



Final Report

On Farm Series | Cotton Research & Development Corporation

FINAL REPORT 2006

Part 1 - Summary Details

CRDC Project Number: CSP 162 OR Cotton CRC Project Number:

**Project Title: Damage syndromes, economic thresholds
and tolerance of cotton to green mirids**

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Part 3 – Final Report Guide (due 31 October 2006)

Background

Historically, sucking pests such as green mirids are common pests of seedling cotton but were rarely a problem during fruit set. In recent years, mirids have been a problem in the fruiting period when they appear to be damaging young bolls, causing shedding or sometimes damaging one or several locks of a boll causing it to develop poorly. The problem has occurred in some INGARD crops and also in some conventional crops managed under progressive IPM strategies. In both cases, there has been either reduced use of insecticides for control of *Helicoverpa* or a switch to insecticides that selectively control *Helicoverpa* but not sucking pests. This has allowed sucking pests to establish where in the past some of the insecticides applied to control *Helicoverpa*, such as endosulfan, would also have coincidentally controlled or suppressed them. Managing sucking pests on cotton will likely become more critical as new transgenic varieties better protected against *Helicoverpa* are planted widely e.g. Bollgard II. Appropriate management of mirids is critical so that gains already made in IPM with transgenic cotton (i.e. reduced costs, pesticide resistance and beneficial insects) are not undermined. In Australia, the rapid transition of commercial cotton cropping from INGARD to Bollgard II (to be completed by 2004-05) demands proactive research against sucking pests to maintain a sustainable and profitable cotton industry.

Research on mirid and green vegetable bug damage by Dr. M. Khan and others found that mirid feeding can cause shedding of small and medium squares but not large squares (see Figure 1 for a schematic of the likely effects of mirid damage on different ages of fruit). They will also feed on bolls and cause shedding of small bolls but not larger bolls. Younger bolls less than 2 weeks old are most vulnerable to green mirids but feeding scars on the boll wall do not always correlate with internal lint damage. Preliminary studies conducted under CSP124C suggest that feeding entails probing by piercing the boll wall and feeding only when a seed is located such that several external scars often equates to a single feeding event. A seed fed upon by a mirid will die, halting lint development and often resulting in fibre discolouration possibly because of fungal or bacterial breakdown of surrounding tissue. It is critical that robust relationships between mirid numbers, external scarring and internal damage be developed for sound management decisions based on reliable damage assessment methodology. Currently, a variety of approaches are used to assess mirid numbers (i.e. beat sheets, visual, D-Vac) and fruit damage, a single reliable method linking these to yield outcome is desirable.

Of concern to growers and consultants will be the effect of sucking pests on yield and fibre quality, and the ability of cotton to compensate for damage. In a preliminary study initiated in CSP124C, plants sustaining high mirid damage had reduced yield but showed no downgrading of fibre quality. It appears that during the picking and ginning process, damaged locules and lint were selectively removed as trash. This is supported by the lower gin turnout of damaged bolls. Hence, the risk of penalty for low fibre quality directly resulting from damaged lint may be relatively low. We also found that plants with some bolls damaged showed an increase in the size of the remaining undamaged bolls. This suggests some capacity for cotton to compensate by re-allocating resources from damaged to healthy bolls. But the degree to which this form of compensation can prevent yield loss remains to be determined. Similar to *Helicoverpa* damage, the degree of compensation could vary among diverse cotton growing regions (e.g. between south-eastern and northern Australia). It is therefore important to assess economic thresholds for mirid damage in a range of locations.

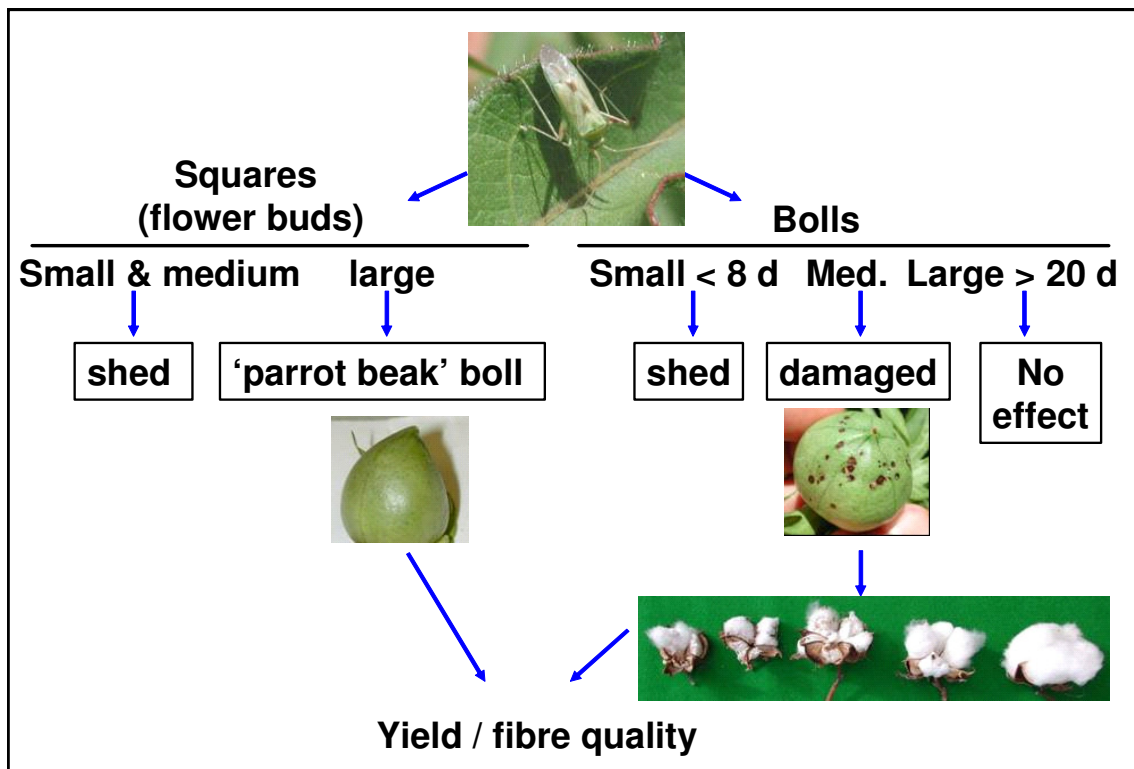


Figure 1. Effect of mirid feeding damage at different ages of the development of cotton fruit.

Objectives

- i. Developing and using methodologies to quantify the impact of boll damage –in particular validate the accuracy of mimicking natural boll damage using pectinase injection.
- ii. Investigate the response of cotton to simulated mirid damage at a range of timings, intensities and locations (cotton regions).
- iii. Compare results of experiments with simulated damage to real damage in the field.
- iv. Modify the existing OZCOT simulation model accommodate compensation for sucking pest damage. Create decision making management tools for the industry based on new functionalities specific to sucking pests.

Methods

- i. *Developing and using methodologies to quantify the impact of boll damage –in particular validate the accuracy of mimicking natural boll damage using pectinase injection.* The effect of mirid damage was compared with that of boll injecting, initially in the glasshouse (eg Figure 2a).

