



***CSIRO Plant Industry  
Cotton Research Unit  
and  
CRC for Sustainable Cotton Production***

**FINAL REPORT**

- Project title:** Improved pest management for mites and thrips on cotton.
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*A final report prepared for the Cotton Research and Development Corporation*

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## Improved pest management for mites and thrips on cotton.

**Project Number:** CSP46C

**Organisation:** CSIRO Division of Plant Industry

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### Aims:

- Determine the economic impact of thrips on cotton and evaluate new means of control.
- Evaluate the range and possible mechanisms of plant resistance to thrips and mites.
- Investigate host preferences of thrips and manipulation of hosts to increase thrips predation.
- Investigate further the impact of thrips on mites through predation, induced resistance and effects on plant quality.
- Refine action thresholds for the control of two-spotted spider mites on cotton.
- Evaluate the efficacy of new acaricides and investigate novel technologies for controlling mites.
- Determine resistance levels in mites to acaricides and factors influencing development of resistance.
- Evaluate the effect of early season insecticides on mites and their predators.

### Summary of Results

A summary of the research, methodology, results and outcomes is given below.

- **Determine the economic impact of thrips on cotton and evaluate new means of control.** The economic impact of thrips on cotton was studied in experiments on commercial cotton farms during each season for the life of the project. In all experiments the growth, yield and maturity of cotton protected from thrips using aldicarb (Temik at 3 kg/ha) was compared with unprotected cotton. In some experiments seed treatments such as Semevin or Gaucho were also included. All of these large scale replicated experiments (13) were conducted successfully.

Counts of thrips adults or immature stages in the field were compared with those from

accurate laboratory counts based on plant washes. Laboratory counts of adult thrips showed an adequate relationship with field counts with an  $r^2$  of 0.63 ( $r^2$  indicates the proportion of variability explained by the relationship between two variables with 0 being no relationship and 1 being a perfect relationship), but field counts consistently underestimated true thrips abundance. Field counts of thrips larvae showed a poor relationship with laboratory counts ( $r^2$  of 0.34). Field counts tended to grossly and inconsistently underestimate the abundance of larval thrips. Comparisons of field counts by three very experienced technical staff further revealed that between-person variability in counts was also quite high. Over the season one staff member consistently counted half as many thrips as another, probably due largely to differences in visual acuity. These findings suggested that field counts were of limited value other than to indicate generally if thrips were present and abundant or not. We therefore placed effort into developing and expediting the laboratory plant wash technique for future work. This technique was made available to other organisations wishing to estimate thrips abundance in cotton and is now widely adopted by Cotton Seed Distributors, Deltapine, Bayer and Rhone-Poulenc and was resulted in acquisition of high quality data on the efficacy of insecticides against thrips by these companies.

In experiments, thrips abundance was found to be well correlated with superficial damage to tips and terminal leaves. That is the damage caused to the edges of embryo leaves which results in the distorted and cupped leaves typical of thrips damage. However, thrips abundance was poorly correlated with tipping out; in fact within the range of thrips densities in these experiments, 10 - 50 thrips per plant, thrips were rarely responsible for tip damage. Most tipping out was attributable to *Helicoverpa* spp., mirids and occasionally other Lepidoptera.

Thrips abundance showed a reasonable correlation with early season measures of plant growth such as plant height and dry weight. More thrips resulted in a greater reduction in plant height and dry weight. These differences were highly visible in the field, ie protected plants looked much bigger and more vigorous. However, poor correlations were found between thrips abundance and node production or time to first square, indicating that plant size (dry weight) was affected but plant development was not. Furthermore there was no significant correlation between thrips abundance and yield or crop maturity.

