



**"CONSERVATION AND UTILISATION OF BENEFICIAL
INSECTS IN THE COTTON AGROECOSYSTEM FOR
INTEGRATED PEST MANAGEMENT IN CONVENTIONAL AND
TRANSGENIC COTTON"**

SELECTED PUBLICATIONS

COTTON RESEARCH AND DEVELOPMENT CORPORATION

FUNDED PROJECT (DAN 98 C) (July 1995 to June 1998)

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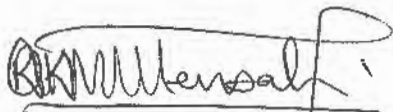
NSW AGRICULTURE

"A Final Report prepared for the Cotton Research and Development Corporation"

ISBN 0 - 7313-1549-9

DECLARATION

This addendum of the final report (DAN 98C) to the best of my knowledge contains no copy or paraphrase of materials previously published by any other person. The studies contained in this report were conducted by myself under the project Code DAN 98C funded by the Australian Cotton Research and Development Corporation (CRDC) and NSW Agriculture.



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Plain English Summary

Introduction

Objectives

A Self-Instruction Manual for Envirofeast® Integrated pest management strategy

Integrated Pest Management in Cotton based on Envirofeast and Lucerne strategies: Where are we

Habitat diversity: Implications for the conservation and use of *Helicoverpa* spp. in cotton systems in Australia

Use of *Medicago sativa* (L.) interplantings/trap crops in the management of the green mirid, *Creontiades dilutus* (Stål) in commercial cotton in Australia

Suppression of *Helicoverpa* spp. oviposition by use of the natural enemy food supplement Envirofeast®

Yellow traps can be used to monitor populations of *Coccinella transversalis* and *Adalia bipunctata* in cotton crops

Evaluation of coloured sticky traps for monitoring populations of *Austroasca viridigrisea* on cotton farms

General Discussion

Conclusions, Recommendations and Applications to Industry

PLAIN ENGLISH SUMMARY

Cotton crops in Australia are attacked by a wide range of pests, the key ones being the larvae of *Helicoverpa* spp., green mirids and mites. To sustain production, the cotton industry currently relies heavily on synthetic insecticides for the control of these pests. A major focus of the cotton industry is to reduce the dependence on insecticides and maximise the long term sustainability of the industry. One way this can be achieved by developing an alternative pest control strategy which minimises insecticide use and places much more emphasis on the role of beneficial insects. This project has developed methods for conservation, augmentation and utilisation of beneficial insects in an integrated pest management (IPM) program in cotton. It has described the numerical and functional responses of beneficial insects and determined some of the factors operating in cotton and other crops that influence the efficacy of beneficial insects. Studies to conserve and utilise beneficial insects particularly predators in the cotton agroecosystem for integrated pest management (IPM) strategies in normal and transgenic cotton were carried out between July 1995 and June 1998.

The study examined habitat diversity and its implications for the conservation and use of predatory insects of *Helicoverpa* spp. in cotton systems. The utility of crops such as sunflower, safflower, sorghum, lucerne and tomato as refugia for predatory insects and as trap crops for other cotton pests such as green mirids were examined. The lucerne crop was found to serve as a refugia for predatory insects and trap crop for green mirids when interplanted with cotton. The refugia function of interplanted lucerne was attributed to the abundance of floral nectar, alternate prey, shelter, mating and oviposition sites in the lucerne crop. Thus given the abundance of food resources, shelter, oviposition and mating sites in the lucerne, higher numbers of predators were not inclined to move from the lucerne strips to forage the adjacent cotton crop. Envirofeast® product applied at the rate of 2.5 kg/ha to the cotton crop was found to attract the beneficial insects from the lucerne to the cotton. The optimum size and the length of lucerne/cotton interplants required to effectively manage green mirids and generate beneficial insects in cotton was 8 or 12 metres of lucerne for every 300 metres of cotton. Lucerne crops planted as borders to a cotton crop were found to generate beneficial insects but were not effective in managing green mirids in cotton blocks which had more than 300 rows.