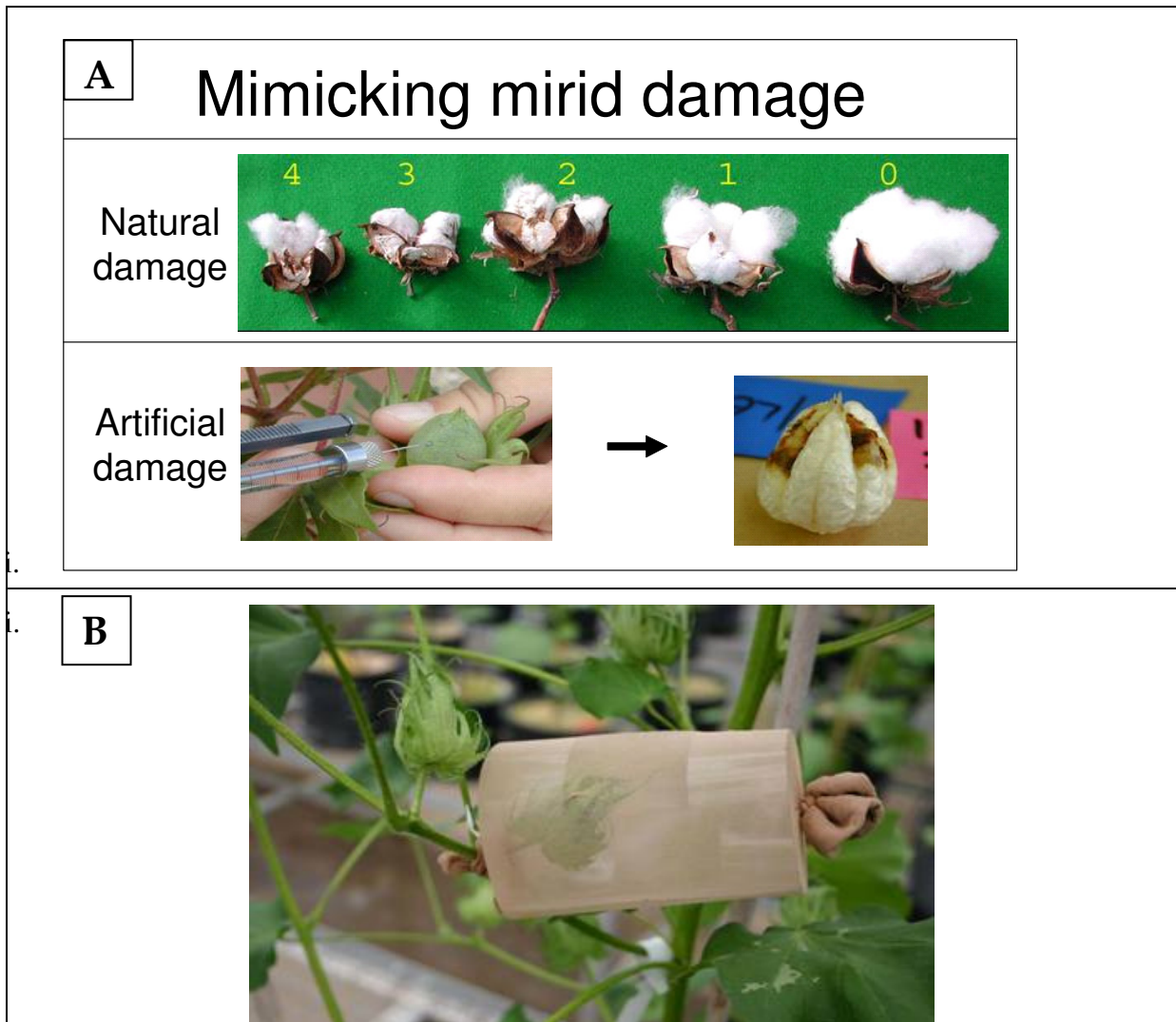


Figure 2A. Comparison of real vs simulated damage to cotton bolls. The numbers 0 – 4 show a scoring system used to rank boll damage by mirids. **B.** Apparatus used for caging mirids on bolls.

Plants were grown in a replicated design in the glasshouse. When the plants had young bolls damage treatments were implemented. These include caging laboratory reared mirids onto bolls of know age or injecting bolls (2 locks per boll) (see Figure 2b) with a pectinase/water solution (2 concentrations) at a known boll age. This was done for three bolls per plant to increase replication. The treatments were;

- control
- 1 caged mirid/boll for 1 day @ 15 days
- 2 caged mirids/boll for 1 day @ 15 days
- 1 caged mirid/boll for 2 days @ 15 days
- 1 caged mirid/boll for 1 day @ 30 days
- 2 caged mirids/boll for 1 day @ 30 days
- 1 caged mirid/boll for 2 days @ 30 days
- 1µl of water @ 15 days into 2 locks
- 1µl of 1:10 pectinase @ 15 days into 2 locks
- 1µl of 1:20 pectinase @ 15 days into 2 locks
- 1µl of water @ 30 days into 2 locks
- 1µl of 1:10 pectinase @ 30 days into 2 locks

- 1µl of 1:20 pectinase @ 30 days into 2 locks

Bolls were scored for damage once they had opened using the scale indicated in Figure 2. For each boll the seed number and average weight, seed cotton and lint weights per boll were recorded. If the mirid or injection damage resulted in reduced boll weight then it is possible that the plant could compensate by making other bolls on the plant heavier. To test this three weights and locations of all other bolls on the plant were also recorded. The data were analysed in Genstat using ANOVA to compare boll weights between treatments for both damaged and undamaged bolls, and using regression to explore relationships between boll weight, damage score and number of locks damaged.

- ii. *Investigate the response of cotton to simulated mirid damage at a range of timings, intensities and locations (cotton regions).*

The response of cotton to simulated mirid damage was investigated in field experiments across a range of regions. Across the sites the varieties were either Sicala 189RR, or 289BR, or Sicot 70RR or Sicot 71BR. Damage was inflicted at three stages post flowering:

- Early (21 DAFF, 20 nodes)
- Mid (35 DAFF, 23 nodes)
- Late (56 DAFF, post-cutout)

At the first date two levels of damage (low, 5 bolls /m and medium, 20 bolls/m) and at the later dates three levels of damage (low, medium and high 50 bolls/m) were inflicted. In each case two locks per boll were injected for bolls in the range 8-12 d old i.e. 20 to 40mm diameter). The experiments all used a randomised block design with four replications. There were 8 experiments conducted across 4 regions, two in the lower Namoi (ACRI – first experiment included two varieties), two in the Upper Namoi (Breeza), two in the Macintyre (near Boggabri), one at Emerald and one at Hillston. At each site yield date was collected by hand harvesting a 2 m section of row from each plot (e.g. 8 m in total per treatment). In each of the 2m sections the number and weight of damaged and undamaged bolls was recorded separately. Total gin-turnout was analysed for the damaged and undamaged bolls combined to approximate a more typical ginning situation. Fibre quality was tested for most of the experiments. The data for all sites was combined and analysed in Genstat using ANOVA with site and treatment as factors.

- iii. *Compare results of experiments with simulated damage to real damage in the field*
Experiments were done in 2004-05 and 2005-06 to compare the effect of boll injecting with damage by mirids in the field. Injecting was carried out as described above. At the same time cages were placed over small areas of cotton (2m x 2 rows) and known numbers of adult mirids introduced into the cages. The mirids were allowed to feed for a week after which the plants were sprayed to kill mirids and the cages were removed. The mirids were captured from nearby lucerne crops and were of mixed age and sex. The treatments were mirid densities of 1.5, 3.0, 6.0 and 12.0/m for 1 week at 5 and 8 weeks after first flower, compared with boll injecting (5, 20 and 50 bolls/m) done at the same times. Each time cages were used to confine mirids, the cotton to be injected and an extra control treatment were also caged to allow for the potential effect of caging on growth. The experiments used a randomized blocks design with four replications. Yield was assessed by hand harvesting each week from the start of boll opening and damaged bolls were harvested separately to undamaged bolls.
- iv. *Plant mapping, dry matter production, maturity, yield and fibre quality data will be collected from manual and natural damage trials.* Data will then be used to modify the OZCOT model to predict the outcomes of known levels of mirid damage.

Results and Discussion

1. Validation of boll injecting vs mirid damage (Glasshouse)

Damage from mirids, in the combinations of numbers and timing tested here, did not affect boll weight in these experiments (Figure 3). In contrast, injecting bolls with water or pectinase when bolls were 15 days old dramatically reduced boll weight. However, injecting bolls with pectinase or water at 30 days old had no effect on boll weight.

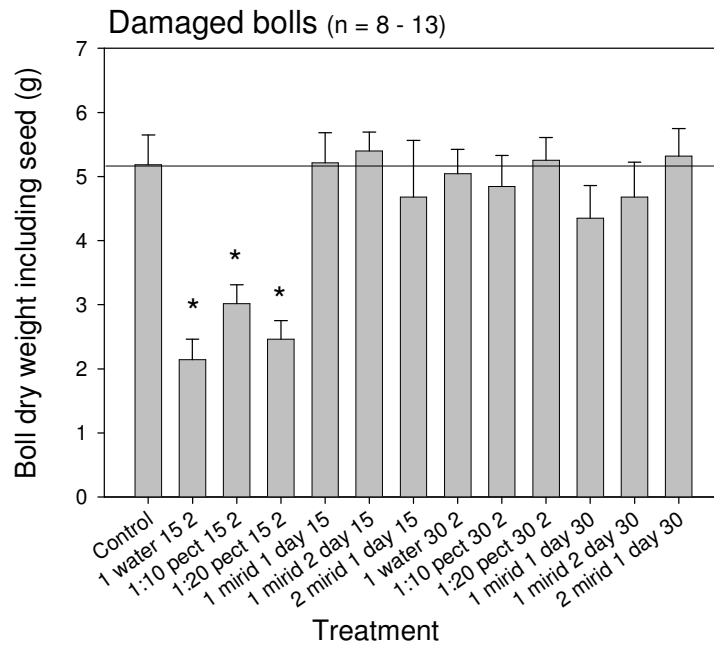


Figure 3. Boll weights of bolls undamaged (Control), injected with water or pectinase or fed on by mirids at either 15 or 30 days old. Asterisks indicate treatments significantly different from the control using ANOVA at $p < 0.05$.

We found no evidence of compensation in boll size for position one (P1) bolls in the same node region at the damaged bolls (nodes 5 – 11) (Figure 4). Second position (P2) bolls in this range were, however, often larger in the damage treatments than the control (Figure 5). This pattern did not follow the expected pattern, e.g. that those treatment with the largest decline in boll weight would tend to have the biggest position 2 bolls, which makes it difficult to explain in terms of compensation for lost boll weight. It is possible that a moderate level of damage to a P1 boll, that doesn't affect its yield, triggers a plant response resulting in increase supply of assimilate to the P2 bolls. This would need further experimentation to sort out. We found no evidence of compensation in boll weight in the upper bolls (nodes 12+, Figure 6).