Plant growth analysis was also used to explore the recovery of cotton from thrips damage (in collaboration with Dr Victor Sadras). Thrips damage was found to cause highly significant reductions in plant dry weight, leaf area and tap root weight, even at relatively low thrips densities (3 - 5 per plant). These effects generally peaked at about 30 to 50 days after sowing, when reductions of 50-60 % in dry weight were common, and resulted in highly visible symptoms which made damaged cotton stand out from protected cotton. However, by about 60-80 days after sowing, the damaged plants had fully recovered and had dry weight, leaf area and tap root size similar to that of undamaged plants. These results indicated that although thrips affected early season plant growth, these effects did not necessarily translate into loss of yield nor delay in maturity.

Overall, however, when data from all experiments were analysed together there was an increase in yield in the aldicarb treated plots of about 2 % compared with the control plots, which was statistically significant and not correlated with thrips abundance.

Crop maturity showed a similar, marginally significant, advantage of about 4 days earliness in the aldicarb treated plots compared with the control plots, which was marginally statistically significant. The exact reasons for the yield benefit in aldicarb plots is unknown and should be investigated further in the glasshouse.

The efficacy of the seed treatments thiodicarb (Semevin) and imidacloprid (Gaucho) for control of thrips was investigated and compared with an in-furrow insecticide aldicarb. Semevin provided moderate control of thrips populations for about 2 weeks, but did not result in an increase in yield or earlier crop maturity. Gaucho provided good control of thrips for about 4 weeks and occasionally this translated into a slight gain in yield. Aldicarb provided superior control to either seed treatment.

The results show that thrips cause plants to have reduced dry weight but they are rarely responsible for tipping out. Cotton is generally able to recover from thrips damage with little reduction in yield or delay in crop maturity. Given that thrips also eat mite eggs (see below), control of thrips, especially with broad-spectrum foliarly applied insecticides, is largely unjustified except in rare years of extreme abundance when populations exceed 20 thrips/plant.

- **Evaluate the range and possible mechanisms of plant resistance to thrips and mites.** The resistance of 17 cotton genotypes to thrips investigated. The abundance of thrips and growth (dry weight) of cotton in plots protected from thrips using aldicarb (Temik at 3 kg/ha) was compared with that of unprotected plots. The results showed only small differences between genotypes in resistance to thrips, either in terms of thrips abundance or in terms of the ratio of thrips to reduction in dry weight. Only two genotypes appeared to offer any useful resistance. These were a high tannin line (HT-35-14-3) and a glandless line. The latter is highly susceptible to other pests though, especially flea beetles and *Helicoverpa* spp..

Two main types of resistance to spider mites were considered in this study – morphological resistance (leaf shape and hairiness) and chemical resistance (elevated levels of tannins, terpenoids or other secondary plant products). Over the course of the project a wide range of genotypes were considered including high gossypol lines, high condensed tannin lines, hairy lines, a range of leaf shapes from super-okra to normal and also a different species *G. barbadense* (Pima). In all experiments cotton was artificially infested with mites in January to evaluate plant resistance to mites.

Overall the experiments showed relatively little chemically based resistance, with the notable exception of the Pima genotype which was highly resistant to mites. The lack of significant resistance due to either elevated levels of terpenoids or condensed tannins was confirmed in the laboratory. The suitability of a high gossypol genotype, HG660, and high condensed tannin genotype, Ht-35-14-3 for development and reproduction of mites was not different to that of the mite susceptible commercial variety Deltapine 90. The poor suitability of Pima was also confirmed in laboratory studies which indicated that mites on Pima took about 12% longer to develop, laid about half as many eggs and died earlier than mites on DP90.

The results showed a strong morphologically based resistance conferred by the okra and super-okra leaf shapes. The mechanism underlying this resistance is related to the reduced proportion of the leaf area that is suitable for mite colonisation on leaves that are more deeply lobed (okra or super-okra). Spider mites eggs are particularly sensitive

to desiccation. As mites are small (adults  $\cong$  0.5 mm and eggs  $\cong$  0.1 mm) the environment they mostly experience is that of the boundary layer of air trapped close to the leaf surface. The humidity of the boundary layer is influenced by the degree of transpiration and by ambient conditions and can be disrupted by air turbulence or buffered by morphological features that create regions of reduced turbulence such as high hair density, leaf folds, prominent leaf veins and leaf shape. The resistance to mites in okra and super-okra leaf cotton is due to the shallower, more disrupted boundary layer of these leaves, which would result in fewer high humidity sites suitable for oviposition and egg survival than on normal leaves. This mechanism was defined as ovipositional non-preference.