The IPM program developed in this project integrated Envirofeast® sprays, lucerne strips, gemstar virus, tracer and synthetic insecticides. The IPM program has reduced synthetic insecticide sprays and achieved a similar level of control of cotton pests and lint yield to that of conventional insecticide managed transgenic and normal cotton. In the IPM strategy, 50-80 per cent of synthetic insecticides were replaced by biological sprays. When the IPM strategy was used without Envirofeast® sprays on both normal and transgenic cotton, the cotton crop suffered a yield loss of 1.24 - 4.57 bales per hectare in the case of normal cotton and 0.74-1.24 bales per hectare on transgenic cotton.

The numbers of beneficial insects per metre were found to be significantly higher ($P < 0.001$) and green mirids per metre significantly lower ($P < 0.0001$) in the IPM managed plots with lucerne strips than on the conventional insecticide managed transgenic and normal cotton crops.

Studies to determine the consumption rate per day and factors affecting predatory beetles showed that *Helicoverpa* spp. or prey densities can affect their consumption rate through competition. Increasing prey density from 5 to 60 *Helicoverpa* spp. eggs increased the consumption rate of transverse ladybirds from 2.5 to 25 eggs per day. Higher predator densities can also affect their consumption rate. Some of the other factors affecting the consumption rate of predatory beetles were the use of synthetic insecticides particularly pyrethroids, food resource, rainfall, relative humidity, temperature, irrigation, soil cultivation.

Field studies to assess the efficacy of *Beauveria bassiana* (Naturalis®) against green mirids showed that the product had no effect on green mirid adults and beneficial insects; it caused 51.9 - 64.4 per cent mortality of green mirid nymphs 2-5 days after application. The product, therefore, cannot be used as a stand alone product for mirid management but can be used successfully in conjunction with other IPM strategies.

INTRODUCTION

Commercial cotton crops in Australia are attacked by a wide range of insects, the major ones being *Helicoverpa* spp. larvae, green mirids, two-spotted mites and thrips. The management of these pests depends almost exclusively on synthetic insecticides; natural enemies of the pests are neglected due to lack of techniques to maximise their abundance and effectiveness. Cotton production in Australia rely on within-field monocultures and this practice discriminate against and reduce the activity of predatory insects because they lack ecological diversity. The lack of ecological diversity could be the major cause of pest problems because the food, hosts, prey and hibernating or overwintering sites of most of the natural enemies of the pests are reduced thereby limiting natural biological control. This can result in pest outbreaks because abundant food is available to the pest and they need not waste time searching for food or a mate or unduly expose themselves to their natural enemies. The development of a strategy that may conserve and maximise the abundance and effectiveness of natural enemies of cotton pests particularly *Helicoverpa* spp. in cotton will be crucial to enhance the development of an integrated pest management (IPM) program in cotton. For a successful conservation and utilisation of beneficial insects as a base of an IPM program, it is important that the industry gain a detail knowledge of predator responses to prey, predator/prey interactions, factors limiting their efficacy and the utility of other crops as refugia for beneficial insects. It is also important for the industry to gain knowledge in the utility of other pest management or insect behaviour modifying tools that can attract beneficial insects or suppress oviposition of pests or control the pest with minimal disruption to the efficacy of the beneficial insects in cotton systems.

The aim of this study was to (1) improve our understanding of predator responses to prey, predator/prey interactions and factors limiting their efficacy in cotton systems, (2) improve the performance of Envirofeast® product developed in DAN 68 and 89C (3) develop strategies to attract, conserve and utilise beneficial insects as basic components of IPM in cotton and (4) manage green mirids and aphids through conservation of beneficial insects.

GENERAL DISCUSSION

The trend to achieve higher cotton yields and produce early cotton in Australia has resulted in an over-reliance on synthetic insecticides in the management of cotton pests. The cotton industry is currently at risk of losing most of the currently registered products due to increasing resistance and environmental problems. The development and introduction of transgenic cotton into the cotton industry was originally viewed as an answer to the industry's problems, but now there is the belief that *Helicoverpa* spp. will develop resistance to the transgenic crops. The crops will need to be managed in the context of IPM program if insect resistance to the crops is to be delayed. Also, despite the introduction of transgenic cotton in the cotton industry, there will still be 50-60 per cent normal cotton crops grown in the industry to avert risk and guarantee the future sustainability of the cotton industry. These normal cotton crops will require management against pests. However, with increasing resistance and societal pressure to progress from application of synthetic insecticides to innovative methods for insect control that are non-hazardous to human health and to environmental quality, pest management strategies involving the use of beneficial insects as basic components are essential to reach this goal. This is because *Helicoverpa* spp. which are major pests of cotton crops in Australia, are highly migratory and therefore can rapidly infest cotton crops and lay their eggs; natural enemies should therefore be present and well established in high numbers before the pest arrive to respond rapidly and control them. The development of a strategy that may conserve and maximise the abundance and effectiveness of the natural enemies of *Helicoverpa* spp. in cotton fields is important to enhance the control of these pests.