The damage scores followed a similar trend to the boll weights, with the bolls injected with water or pectinase at 15 days old having high damage scores (Figure 7). The bolls fed on by mirid did show a slight, but not significant, trend toward higher damage scores than the control. The damage scores correlated well with boll weight, with the injected bolls at 15 days old having both low weights and high damage scores (Figure 8).

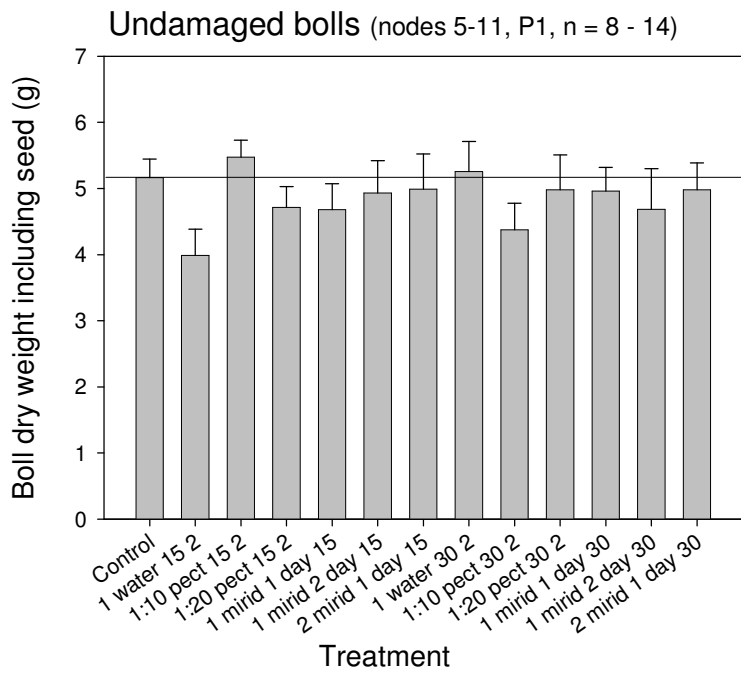


Figure 4. Boll weights of undamaged P1 bolls from nodes 5 -11 in plants where 3 other P1 bolls in this node range were either undamaged (Control), injected with water or pectinase or fed on by mirids at either 15 or 30 days old. Asterisks indicate treatments significantly different from the control using ANOVA at $p < 0.05$.

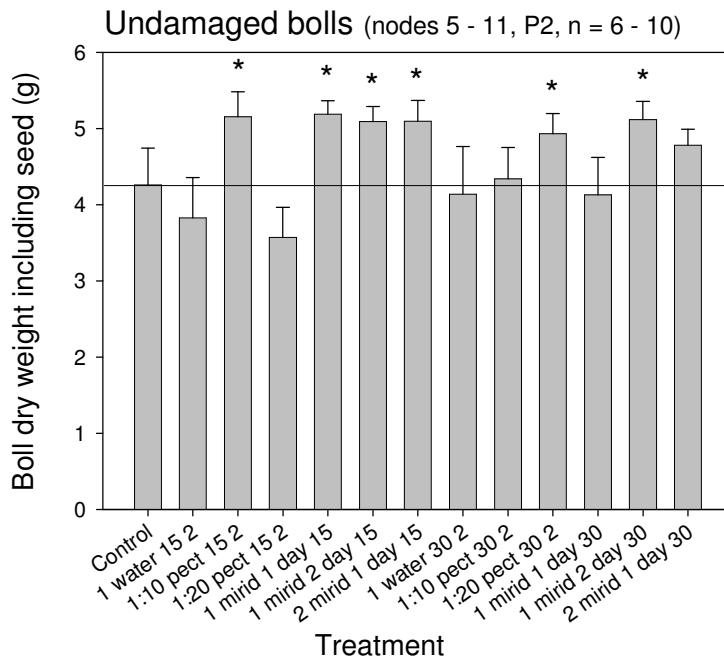


Figure 5. Boll weights of undamaged P2 bolls from nodes 5 -11 in plants where 3 other P1 bolls in this node range were either undamaged (Control), injected with water or pectinase or fed on by mirids at either 15 or 30 days old. Asterisks indicate treatments significantly different from the control using ANOVA at $p < 0.05$.

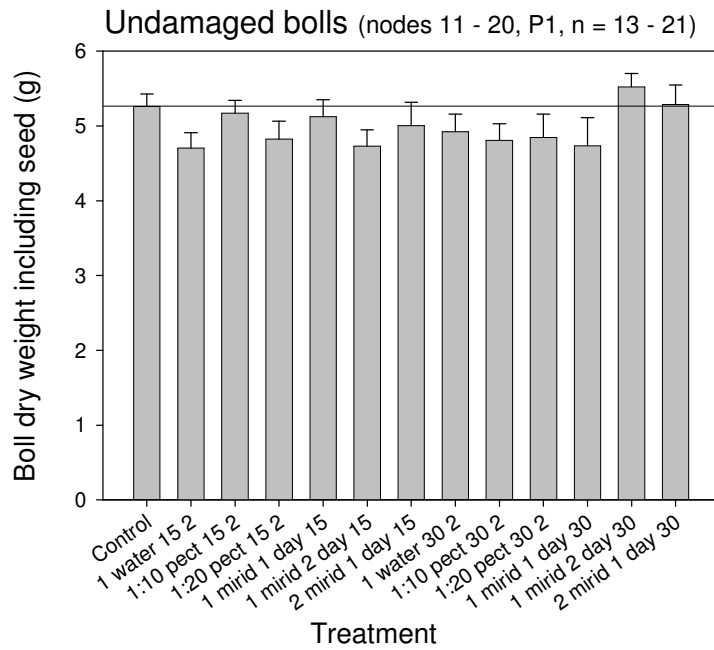


Figure 6. Boll weights of undamaged P1 bolls from nodes 12+ in plants where 3 other P1 bolls in this node range were either undamaged (Control), injected with water or pectinase or fed on by mirids at either 15 or 30 days old.

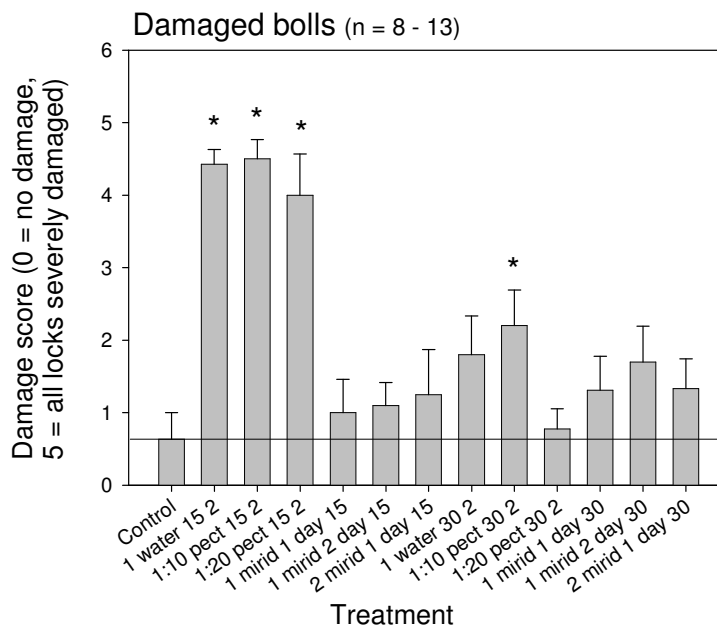


Figure 7. Damage scores of bolls either undamaged (Control), injected with water or pectinase or fed on by mirids at either 15 or 30 days old. Asterisks indicate treatments significantly different from the control using ANOVA at $p < 0.05$.

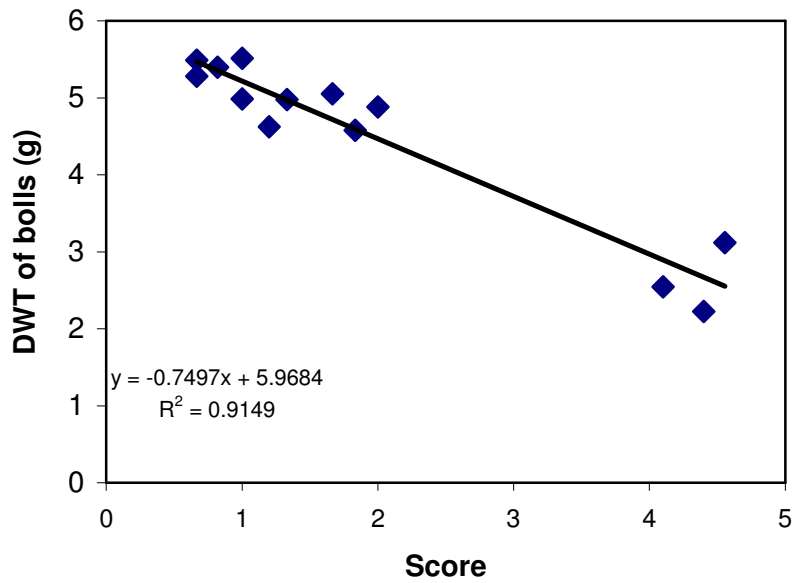


Figure 8. Relationship between boll dry weight and damage scores.