Addition of the glabrous trait (completely hairless leaf) also increased resistance to mites, with normal and okra glabrous lines showing higher resistance than normal or okra lines with standard (delta-smooth) hairiness. The glabrous trait probably reduced the degree of protection on the leaf surface from the disrupting effects of turbulence, resulting in an even more disturbed boundary layer (see above). Observation on moderately hairy genotypes support this assertion: increasing density of leaf hairs could be expected to act as an 'insulation' against turbulence, thereby making more of the leaf surface suitable for oviposition by mites. In the field, mites increased more quickly on hairy cotton varieties than on glabrous lines. In the laboratory, mites developed equally as well on hairy or glabrous lines indicating that neither food quality nor antibiosis explains the higher suitability of hairy lines. In preference tests mites strongly preferred to feed and oviposit on hairy lines compared with glabrous or delta-smooth lines. The distribution of mites on the leaf surface of glabrous leaves was closely defined to 'protected' locations on the leaf surface such as near veins or in leaf folds. In contrast, on hairy leaves mites tended to be spread over most of the leaf surface and showed no particular preference for protected sites. The results suggest that the presence of leaf hairs may make the micro-environment of the leaf surface more uniformly suitable for mites.

- **Investigate host preferences of thrips and manipulation of hosts to increase thrips predation.** This component of research was undertaken by Dr Manthana Milne (nee Khumlekhasing), then a Phd student in the Entomology Department at the University of Qld who received partial funding from this grant. Dr Milne was supervised by Dr G. Walter at UQld and Dr Wilson was an associate supervisor. Dr Milne undertook a systematic survey of the abundance of the key thrips pest species on a wide range of weeds and cultivated hosts in the Namoi Valley. She found that cotton is probably not a primary host for thrips and is utilised through summer mainly due to the absence of other preferred hosts such as turnip weed.
- **Investigate further the impact of thrips on mites through predation, induced resistance and effects on plant quality.** Dr Milne also investigated the predacious capacity of *Frankliniella schultzei* and *Thrips tabaci* two species of thrips which damage cotton but also eat mite eggs. Dr Milne (1) confirmed that *Frankliniella schultzei* does eat mite eggs, (2) showed that if thrips have access to mite eggs they develop faster, lay more eggs and live longer than if they only have access to cotton cotyledons, hence they derive a benefit from predacious activity, (3) predation was age dependant: 1st instars ate few eggs and most consumption was by 2nd instars, though adults also eat mite eggs, and (4) mite webbing reduces the mite egg consumption rate of thrips. It was suggested that *F. schultzei* eats mite eggs to make up for the deficient

diet provided by cotton cotyledons. Nevertheless, this species does better when offered a diet of the floral parts of its primary host (*Malvaviscus arboreus*) than on a diet of cotton cotyledons plus mite eggs. This suggests that mite eggs do not completely make up for a deficient adult or larval diet. Dr Milne subsequently confirmed that *T. tabaci* is also predacious on mite eggs and that the addition of mite eggs to the diet of larvae of this species, raised on cotton cotyledons, similarly leads to increased fitness (faster development and higher fecundity). Dr Milne submitted her Phd Thesis in December 1996, and it was awarded in 1997.

- **Refine action thresholds for the control of two-spotted spider mites on cotton.** In a previous project a statistical model was developed which allows prediction of the yield loss expected from a mite population given the current date, the rate of increase of the population and the expected 60% open date for the crop. This model has been used to develop thresholds for spider mites in cotton and has been incorporated into the entomoLOGIC decision support package. However the point at which mite feeding damage begins to translate into yield loss, the damage boundary, is not known. It is important to define the damage boundary as it indicates the degree of urgency in the need to control a mite population that it is predicted will eventually cause economic yield loss.

