators will be studied. So far studies of the effect of the fungal insecticide products have focussed on green mirids, *Helicoverpa* and some aspects of cotton aphids. Future research will focus on the effect of the products on other cotton pests such as green vegetable bugs, silverleaf whiteflies, cotton stainers, mealybugs etc. In collaboration with the commercial partner, research will concentrate on lower rates of the fungal insecticides as a stand alone and as mixtures with reduced rates of synthetic insecticides on cotton and other crop pests. It is important that the products are evaluated for efficacy against a whole range of cotton pests.

**9. A. List the publications arising from the research project and/or a publication plan.
(NB: Where possible, please provide a copy of any publication/s)**

Due to the IP issue related to this project and the involvement of a commercial partner, no peer review journal articles related to this research has been published. However, with research focus now on BC667 and DAT511, all research results collated on BC639 (*Aspergillus* sp.) will be published in peer review journal within the next 2 years. A couple of publications have been made in grower articles in the cotton industry.

Research publications 2007-2010

9.1 Refereed peer review Journal Articles

1. Bahar, H., MENSAH, R., Backhouse, D. and Gregg, P. (2011). Pathogenecity test of *Cladosporium* sp. Against *Helicoverpa armigera* and other insect pests on cotton. *Journal of Invertebrate Pathology* (In press).
2. MENSAH, R. K. and MACPHERSON, I. (2010). Lure-and-kill as reduced-risk strategy for managing *Helicoverpa* spp. on conventional cotton crops within transgenic cotton fields. *Journal of Biocontrol* 24 92); 91-103.
3. ADRIANA, J. NAJAR-RODRIGUEZ, ELIZABETH A. MCGRAW, CRAIG D. HULL, ROBERT K. MENSAH and GIMME WALTERS (2009). The ecological differentiation of asexual lineages of cotton aphids: alate behaviour, sensory physiology, and differential host associations. *Biological Journal of the Linnean Society*, 1235-1252.
4. MOAZZEM K., GREGG, P. and MENSAH, R. K. (2009). Effect of temperature on the biology of *Creontiades dilutus* (Stål) (Heteroptera: Miridae). *Australian Journal of Entomology* 48 (3), 204 -210.
5. AL DABEL, F., MENSAH, R. K. and FREROT, B. (2008). Effects of nC24 and nC27 petroleum spray oils on oviposition and egg survival of *Ostrinia nubilalis* Hubner (Lepidoptera: Pyralidae) and *Trichogramma brassicae* Bezdenko (Hymenoptera, Trichogrammatidae) adults on maize plants. *International Journal of Pest Management* 54 (1), 5-11
6. ADRIANA J. NAJAR-RODRIGUEZ, ELIZABETH A. MCGRAW, ROBERT K. MENSAH, GEOFFREY W. PITTMAN and GIMME WALTERS (2008). The microbial flora of *Aphis gossypii*: Patterns across host plants and geographical space. *Journal of Invertebrate Pathology* 100, 123 - 126.

7. A. J. NAJAR-RODRIGUEZ, N. A. LAVIDIS, R. K. MENSAH, P. T. CHOY and G. H. WALTER (2008). The toxicological effects of petroleum spray oils on insects – Evidence for an alternative mode of action and possible new control options. *Food and Chemical Toxicology* 46, 3003 – 3014.
8. MENSAH, R. K., VODOUHE, D. S. and SANFILLIPO, D. (2008). Food sprays: A new tool for Africa’s Organic cotton growers. *Pesticide News* 79, 5-7
9. NAJAR, R. A. J., WALTER, G. H. and MENSAH, R. K. (2007). The efficacy of petroleum spray oils against *Aphis gossypii* Glover on cotton: (Part 1) Mortality rates and sources of variation” *Pest Management Science*, 63, 586 - 595.
10. NAJAR, R. A. J., WALTER, G. H. and MENSAH, R. K. (2007). “The efficacy of petroleum spray oils against *Aphis gossypii* Glover on cotton: (Part 2) Indirect effects of oil deposits”. *Pest Management Science*, 63, 596-607.

9.2 Book chapter

- 1 Fitt, GP, Wilson, LJ, Kelly, D and Mensah, RK (2009). Advances in integrated pest management as a component of sustainable agriculture: The case study of the Australian Cotton Industry. In: Peshin R and Dhawan, AK (eds) *Integrated Pest Management*, vol 1. Innovation Development, Springer, Berlin, pp 507-524.
- 2 MENSAH, R. K. and PYKE, B. A. (2007). Beneficial insects in cotton in Australia In: *Insects of Australian Field Crops and Pastures*; (Editor) P. T. Bailey, CSIRO Publications, Canberra, Australia, pages 102-119.

9.3 Confidential Patent Articles

1. MENSAH, R. K., YOUNG, A and AUSTIN L. (2010). Chemical composition of a new plant extracts for control of sucking pests on cotton crops, , De Groot Technical Services Pty Ltd, Brisbane, Australia, 67pp (Patent application 2010900721, 15 February 2010).
2. MENSAH, R. K. (2009). Use of Fungus (BC 639) as a pesticide. The Australian Provisional Patent Application 2009905612. 17 November 2009, FB Rice & Co, Australia and UK Patent Attorney , Sydney Australia, 76 pp

9.4 Theses and Final Reports

1. MENSAH, R. K. (2011). Behaviour modifying plant extracts for managing cotton pests. A Final report presented to the Cotton Research & Development Corporation, Narrabri, January 2011; 192 pp.
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B. Have you developed any online resources and what is the website address?