The number of damaged locks was significantly more than the control in the injection at 15 days old treatments and two of the injection at 30 days old treatments (Figure 9). Also there was a trend for mirid damaged bolls to have slightly higher scores than the control, though this was only significant for the 1 mirid for 2 days at 30 days old treatment. Similar to the damage scores there was a strong correlation between damage and boll dry weight (Figure 10).

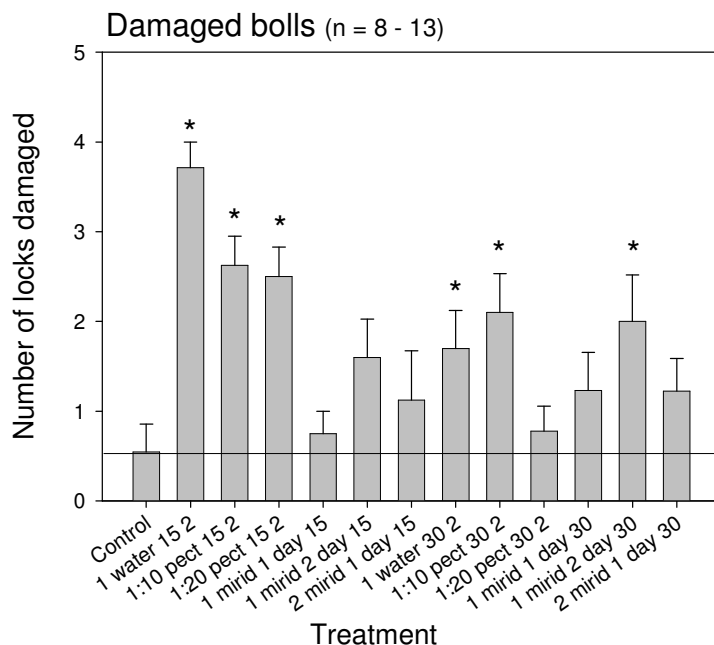


Figure 9. Damage scores of bolls either undamaged (Control), injected with water or pectinase or fed on by mirids at either 15 or 30 days old. Asterisks indicate treatments significantly different from the control using ANOVA at $p < 0.05$.

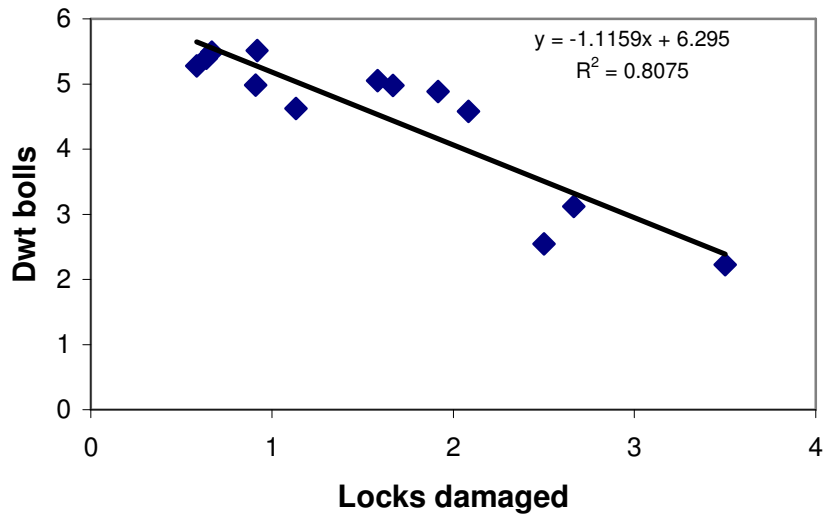


Figure 8. Relationship between boll dry weight and lock damage.

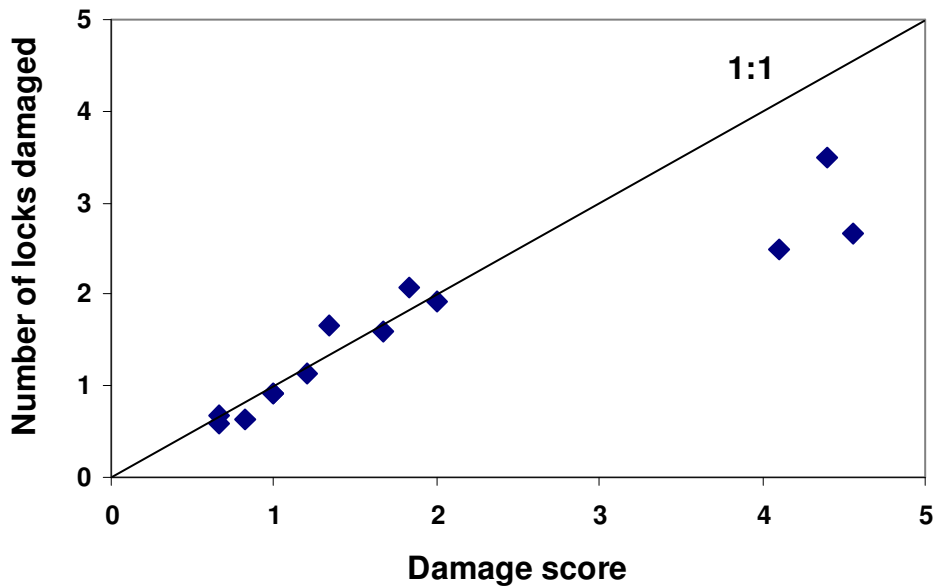


Figure 9. Relationship between damage score and lock damage.

The relationship between number of locks damaged and damage score is linear up to a damage score of 2. At higher damage scores the number of locks damaged is less than predicted, but this is to be expected as these points are from the injection and only two bolls were injected. Nevertheless for the damage score to be so high there must have been some ‘spill over’ effect from the damaged locks to undamaged locks in terms of lint produced.

In summary, this experiment suggested that ;

1. 15 day old bolls were susceptible to simulated mirid damage, 30 day old bolls were not.
2. Mirid feeding at the levels evaluated did not affect boll weight.

3. Simulated damage, using injection of water or pectinase was more severe than damage caused by mirid feeding, for damage of up to 2 mirids per boll for one day or 1 mirid per boll for 2 days.
4. Both the damage scores and the number of locks damage were approximately linearly negatively related to boll dry weight.

2. Use of simulated damage (boll injecting with pectinase) to evaluate compensation in the field.

Across all sites for each attribute (yield, boll number and weigh of damaged or undamaged bolls and gin-out turn) there were significant differences between sites, as expected, and between treatments, but the treatment by site interactions were generally not significant, indicating a similar response to damage treatment across the eight sites.

There were significant differences between sites for yield, as expected, and between treatments, but the treatment by site interaction was not significant, indicating a similar response to damage treatment across the eight sites. Manually injecting dilute solutions of pectinase into small cotton bolls significantly reduced lint yield this occurred in the mid or late season and typically only when medium to high numbers of bolls were injected (Fig 10). Generally, 50 bolls m^{-1} were difficult to find eight weeks after first flower so this was always considered to be an extreme treatment.

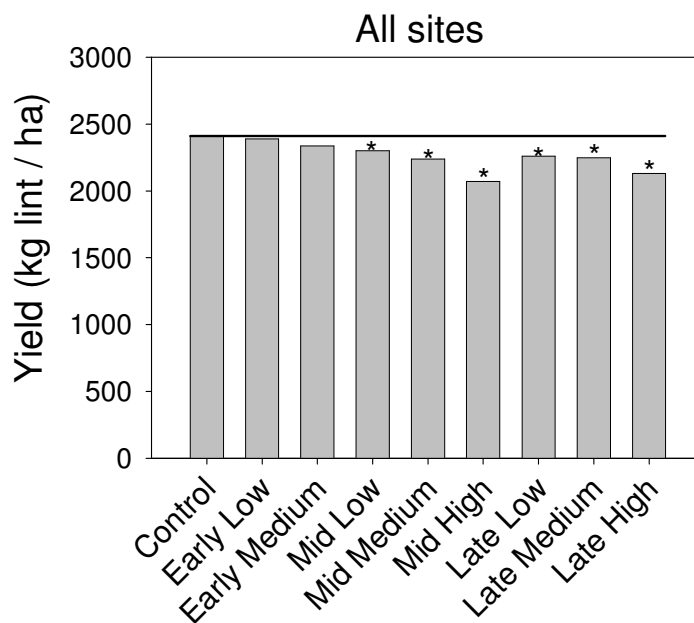


Figure 10. Lint yield in response to damaging bolls by injecting with dilute solutions of pectinase (Early – 3 weeks after first flower; Mid – 5 weeks after first flower; Late – 8 weeks after first flower; 5 = 5 bolls m^{-1} injected; 20 = 20 bolls m^{-1} injected; 50 = 50 bolls m^{-1} injected). Trials were conducted at 8 site/years. Asterisks indicate treatments significantly different from the control using ANOVA at $p < 0.05$.