Experiments were set-up in which cotton was artificially infested with mites at given times through the season or left uninfested. Mite populations in the infested plots were either left untreated to develop to their maximum potential, or were controlled at a range of densities along their population increase trajectory. In this way the effects of known increments of mite damage on yield, maturity and fibre quality could be determined.

Three experiments of this type were successfully conducted and a wide range of mite control levels achieved. Unfortunately this data still needs to be fully analysed and written up. Nevertheless, initial observation of the data reveals that it is not until there is significant damage from mites that yield actually declines. However, at the densities where mite damage translates to yield loss the population are too high to achieve adequate control in commercial situations. The existing yield loss prediction equations are therefore still the most appropriate way of forecasting potential yield losses from mites and making control decisions when mite populations are still at levels that can be effectively controlled. The value of the information found in these experiments is that it indicates how much time the grower/consultant has in which to make decisions regarding the need for mite control, before yield loss starts to occur.

Flowing from the original interest in the effects of mites on yield, discussions were initiated with Dr Victor Sadras, then a newly appointed crop physiologist, to look at the effects of mites on plant growth and radiation use efficiency. This work has doubled the value of the experiments. Additional measurements of light interception, crop temperature, dry matter partitioning and analysis of the nitrogen content of plant tissues were taken throughout the experiments described above.

This element of research was highly successful and has been fully analysed and written up for publication in journals. Mites reduced the radiation use efficiency (conversion of sunlight and CO<sub>2</sub> into plant biomass) of cotton crops in a consistent and predictable manner that was highly negatively correlated with mite abundance and duration of infestation. A quantitative relationship was developed between RUE and

an index of mite abundance. Confirming the findings outlined above a degree of compensatory RUE was found at low to moderate mite densities. Okra leaf and normal leaf varieties responded in the same way, but reductions in RUE were less on okra leave varieties due to fewer mites. Mites affected the amount of dry matter accumulated by plants, resulting in smaller plants but did not affect the allocation of dry matter between vegetative and reproductive growth. This indicated that most of the effect of mites on plant growth can be captured by the relationship between RUE and the mite population index.

This information will enable counts of mites to be coupled with the Ozcott/Cercott crop models. This will allow estimation of the effects of mites on yield loss, primarily through their effect on the crops radiation use efficiency, and the interaction of mite damage with other forms of stress to be explored. Other stress where interactions might be expected could be damage from other pests, water stress, nutritional stress and stress from diseases. These interactions would of course need to be validated by limited field experimentation, but the work undertaken here would forms the basis for the initial link between mites and the cotton model(s). Data sets from previous experiments are available to validate such initial modifications to the model.

- **Evaluate the efficacy of new acaricides and investigate novel technologies for controlling mites.** The efficacy of new acaricides was investigated in several experiments during the life of the project.

*Experiment 1.* Efficacy of three rates of each of three new acaricides, AC303630 (Intrepid), MK239 (Pyranica) and Avermectin (Agrimec), was compared with that of the current standard, propargite (Comite). AC303630 and MK239 at the two higher rates showed efficacy equivalent to or greater than propargite. Avermectin gave poor results at the lower rates, but the highest rate was equivalent to propargite.

*Experiment 2.* Efficacy was compared for 7 new and existing acaricides for which there is little local independent information. The initial mite population in the experiments was quite high at about 30 mites per leaf or about 80-90 % of plants infested. Under these conditions profenofos (Curacron, Sabre), amitraz (Ovasyn, Amitraz) and dicofol (Kelthane, Mitifol) gave a relatively short period of control (about 7 days). The poor result with profenofos was probably due to mite resistance. Amitraz and dicofol are contact acaricides with relatively low activity. Obtaining sufficient coverage to provide good control in a dense actively growing canopy probably reduced the efficacy of these products. Kelthane usually gives much longer residual control when applied to young cotton. The other acaricides, bifenthrin (Talstar), propargite (Comite), avermectin (Agrimec) and the new product diafenthiuron (Pegasus) all performed well and kept mites to pre-spray levels or lower for two weeks but by the third week mites had begun to increase in all plots. More durable control would have resulted if mites had been sprayed at the mite threshold of 30% of plants infested.