This study has shown that interplanting lucerne in cotton fields by strip-cropping can serve as a refugia to conserve beneficial insects in cotton fields. The refugia function of the lucerne strips may be attributed to the abundance of floral nectar and alternate prey, shelter, mating and oviposition sites etc harboured in the lucerne crop compared to monocultural conventional cotton. These resources enhanced the establishment of the predators in the lucerne. However, given the abundance of food resources, shelter, mating, oviposition sites etc within the lucerne strips, beneficial insects may not be inclined to move from the strips to forage the adjacent cotton crop. The movement of these beneficial insects from the lucerne to the adjacent cotton crop can be improved by applying Envirofeast® product to the cotton crop to attract the predators. Local density responses of predatory insects to Envirofeast® spray is not drastic but is a slow process resulting from attraction and arrestment of predators enabling them to build up over time and space. The build up of predators in cotton can also be affected by other factors such as use of synthetic insecticides especially pyrethroids, quantity and quality of food resource available, density of predators themselves, rainfall, relative humidity, temperature, irrigation, soil cultivation etc.,

Currently, there are many pest control tools ranging from biological pesticides such as NPV virus, conventional Bt, transgenic crops with Bt toxin, pheromones, *Trichogramma* spp., *Helicoverpa* spp. moth attractants, synthetic insecticides etc. which are available to cotton growers for managing cotton pests. Unfortunately, these tools have not been integrated into IPM programmes for use by growers. The current pest management strategy despite widespread use of thresholds and objective sampling belies any application of the term IPM because of their over-reliance on synthetic insecticides and there are no strategies to maximise the abundance of beneficial insects and utilise them in the strategy. A true IPM program can only be developed if pest control tools are integrated with strategies or techniques to use beneficial insects as basic components or base of the program.

This study has developed an IPM strategy based on Envirofeast® spray, lucerne refugia strategy, biological insecticides particularly Gemstar® (NPV) virus and selective insecticides and achieved cotton yields similar to or sometimes higher than conventional insecticides. This is the first attempt to courageously develop a true IPM program for the cotton industry. The study also has developed a threshold based not only on the pest (*Helicoverpa* spp.) as has been done and used originally (Entomologic) but based on the predator to pest ratio for any decision to intervene with any of the tools within the IPM program. The Envirofeast® IPM program has been developed on both normal and transgenic cotton.

The IPM program apart from achieving cotton yields similar to conventional insecticide managed cotton has also reduced the total insecticide use and replacement of synthetic insecticides particularly endosulfan with Envirofeast® and other biological insecticides. For the IPM strategy developed in this study to work effectively, it should be used in areas free from disruptive insecticides such as pyrethroids and this can be best achieved if neighbours co-operate to form a regional or area-wide group and use the strategy. Thus an area-wide or regional based Envirofeast® IPM program can be more successful than an individual grower adjacent to neighbours managing their cotton with synthetic insecticides.

After 6 years of developing this strategy, it has been shown that good results could be achieved with growers who do not panic spray, spend time to check their crops thoroughly, have a good power of observation and can predict an onset of pest problems and apply sprays at the correct time.

The study has also strengthened and confirmed the benefits of using Envirofeast® product within the IPM program. The results of the study showed that cotton crops managed with IPM tools without Envirofeast® had a yield loss of between 1.24 to 3.46 bales per hectare. This clearly shows that each of the components within the program contributes to the success of the whole IPM strategy.

For the future sustainability of the Australian cotton industry, there should be a reduction in the use of chemical pesticides. Envirofeast® IPM which has been developed in this study is an option to assist in this process.