The reduction in yield in the mid- and late season damage treatments was due to several factors. The first is the reduced gin out-turn of the more heavily damaged treatments (Figure 11) (ANOVA Site and treatments $p < 0.05$, interaction ns). This indicates that a

portion of the lint was lost in the ginning process, possibly because at the damage sites the lint is often very hard and compacted, which probably results in it being removed in the ginning process. This also prevents the damaged lint from affecting the overall fibre quality.

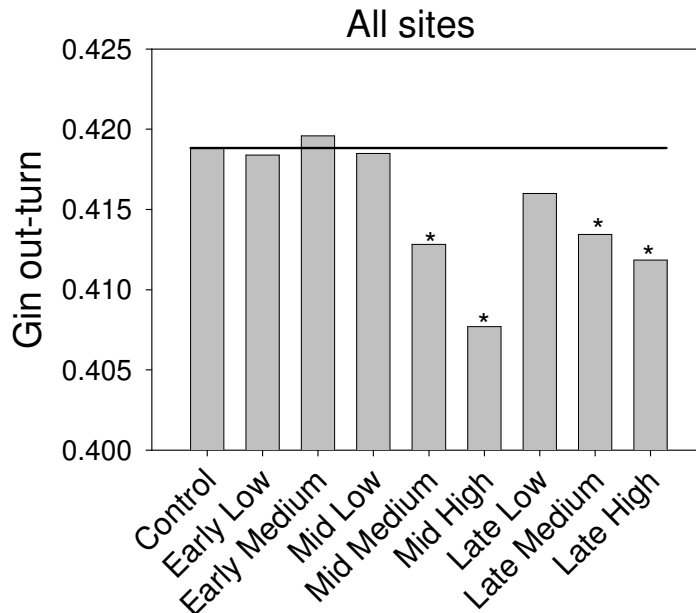


Figure 11. Gin out-turn in response to damaging bolls by injecting with dilute solutions of pectinase (Early – 3 weeks after first flower; Mid – 5 weeks after first flower; Late – 8 weeks after first flower; 5 = 5 bolls m⁻¹ injected; 20 = 20 bolls m⁻¹ injected; 50 = 50 bolls m⁻¹ injected). Trials were conducted at 8 site/years. * = significantly different from control treatment at P<0.05

The second factor in the reduction in yield is the reduction in the total number bolls in some of the damage treatments, such as mid and late low and high, and early medium (Figure 12). The number of undamaged bolls per m was also significantly lower in all except the early low treatments, and the magnitude of difference essentially followed the number of bolls injected. The number of damaged bolls harvested per m increased in line with the number of bolls injected. Two issues are worth noting, firstly the difference between the number of undamaged boll in the treatments and control was always less than the number of bolls injected, indicating a degree of compensation via retention of undamaged bolls that would have been shed. Secondly, the number of damaged bolls harvested per m was always much less than the number actually injected indicating that some of the injected bolls must have been shed (contributing to the reduction in the total number of bolls). This may have contributed to the plant’s capacity to compensate by substituting undamaged bolls for these shed injected bolls.

For instance for the mid high treatment we damaged 50 bolls per m and would expect to have harvested 73.2 undamaged bolls (i.e. the control (123.2) minus 50 damaged). Yet we harvested 95.4 undamaged bolls, so we have retained an extra 22 undamaged bolls. Further, we damaged 50 bolls yet harvested only 21.3 damaged bolls, so 28.7 of the bolls injected must have shed. Hence, though there is yield loss, it is evident that there has also been

considerable compensation, mainly through retention of undamaged bolls that would have been shed, in replacement for bolls shed due to injection.

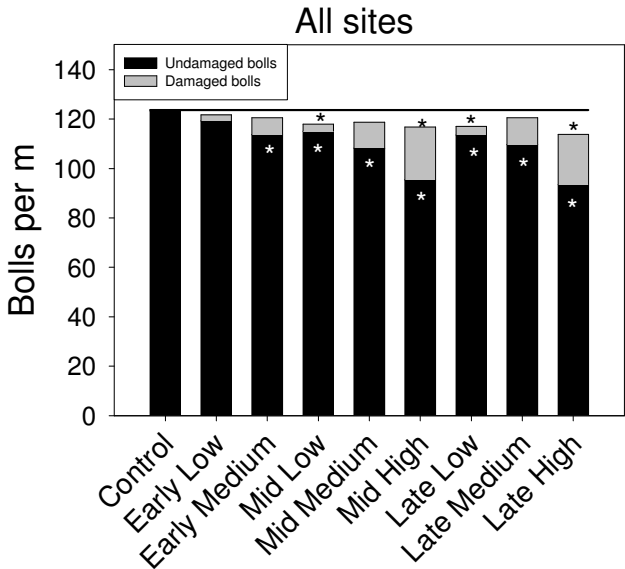


Figure 12. Boll number in response to damaging bolls by injecting with dilute solutions of pectinase (Early – 3 weeks after first flower; Mid – 5 weeks after first flower; Late – 8 weeks after first flower; 5 = 5 bolls m⁻¹ injected; 20 = 20 bolls m⁻¹ injected; 50 = 50 bolls m⁻¹ injected). Trials were conducted at 8 site/years. * = significantly different from control treatment at P<0.05.

The third component in reduced yield was the reduced boll weight of damaged bolls that were retained (Figure 13). The boll weights of damaged bolls were about 1.1 g per boll compared with about 2 g per boll for undamaged bolls. The boll weight of undamaged bolls did not vary between treatments; hence there is no evidence of increased boll size as a compensation mechanism.

Even though yield was reduced in all except the early injection treatments, crop maturity was affected very little (Figure 14). Maturity was significantly delayed in the early medium and mid medium and high treatments, and even this was only by a maximum of 2.75 days. This indicates that the compensation reported above has occurred predominantly through retention of other fruit from the same ‘cohort’ as that injected, rather than through production of new fruit, as the latter would have resulted in more obvious delays in maturity as the new fruit would be at least 8 -12 days younger than the fruit injected.

The fibre quality of damaged and undamaged bolls from each treatment was measured using the HVI at ACRI. Across each of the sites there was a strong trend for damaged bolls to be poorer in quality than undamaged bolls though the differences were not large. Damaged bolls had fibre with lower uniformity, shorter length, slightly reduced strength, higher short fibre content and reduced elongation (Figure 15). However, when the damaged bolls were included with the undamaged bolls and the weighted average values obtained, the damage treatments had little effect on overall fibre quality (see Figure 16 for Breeza 2002-03 as an example).

In conclusion these field experiments using artificial damage showed that the higher damage in the mid – late season reduced yield. This was due to (i) a slight reduction in gin out-turn, due to removal of ‘tight’ portions of lint at the sites of damage (ii) shedding of some fruit resulting in reduced boll number and (iii) reduced weight of damaged bolls. There is evidence of compensation due to retention of extra undamaged bolls in partial replacement of some of those shed due to damage. Fibre quality of damage bolls was slightly poorer than that of undamaged bolls, but for pooled lint samples the overall effect on fibre quality was minimal.

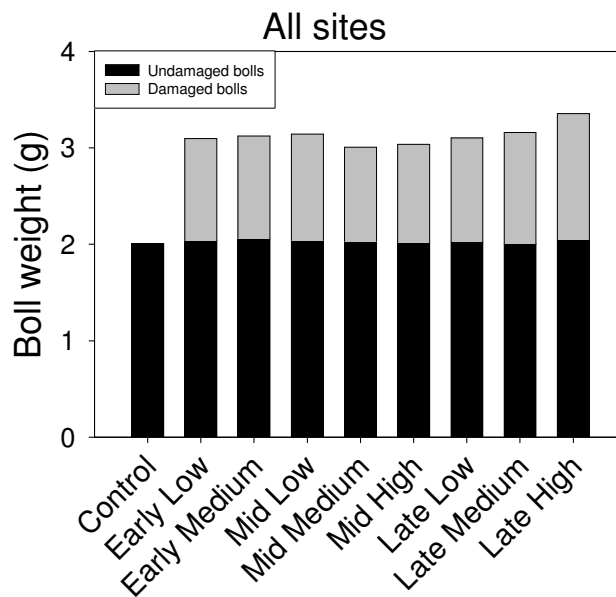


Figure 13. Boll weight (g) of damaged and undamaged bolls in response to damaging bolls by injecting with dilute solutions of pectinase (Early – 3 weeks after first flower; Mid – 5 weeks after first flower; Late – 8 weeks after first flower; 5 = 5 bolls m⁻¹ injected; 20 = 20 bolls m⁻¹ injected; 50 = 50 bolls m⁻¹ injected). Trials were conducted at 8 site/years. * = significantly different from control treatment at P<0.05.