- **Determine resistance levels in mites to acaricides and factors influencing development of resistance.** In each year of the project collections of mites were taken from commercial farms where there had been repeated use of acaricides or where there had been reported problems with the efficacy of acaricides. These collections were sent to Dr Grant Herron at BCRI, Rydalmer to investigate possible acaricide resistance. Acaricides considered included propargite, dicofol, profenofos, monocrotophos,

aldicarb and bifenthrin. Discriminating doses were developed for each of these compounds to simplify testing.

1992/93. No indication of resistance was found to either propargite, dicofol or bifenthrin and the cause of the only reported control failure with propargite was therefore probably due to poor application or to low temperature at the time of application which reduced the fumigant action of this product. Resistance to monocrotophos and profenofos remained at moderate levels as expected.

1994-95. Resistance in mites was monitored in 6 strains from the Namoi and Macquarie Valleys. Resistance to monocrotophos and profenofos increased dramatically to average 240x and 64x respectively. This increase is most likely due to the increase in profenofos use late in this season, caused by heavy *Heliothis* pressure and loss of Helix. Cross-resistance between monocrotophos and profenofos probably explains the increase in resistance to monocrotophos, which was used little. Fortunately no indications of resistance were found to dicofol, propargite or bifenthrin.

1995-96. Resistance in mites to was monitored in 7 strains from the Namoi Valley. Resistance to profenofos and monocrotophos declined to levels similar to 1993/94. This may be because the introduction of Agrimec and increased use of propargite as a synergist with pyrethroids for *Heliothis* control. This probably reduced selection pressure with profenofos. No indications of resistance were found to dicofol, propargite, bifenthrin or aldicarb.

The loss of the OP's as effective acaricides in cotton highlights the potential for resistance to develop to other acaricides as well. This threat is particularly great for those products that are also used for *Helicoverpa* control such as bifenthrin (a pyrethroid) and propargite (which is used as a synergist for the pyrethroids). To address this problem an acaricide resistance management strategy was developed in collaboration with Dr Herron and Dr Neil Forrester. The strategy was based around two principles (i) limiting use of any acaricide to no more than two applications per season and (ii) recommending that applications of the same acaricide should not be made consecutively, ie enforced rotation of acaricides. These tactics should be effective because there is no evidence of cross-resistance between the key acaricides (propargite, dicofol and bifenthrin). The first acaricide resistance strategy was widely publicised as part of the development of the Resistance Management Strategy for 1992-93 and accepted by AIRAC, the CCA and the growers associations and ratified each year thereafter as a component of the strategy.

The granular carbamate insecticide/miticide aldicarb is used by about 10-20% of the cotton industry as an at-planting treatment to protect plants against thrips and other sucking pests. Aldicarb is also an effective acaricide and provided the amount taken up by the plant is high enough will control mites on seedling cotton – thereby delaying the build-up of mite populations to some extent. Long-term use of aldicarb on a farm could lead to local selection for resistance to aldicarb in mite populations. This problem is compounded by evidence from earlier research of a degree of cross-resistance between carbamates and organophosphates in mites. We therefore developed an approach to investigate if long term use of aldicarb selects for increased carbamate resistance in spider mites or for cross resistance to organophosphates. Dr Herron successfully developed and tested a safe reliable bio-assay procedure for aldicarb,

is the possible 'stimulatory' effects of insecticides on mites. Proposed stimulatory effects involve altered mite metabolism following contact with insecticide residues which results in faster development, increased fecundity or altered sex ratios of spider mites. Less direct effects such as improved nutritional quality of the host plant or dispersal and release from competition may also be involved. Although there is considerable evidence from laboratory studies to support the potential role of such stimulatory effects in outbreaks of mites, supporting evidence from field studies is limited and there was no evidence from Australia at all. Our results also showed that endosulfan did not cause outbreaks of spider mites, despite having a significant negative effect on some mite predator groups. This suggested that endosulfan may be moderately acaricidal, so that the potential to create mite outbreaks through predator reductions was offset by control of mites.