No

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Part 4 – Final Report Executive Summary

This report presents the experimental work and outcomes of the project that commenced in 2006 and was completed on 30 June 2010 (03DAN001). The aim of the project was to develop and commercialize two new fungal insecticides viz; BC667 (*Beauveria* spp) and BC 639 (*Aspergillus* sp.) for control of *Helicoverpa* spp. and sucking pests on cotton. In achieving the project's aim various studies were conducted in the laboratory, mesh house and field. The study objectives were (1) assess BC667 and BC639 for efficacy against green mirids and aphids (2) evaluate the efficacy of lower rates (below 50g spore/ha) of BC667 and BC639 against green mirids and aphids on cotton; (3) determine the oviposition and feeding responses of green mirids and aphids to BC 667 and BC639 treated plants; (4) evaluate the efficacy of different rates of BC667 and BC639 fungal insecticides and identify the optimum rate effective against green mirids, aphids and beneficial insects and (5) identify the best method for the manufacture and formulation of large quantities of BC 667 and BC 639 spores for commercial use.

In 2005 - 2007, a commercial formulation of BC 667 and BC 639 that incorporates horticultural oil and emulsifiers was developed. Several laboratory, mesh house and field studies were undertaken to determine the efficacy of the formulated fungal

products against *Helicoverpa* spp, sucking pests and beneficial insects on cotton plants. The results of the studies showed that both BC 667 and BC 639 were pathogenic to *H. armigera* eggs, larvae, and sucking pests including silverleaf whitefly but not pathogenic against predatory insects. The two fungi were also found to be pathogenic to *Helicoverpa* spp. first to third instar larvae within 3-4 days after treatment. In contrast, the fungus was found ineffective against medium to large *Helicoverpa* spp. larvae.

In 2008 - 2010, field trials concentrated on BC 639 to generate more efficacy data to support registration of the BC 639 fungus upon the advice of the commercial partner (Becker Underwood Pty Ltd). Overall, the efficacy of the fungal insecticides particularly BC639 was tested at 14 different sites on commercial cotton crops against *Helicoverpa* spp eggs, very small and small larvae, medium and large larvae, green mirid adults and nymphs, green vegetable bugs, apple dimpling bugs, cotton aphids, silverleaf whiteflies (b-type). A total of 65 experiments were conducted on commercial cotton crops in terms of individual insects assessed. In each experiment, different rates of BC 639 was assessed and compared with commercial insecticides used against these pests on commercial cotton crops.

The results showed that BC 639 applied at the following rates: 125ml/ha, 250ml/ha, 500ml/ha, 750ml/ha and 1.0L/ha were found to be efficacious against all the test insects. No significant difference in efficacy was found when the product was applied at 1.0 L/ha, 750ml/ha and 500ml/ha against all the test insects. However, application of lower rates of BC 639 at 250ml/ha and 125ml/ha were efficacious at low pest pressure situations but at high pest pressure it will require paired application of the product especially sucking pests such as green mirids, green vegetable bug, aphids and whiteflies.

The optimum rate of application of BC 639 was identified as 500ml/ha. The 500ml/ha rate was as effective as 1.0 L/ha, 0.75L/ha BC 639 and also the recommended rates of commercial insecticides used in controlling green mirids, green vegetable bugs, silverleaf whiteflies, aphids, apple dimpling bugs and *Helicoverpa* spp. Application of BC 639 rates was done at the recommended thresholds for each of the targeted pests. For example, application of BC 639 against green mirids was done when the number of green mirids per metre row of cotton was equal or greater than 0.5 per metre (recommended visual counts threshold). It should be noted that when green mirid nymphs and adults reached a threshold of 0.5 per metre, there may be eggs already laid in the crop that have not hatched. Therefore, application of BC 639 will control the green mirid adults and the nymphs already on the plants not unhatched nymphs. Thus, any nymphs hatching from eggs after BC639 application may not be infected and killed due to lack of residual effect and low number of BC 639 spores after initial application. In this situation, pair applications of BC 639 irrespective of the rate will be required.

In general, the efficacy of BC 639 rates against the test insects was found to be similar and in most instances better than the commercial insecticides especially green mirids

and silverleaf whiteflies. Additionally, the studies found that both BC 667 and BC 639 were more selective to beneficial insects especially predatory insects than the commercial insecticides used by the cotton industry to manage *Helicoverpa* and sucking pests on cotton. The product was also found not to be phyto-toxic to the cotton plant itself nor squares and bolls of the plant. The yield recorded on plots treated with conventional insecticide and BC 639 was not significantly different. Thus the application of BC 639 did not have any detrimental effect on yield relative to commercial conventional treated plots. In terms of quality, there was no difference between the BC 639 treatments and conventional insecticides for the characteristics of length, strength or micronaire.

In conclusion, application of entomopathogenic fungus to manage cotton pests will enhance conservational biological control, support IPM and reduce pest control costs on both Bollgard and conventional cotton.