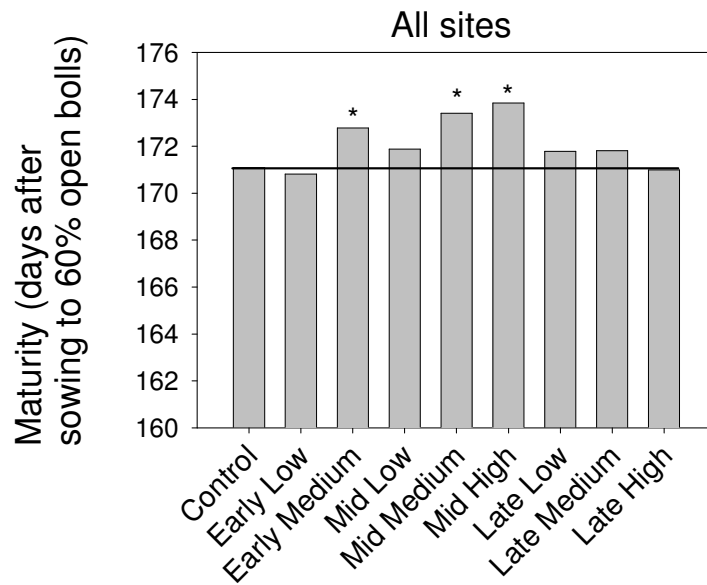


Figure 14. Maturity date of crops in response to damaging a number of bolls by injecting with dilute solutions of pectinase (Early – 3 weeks after first flower; Mid – 5 weeks after first flower; Late – 8 weeks after first flower; 5 = 5 bolls m^{-1} injected; 20 = 20 bolls m^{-1} injected; 50 = 50 bolls m^{-1} injected). Trials were conducted at 8 site/years. * = significantly different from control treatment at $P < 0.05$.

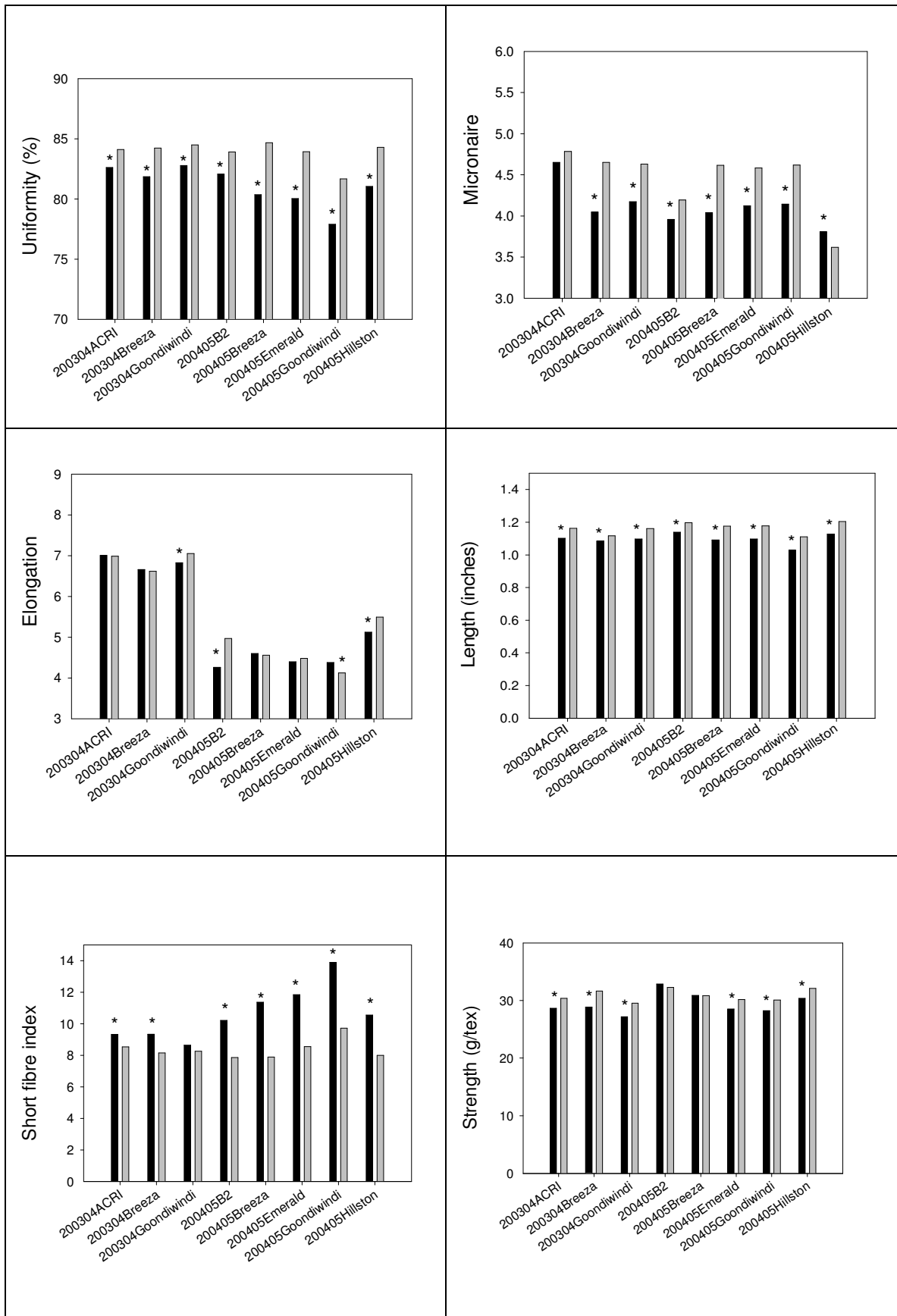


Figure 15. Fibre properties of damaged and undamaged boll from 8 sites, 2003-2005. * indicates significant difference between damaged and undamaged bolls at that site, using REML and $p < 0.05$

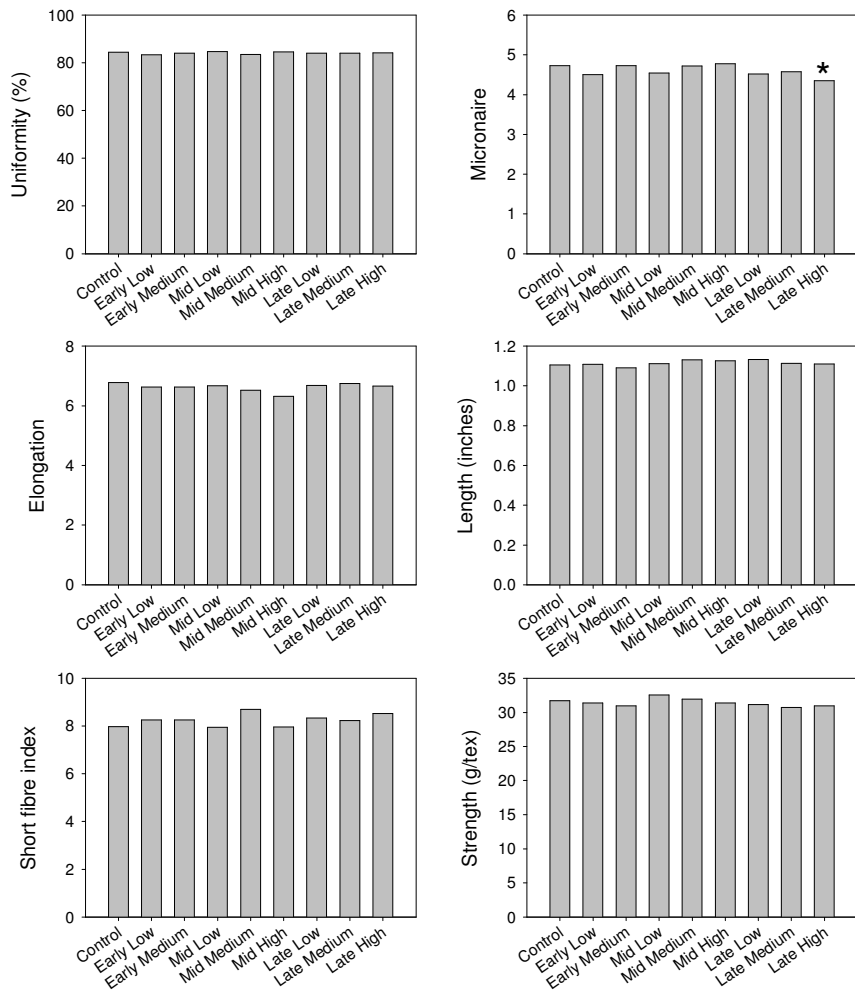


Figure 16. Weighted fibre quality parameters for each treatment, Breeza, 2003-04. * = significantly different from Control using ANOVA at $p < 0.05$.

3. Comparison of simulated damage with real damage in the field

Confining mirids to a small section of flowering cotton was however successfully performed at 4 site/years (2004/05 at ACRI and at Hillston, ACRI and Emerald in 2005/06) Figure 17.



Figure 17. Cages used to confine mirids to compare real with simulated damage.