CONCLUSIONS, RECOMMENDATIONS AND APPLICATION TO INDUSTRY

For years now, beneficial insects have been neglected in cotton pest management systems due to the disruptive impact of pesticides, the lack of techniques to maximise their abundance and effectiveness and also the lack of ecological diversity in Australian cotton systems. This study has developed an IPM strategy based on Envirofeast® spray, lucerne refugia, biological insecticides particularly Gemstar® (NPV) virus and selective insecticides and achieved cotton yields similar to or sometimes higher than conventional insecticides. The IPM program apart from achieving cotton yields similar to conventional insecticide managed cotton, has also reduced the total insecticide use and replaced synthetic insecticides particularly endosulfan with Envirofeast® and other biological insecticides. The reduction in the total chemical use particularly endosulfan is important for the industry in line with NRA's recent restriction on the continuous use of endosulfan in the cotton industry. The refugia strategy which involves growing lucerne as strips within cotton farms served as trap crops for early season cotton pests particularly green mirids and as refugia to generate beneficial insects for cotton. The management of green mirids through the use of lucerne strips will help limit the use of dimethoate to control these pests during infestations. To conclude, this study has shown that

- Envirofeast IPM program can effectively manage cotton pests to achieve cotton yields similar to or sometimes higher than conventional insecticides.

- Envirofeast® when applied to cotton can attract and sustain beneficial insects enabling them to be utilised in IPM programmes.
- Performance of Envirofeast is enhanced by the presence of lucerne strips which serve as a refuge for beneficial insects and sinks to manage green mirids on cotton.
- Cotton crops managed with IPM tools without Envirofeast® had a yield loss of between 1.24 to 3.46 bales per hectare.
- Envirofeast® IPM on conventional cotton can help manage resistance through the reduction in total insecticide use and replacement of synthetic insecticides, particularly endosulfan.
- Envirofeast® IPM on transgenic cotton enhances the efficacy and durability of the transgenic crops by increasing the activity of the beneficial insects and exposing *Helicoverpa* spp. neonates to a second mortality factor instead of a single killing mechanism i.e. the transgenic crop.
- Envirofeast IPM should be used in areas free from disruptive insecticides such as pyrethroids and this can be best achieved if neighbours co-operate to form a regional or area wide group and use the strategy. Thus area-wide or regional based Envirofeast® IPM program can be more successful than an individual adjacent to neighbours managing their cotton with synthetic insecticides.
- Envirofeast IPM will work for users who do not panic spray, spend time to check their crops thoroughly and apply the sprays at the correct time.
- Any decision to intervene with insecticides within the Envirofeast® IPM program should be based on the predator to *Helicoverpa* spp.(*Heliothis*) ratio which is calculated from regular sampling (bug checking). Guidelines for use of Envirofeast IPM are available to growers from the Technology Resource Centre at ACRI and Rhone-Poulenc representatives.
- For the future sustainability of the cotton industry there should be a reduction in the use of chemical pesticides and Envirofeast® IPM is an option to assist in this process.

For the Envirofeast and refugia technologies developed in this study to be fully adopted growers, the industry should place much more emphasis on educating farmers on the concept of a true IPM. Growers should improve their understanding of a true IPM, how it is developed and works and also the differences between Insecticide Resistance Management Strategy and IPM. The Best Management Program should incorporate the IPM program developed in this study and assist growers to adopt it. Extension staff should also be involved in educating growers about the Envirofeast technology through workshops, field days, seminars and conferences.