The possible stimulatory or acaricidal effects of thiodicarb, dimethoate and endosulfan on two-spotted spider mite were therefore tested in the glasshouse. Cotton plants were grown in pots in a glasshouse until early squaring stage, artificially infested with four adult female mites, and randomly allotted to 4 spray treatments; control, endosulfan, dimethoate or thiodicarb. Sprays were applied 3 times at weekly intervals. Plants were taken outside the glasshouse and sprayed with a conventional ground rig. Population development of mites was monitored, with the expectation that any stimulatory or acaricidal effects would be reflected in different population growth relative to untreated plants. Population growth on thiodicarb or dimethoate treated plants was no different to that on untreated plants but was slower on plants treated with endosulfan.

The acaricidal activity of the three insecticides was also investigated using a standard bio-assay technique, in collaboration with Dr Grant Herron (NSW Agriculture). Bio-assays showed that endosulfan was moderately acaricidal, that mites were highly resistant to dimethoate and that thiodicarb was of very low acaricidal activity. No evidence of stimulatory effects of dimethoate or thiodicarb was found. The data suggest that stimulation is an unlikely explanation for outbreaks of mites in cotton and that endosulfan sprayed for control of *Helicoverpa* spp. may delay the development of mite outbreaks.

Aphids were also more abundant in the full rate thiodicarb plots than in other treatments. Thiodicarb probably induces aphid outbreaks because it eliminates predators of aphids, especially lady beetles. Dimethoate and endosulfan do not induce aphid outbreaks, even though they reduce aphid predators, because they are partly aphicidal.

These outcomes have had a major impact in (i) the appreciation by all facets of the industry involved in cotton production of the role of predators in cotton (ii) the effects that insecticides can have on later outbreaks of secondary pests such as aphids or mites and (iii) providing the first independent data on the comparative effects of a range of key cotton insecticides on beneficial insects. The outcomes have been used to generate appropriate management recommendations for mites and have been widely communicated to industry via numerous meetings in the major growing regions as part of the annual Resistance Management Tour, in presentations at and in the proceedings of the Australian Cotton Conference, the 'Cotton Video', the 'Land' paper and the Australian Cottongrower magazine.

### Other achievements

- Investigation of mite survival in soil or litter of cotton fields through winter found no over-wintering mites from any of the locations sampled. This confirms earlier results and reinforces the hypothesis that mites overwinter on suitable vegetation.
- Assisted Dr Paul De Barro with initial surveys of cotton to look for B-Type *Bemisia tabaci* and for predators or parasites of whitefly. This was very worthwhile – we found B-type whitefly on cotton in the Namoi Valley and on several weed species, most notably sowthistle. A wide range of predators and potential parasitoids were also collected. We have continued to provide Dr De Barro with regular collections of whitefly from cotton to track the establishment of B-type in cotton.
- In each year of the project Dr Wilson presented information on resistance in mites and on IPM research to grower/consultant groups at 10 locations (Narrabri, Moree, Goondiwindi, St George, Dalby, Emerald, Warren, Mungindi, Theodore and Gunnedah) on the "Insecticide Resistance Management Tour" organised by Dr Neil Forrester and Mr Bruce Pyke.
- In collaboration with Mr Bruce Pyke organised and ran a two-day workshop on IPM in cotton. The workshop provided a forum for researchers to present to their peers their latest research findings, to discuss research outcomes and directions and to review priorities for future research in an informal, collaborative setting. This was important because researchers are geographically separated which means opportunities to meet and review findings as a group were few. A report was written which provided a 'digested' summary of the key points to emerge from each research project discussed and the report provided to all participants and to CRDC.