Across each of the four sites, lint yield tended to be reduced relative to the control when large numbers of bolls were injected, particularly late in the season (Fig 18), though this was rarely significant. In each case the appropriate caged control was used for comparison as caging tended to increase yield, possible due to protection from weather. However, caged mirids did not affect yield even at four mirids per metre for a week.

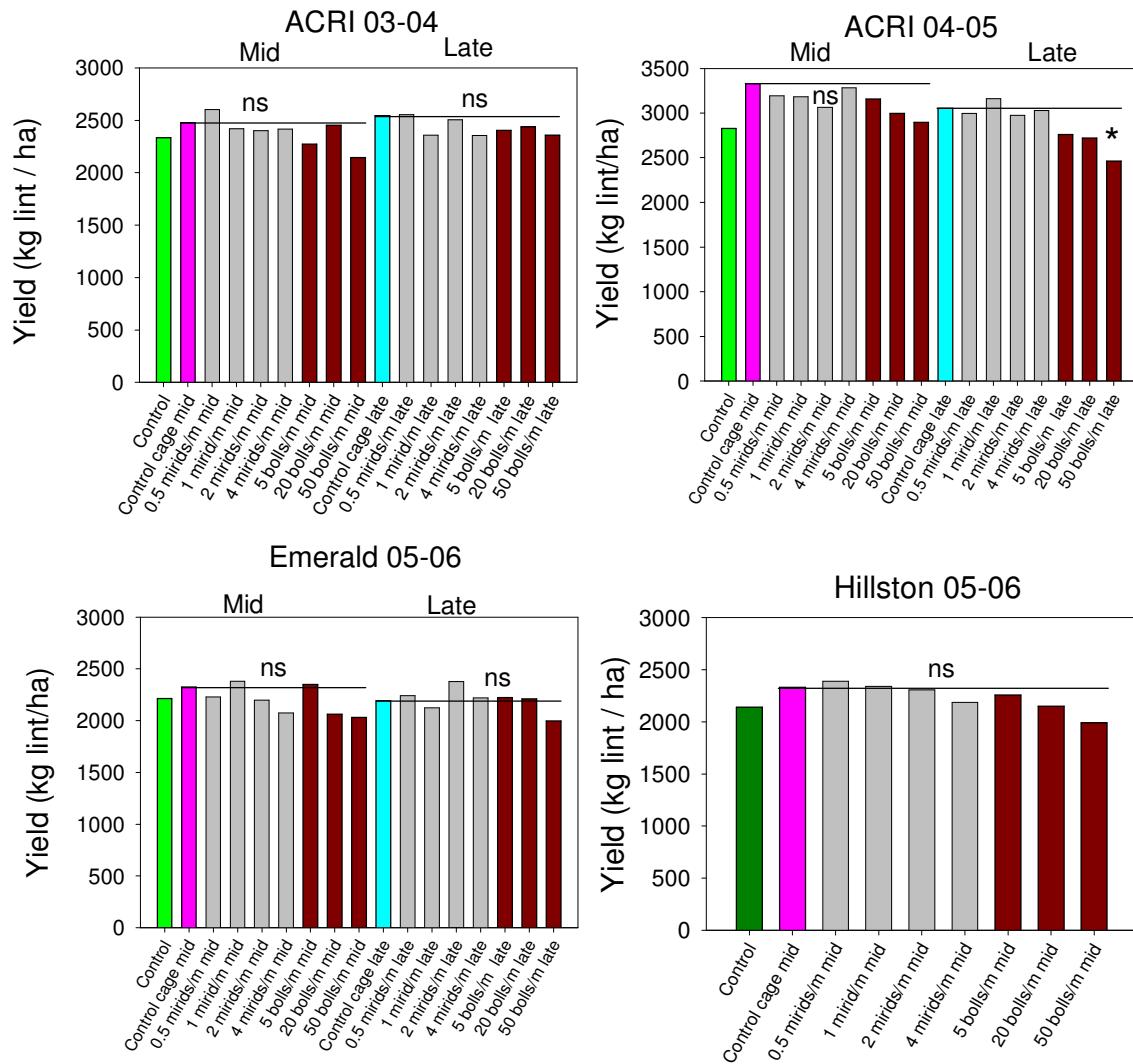


Figure 18. Effect of mirid feeding or boll injecting on yield of cotton at four sites, 2004-2006. * indicates significantly different to the control at $P < 0.05$ using ANOVA.

When the three sites with all treatments were analysed together there were significant site and treatment effects but the interaction was not significant. Overall, boll injecting of 20 or 50 bolls per metre in the mid season or 50 bolls per metre in the late season significantly reduced yield. However, none of the mirid damage treatments reduced yield (Figure 19). This essentially confirms recent research by Khan., Quade and Murray (2006 ACGRA Cotton Conference Proceedings) of a threshold of 3 mirids per metre in the mid season and 4-5 mirids per m in the late season.

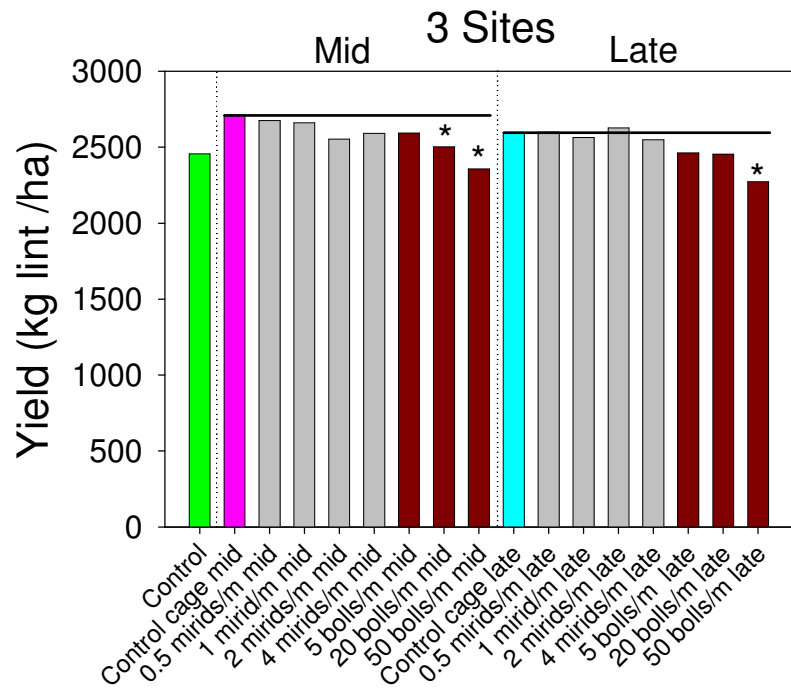


Figure 19. Effect of mirid feeding or boll injecting on yield of cotton across three sites (ACRI 2004-05, ACRI 2005-06 and Emerald 2005-06). * indicates significantly different to the control at P <0.05 using ANOVA.

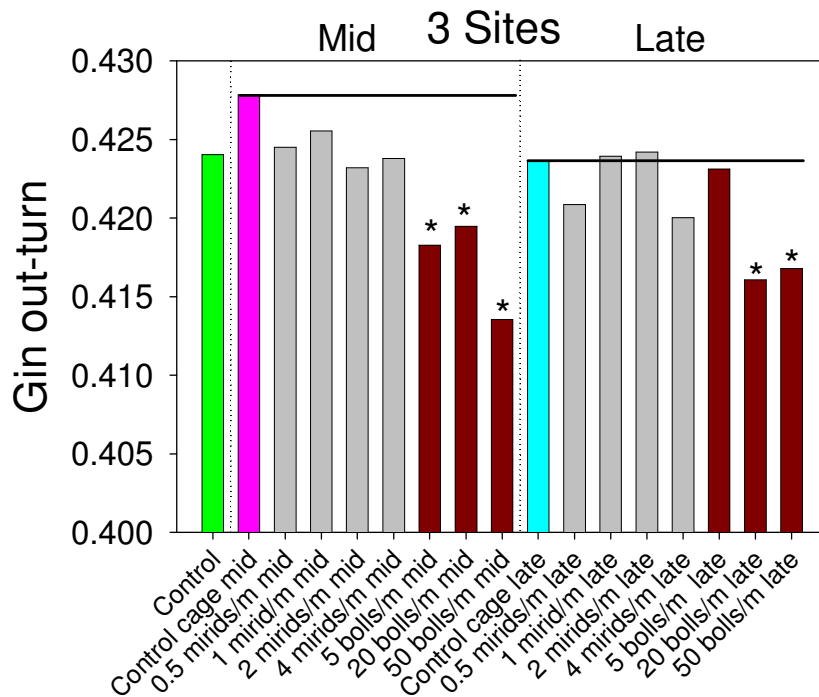


Figure 20. Effect of mirid feeding or boll injecting on gin out-turn of cotton across three sites (ACRI 2004-05, ACRI 2005-06 and Emerald 2005-06). * indicates significantly different to the control at P <0.05 using ANOVA.