COMMUNICATION OF RESULTS

1. MENSAH, R. K. (1998). Habitat diversity: Implications for the conservation and use of predatory insects of *Helicoverpa* spp. in cotton systems in Australia. *International Journal of Pest Management* (In press).
2. HULLUGALLE, N. R., MENSAH, R. K. and ENTWISTLE, P. C. (1998). Can Lucerne (*Medicago sativa* L.) Strips Improve Soil quality in Irrigated Cotton Fields? *Journal of Applied Soil Ecology* (In press).
3. WILSON, L. J., FITT, G. P. and MENSAH, R. K. (1998). Transgenic (Ingard) cotton: its role in cotton IPM in Australia. in "Pest Management-future challenges" (In press).
4. MENSAH, R. K. and SINGLETON, A. (1998). IPM based on Envirofeast and Lucerne technologies: Where are we now? *Australian Cotton Grower* 19(3): 65-69.
5. HULLUGALLE, N. R., MENSAH, R. K. and ENTWISTLE, P. C. (1998). Interplanted Lucerne and the quality of soils in field crops. *The Australian Cotton Grower* 19(2): 77-80.
6. GURR, G. M., WRATTEN, S. D., MENSAH, R. K., HOSSAIN, Z., BAGGEN, L. R. and WALKER, P. W. (1998). Habitat Manipulation in Australasia: recent biological control progress and prospects for adoption in "Pest Management-future challenges" (In press).
7. MENSAH, R K and KHAN, M (1997). Use of *Medicago sativa*(L) interplantings/trap crops in the management of the green mirid, *Creontiades dilutus* (Stal) in commercial cotton in Australia. *International Journal of Pest Management* 43 (3): 197-202.
8. MENSAH, R K (1997). Local density responses of predatory insects of *Helicoverpa* spp. to a newly developed food supplement "Envirofeast" in commercial cotton farm in Australia. *International Journal of Pest Management* 43 (3): 221-225.
9. MENSAH, R K (1997). Organic cotton production: An Australian Experience. In: *World Organic Cotton Production and Consumption* (ed Dorothy Myers, Cotton Project Co-ordinator, The Pesticide Trust, London, UK) (In press).
10. MENSAH, R. K. and SINGLETON, A. (1997). Conservation of Beneficial arthropods through habitat manipulation. *Australian Entomological Society Scientific Conference* 28: 54.
11. MENSAH, R K (1997). A self-instruction manual for Envirofeast® integrated pest management program for cotton pests. CRDC/Rhone-Poulenc (Aust) Pty Ltd Envirofeast IPM Support Group, pp12.
12. MENSAH, R K (1997). Farmers Cotton on to bugs for protection. *GEO Australasia* 19:11.
13. MENSAH, R K, HARRIS, W and G A C Beattie (1996). Response of *Helicoverpa* spp. and its natural enemies to petroleum oil sprays in cotton. *Entomophaga* 40 (2) 263-272.
14. MENSAH, R K (1997). Habitat diversity in agriculture and its implications to pest management: An Australian Cotton Industry perspective. *The South African Holistic Reporter* 5: 7-10.
15. MENSAH, R K, (1996). Suppression of *Helicoverpa* spp. oviposition by use of the natural enemy food supplement Envirofeast®. *Journal of Australian Entomological Society* 35: 323-329.
16. MENSAH, R K, (1996). Evaluation of coloured sticky traps for monitoring populations of *Austroasca viridigrisea* (Paoli) (Hemiptera: Cicadellidae) on cotton farms. *Journal of Australian Entomological Society* 35: 349-353.
17. MENSAH, R K and HARRIS, W (1996). Envirofeast® IPM in cotton: Part 1. Integration with lucerne strips to manage green mirids in cotton. *Proceeding 8th Australian Cotton Conference, Broadbeach, Queensland, pages 221-226.*
18. MENSAH, R K and HARRIS, W (1996). Envirofeast® IPM in cotton: Part 2. Integration with lucerne strips as refugia for beneficial insects in cotton. *Proceeding 8th Australian Cotton*

- Conference, Broadbeach, Queensland, pages 229-236.
19. MENSAH, R K and HARRIS, W (1996). Envirofeast® IPM in cotton: Part 3. --Integration with Nuclear Polyhedrosis virus. Proceeding 8th Australian Cotton Conference, Broadbeach, Queensland, pages 237-246.
 20. MENSAH, R K and HARRIS, W (1996). Responses of transverse and two-spotted ladybird beetles to coloured sticky traps in commercial cotton. Proceeding 8th Australian Cotton Conference, Broadbeach, Queensland, pages 257-262.
 21. MURRAY, D and MENSAH, R K (1996). Using predators and parasites to control cotton pests. Proceeding 8th Australian Cotton Conference, Broadbeach, Queensland, pages 147-151.
 22. MENSAH, R K (1996). Lucerne strips in Cotton-Envirofeast IPM: Guidelines pp3.