### Recommendations for Future Research

1. Further define the economic impact of thrips on cotton with emphasis on short season areas.
2. Further define the economic impact of early season damage to cotton in terms of yield and maturity for transgenic cotton, considering effects of specific pests (thrips, mirids and *Heliothis*) both alone and in combination, and interactions with plant density.
3. Evaluate the effect of new insecticides on non-target insects and on secondary pest outbreaks (mites, aphids and whitefly).
4. Investigate the interaction between biotic and abiotic stresses on cotton yield, quality and maturity with specific emphasis on mite damage (biotic) and drought or nutritional stress (abiotic)
5. Investigate the effects of aphids on yield of cotton.
6. Monitor resistance levels in mites to acaricides and investigate the effects of insecticides on mite reproduction and development.
7. Continue research to into plant resistance to mites focussing on new genotypes from the Australian Cotton Breeding Program.
8. Investigate over-wintering of mites on winter rotation crops.

### Application of Results to Industry

The results of the research reported build strongly on the basic information provided by the previous project (CSP1C). Extension of this research to industry has contributed to changes in practices. Key impacts have been;

1. Highlighting the importance of early season pest management in 'setting the stage' for IPM in cotton. Consultants and growers are aware of the role of beneficial insects in cotton and beginning to include their effects in decision making (collaboration with Dr Herron).

2. Confirming the role of thrips as predators of spider mite eggs
3. Providing growers/consultants with independent information on the effect of different insecticides on beneficial insects
4. Increasing awareness of the wider issue of plant compensation for early damage in general and the recovery of plants from early season thrips damage in particular (collaboration with Dr Sadras).
5. Providing independent information on the efficacy of new acaricides.
6. Developing an acaricide resistance management strategy in cotton and monitored resistance levels to all current acaricides (in collaboration with Dr Herron and Dr Forrester).
7. Providing a deeper understanding of how mites affect plant growth to help growers/consultants in managing mites (collaboration with Dr Sadras).
8. Finding that super okra cotton varieties are more resistant to spider mites than okra leaf varieties.

### **Publications arising from this project**

#### Refereed scientific publications

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3. Milne, M. and Walter, G.H. (1997) The significance of prey in the diet of the phytophagous thrips, *Frankliniella schultzei*. *Ecological Entomology* 22, 74-81.
4. Milne, M. and Walter, G.H. (1998) Host species and plant part specificity of the polyphagous onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae), in an Australian cotton growing area. *Australian Journal of Entomology* 37, 115-119.
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6. Sadras, V.O. and Wilson, L.J. (1996) Effect of timing and intensity of spider mite infestation on the oil yield of cotton crops. *Aust. J. Exp. Agric.* 36, 577-580
7. Sadras, V.O. and Wilson, L.J. (1997) Nitrogen accumulation and partitioning in shoots of cotton plants infested with two-spotted spider mites. *Aust. J. Agric. Res.* 48, 525 -533.
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#### **Detailed Project Report**

Most of the findings of this project have been written up either as formal scientific manuscripts or as extension articles for industry and a selection of these articles are included as the detailed project report.

#### **Acknowledgments**

We would like to thank the manager at ACRI during this period, Mr Russell Martin, for his assistance with field management and the farms foreman, Des Magann and farm staff for their assistance and co-operation with the agronomic management of the experiments. We would also like to thank the consultants and growers that assisted us with the experiments on the effects of thrips on cotton, including Peter Glennie, Kylie May, John Mohr-Bell, Peter Haslem, Mike Logan, Jeremy Killen, Jeff Carolan and their staff and also Cotton Seed Distributors for supply of seed for these experiments. The input on colleagues at ACRI and elsewhere is also gratefully acknowledged, especially that of Dr Gary Fitt, Dr Neil Forrester, Dr Victor Sadras, Dr Stephen Milroy, Dr Robert Mensah, Dr Grant Herron and Dr Greg Constable.