Similar to the earlier boll injection research, the yield loss in the injection treatments was a product of reduced gin out-turn (Figure 20) and higher numbers of damaged bolls (Figure 21) which weighed less than undamaged bolls (Figure 22). There were more damaged bolls in many treatments than in the controls, but especially the heavier injection treatments. However, numbers of undamaged bolls and total boll numbers (damaged plus undamaged) did not differ significantly between treatments. Again there is evidence of compensation in boll numbers by retention of more undamaged bolls, as indicated by the low number of damaged bolls retained compared to the number damaged.

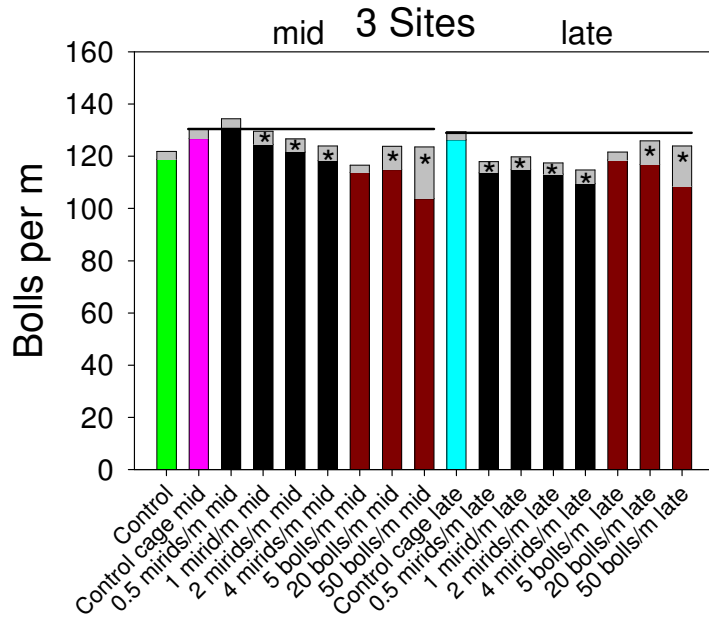


Figure 21. Effect of mirid feeding or boll injecting on numbers of undamaged, damaged or total boll numbers of different damage treatments across three sites (ACRI 2004-05, ACRI 2005-06 and Emerald 2005-06). * indicates numbers of damaged bolls significantly different to the control at $P < 0.05$ using ANOVA.

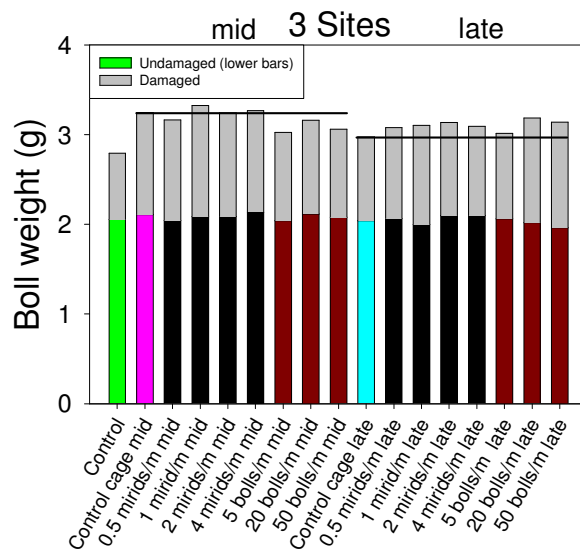


Figure 22. Effect of mirid feeding or boll injecting on weight of undamaged or damaged bolls in different damage treatments across three sites (ACRI 2004-05, ACRI 2005-06 and Emerald 2005-06).

The key conclusions from these experiments are;

1. Boll injecting caused more severe effects than mirids, similar to earlier experiments
2. Yield was affected in one experiment and overall by heavier boll injecting treatments
3. Partial compensation for bolls lost through injection was by increased retention, not boll size
4. Reduction in out-turn and reduced weight of damaged bolls were the main factors leading to yield loss.

Outcomes

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

This project achieved the aims of exploring the capacity of cotton to compensate for damage by mirids, using both real and simulated damage treatments. A significant number of data sets are now available that can be used to test and if necessary calibrate the capacity of the OZCOT model to simulate the response of cotton to mirid damage. The power of the model approach is that it integrates this new information with the wealth of science already captured in OZCOT. This next phase of model testing and calibration has yet to be complete and will require additional funding to employ a scientist to do it.

2. *Please describe any:-*
 - a) *technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.);*
 - b) *other information developed from research (eg discoveries in methodology, equipment design, etc.); and*
 - c) *required changes to the Intellectual Property register.*

The project evaluated the use of a simulated damage technique involving injection of bolls with mild pectinase solution. The simulated damage generally was more severe, at the levels tested, than real damage was, however, it was useful for understanding more precisely how cotton responds to damage. A startling finding was the degree to which cotton was able to compensate, with small yield losses and minimal delay for quite heavy damage levels (eg up to 50 bolls per metre damaged).

Conclusions

The take home messages from this research were:

1. Boll injecting was a useful tool to simulate damage by mirids, though the damage caused was more severe than that caused by mirid feeding.
2. Cotton was able to recover fully from damage inflicted in the early fruiting period (3 weeks after flowering began) when damage of 5 or 20 bolls per metre was inflicted.
3. Damage in the mid (5 weeks after flowering began) or late (8 weeks after flowering began) tended to reduce yield at heavier levels (20 or 50 bolls damaged per m) but had no effect at 5 bolls per m)
4. Yield reductions were due to reduced gin out-turn, resulting from selective removal of

damaged lint, reduced boll numbers (in some cases), and reduced boll size of damaged bolls.

5. There was strong evidence of compensation for bolls shed due to injecting. This compensation was due to retention of extra undamaged bolls which partially made up for those shed due to damage. In the heavier injection treatments it is possible that too many bolls were lost for immediate replacement by substitution, possibly explaining reduced boll numbers.

6. There is a large data set available which can be used to test and calibrate the OZCOT model, which can then be used to generate 'rules of thumb' for the degree of damage that can be tolerated.

Extension Opportunities

3. *Detail a plan for the activities or other steps that may be taken:*
 - (a) *to further develop or to exploit the project technology.*
 - (b) *for the future presentation and dissemination of the project outcomes.*
 - (c) *for future research.*

Considerable extension of the broad outcome of this project has already occurred through many presentations to grower and consultant groups at field days, farm walks, publication of results in regional trial results booklets and through lectures to the IPM Short Course and the CRC Cotton Production Course.

The main activity that needs to occur is finalising assembly of the data into the REMS format which is suitable for linking with the OZCOT model. Then the data can be used with a modified OZCOT model to allow for changes in boll numbers and size in response to damage to evaluate the capacity of the model to simulate the response of cotton to damage by mirids.

8. 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)

None to date, though Dr Duggan is committed to publishing.

- B. Have you developed any online resources and what is the website address?

None, though the outcomes will contribute to the thresholds in the revised EntomoLOGIC .

Part 4 – Final Report Executive Summary

Damage syndromes, economic thresholds and tolerance of cotton to green mirids

Green mirids (*Creontiades dilutus*) have emerged as a significant problem in commercial Bt-cotton crops, especially in Bollgard II crops. This is believed to be due to the reduced spray regimes in these crops, which allow mirids to survive and reproduce, where in the past they were co-incidentally controlled by insecticides applied against the primary pests *Helicoverpa* spp. Our past experience with mirids has been as early season pests, and although thresholds were available it was not known if these were appropriate for populations occurring later in the fruit setting and maturation period. The level of damage to fruit that can be tolerated without yield loss was poorly understood and this undermines confidence in tentative thresholds and encourages growers and consultants to use low thresholds. This can lead to increased costs, disruption of beneficial population and increases the risk of outbreaks of secondary pests such as silver leaf whitefly, spider mites and aphids. This project investigated the effect of late mirid damage to young bolls through the early, mid and late fruit set and maturation period, using real and simulated damage (boll injecting with weak pectinase solution). The results of a range of glasshouse and field experiment show;

1. Boll injecting was a useful tool to simulate damage by mirids, though the damage caused is more severe than that caused by mirid feeding.
2. Cotton was able to recover fully from damage inflicted in the early fruiting period (3 weeks after flowering began) when damage of 5 or 20 bolls per metre was inflicted.
3. Damage in the mid (5 weeks after flowering began) or late (8 weeks after flowering began) tended to reduce yield at heavier levels (20 or 50 bolls damaged per m) but had no effect at 5 bolls per m)
4. Yield reductions were due to reduced gin out-turn, resulting from selective removal of damaged lint, reduced boll numbers (in some cases), and reduced boll size of damaged bolls.
5. There was strong evidence of compensation for bolls shed due to injecting. This compensation was due to retention of extra undamaged bolls which partially made up for those shed due to damage. In the heavier injection treatments it is possible that too many bolls were lost for immediate replacement by substitution, possibly explaining reduced boll numbers.

There is now a large data set available which can be used to test and calibrate the OZCOT model, which can then be used to generate ‘rules of thumb’ for the degree of damage that can be tolerated. This can also be used as part of a decision support system which integrates mirid information with the wealth of research already captured in OZCOT, allowing interactions between growth, climate and pest damage.