

Research on aphid ecology and management.

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Key Points

- Cotton aphids may become more of a problem in Bollgard II
- Aphids can cause significant yield loss if left uncontrolled. As a rough guide if they are left uncontrolled for 3-4 weeks after 100% of plants are infested yield loss will occur. The current threshold of 90% of plants infested is conservative. This is separate from yield losses due to cotton bunchy top (CBT)
- Aphids use a wide range of hosts, so good farm hygiene is critical to reduce over-winter survival
- Aphids may use hosts in farm gardens as a refuge in dry conditions
- Sampling of aphids should concentrate on the upper terminal area including, terminal plus top 3-4 leaves
- The patchy distribution of aphids makes presence-absence sampling less precise near threshold. This means care should be taken to ensure sampling is as accurate as possible and control action should be taken promptly once populations exceed threshold.

Introduction

Cotton aphids are a potential problem for future cotton systems. Their abundance in different cotton seasons is strongly influenced by the availability of over-winter hosts, hence in the recent dry years they have generally not been as much of a problem as they were in the years following the wetter winters of 1998 and 1999. Consequently, a change to wet conditions would see the potential for high aphid numbers earlier in the season again. This poses a risk to cotton for several reasons. Firstly, because the effect of aphids on the growth and yield of cotton is poorly understood. Secondly, because aphids are vectors of Cotton Bunchy Top disease. Finally, because aphids are increasingly resistant to some of the insecticides used for their control, notably pirimicarb (carbamate) and most of the organophosphates (dimethoate, omethoate, profenofos, chlorpyrifos).

Over the past three years we have completed experiments to determine if aphid populations affect cotton growth and yield. Such information can provide the basis for development of thresholds for control. However, it is also important to obtain information on aphid ecology and distribution that will help in developing more robust management strategies. For this reason we have also monitored the use of alternative hosts by aphids, their distribution within cotton field and within plants. In addition we also interested in the carry-over of resistance from one year to the next.

Effects of aphids on yield

One of our first goals was to establish if aphids could affect cotton yields. Experiments have been run over three years to build up a matrix relating aphid density and duration of infestation to crop yield. Figure 1 shows the range of aphid population curves generated in the 2002-03 cotton season as an example. Data have been collected for aphid populations beginning as early as mid-December with peak populations in excess of 1200 aphids per leaf (3-4th node mainstem below the terminal).

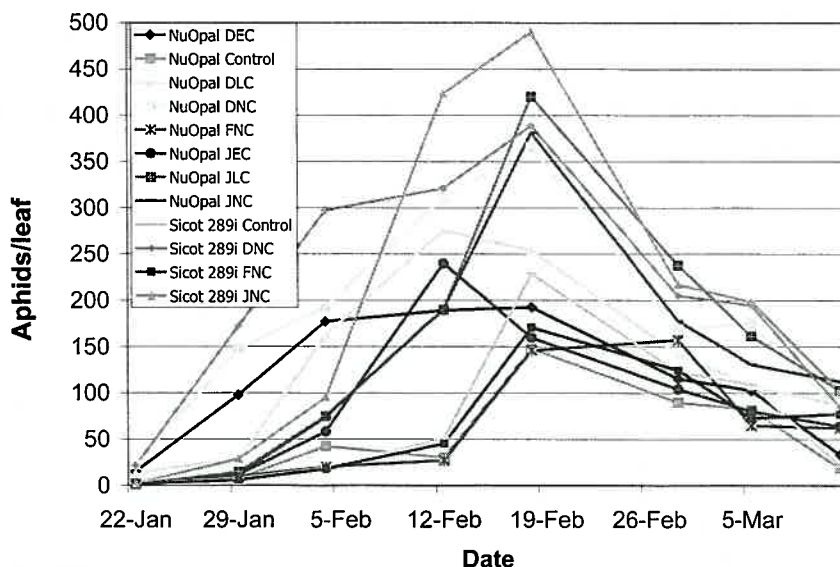


Figure 1. Aphid populations on the 3rd or 4th mainstem node leaf below the terminal in different experimental treatments, ACRI, 2001-02. Each line represents a different treatment, which vary in their starting dates and peak populations levels.

We also monitored the crops growth (dry matter, light interception, photosynthesis) to understand how the aphids are affecting plant development. This will enable us to link the effects of aphids with the OZCOT model so we can predict the likely effects of aphids on growth and also start to explore interactions such the effects of aphids and water stress. Some early data show that high uncontrolled populations of aphids can eventually have a significant effect on cotton growth. Figure 2 shows the effect of a very severe and prolonged aphid infestation initiated in December on the dry weight of cotton plants. Populations initiated later, in January, did not significantly affect growth.

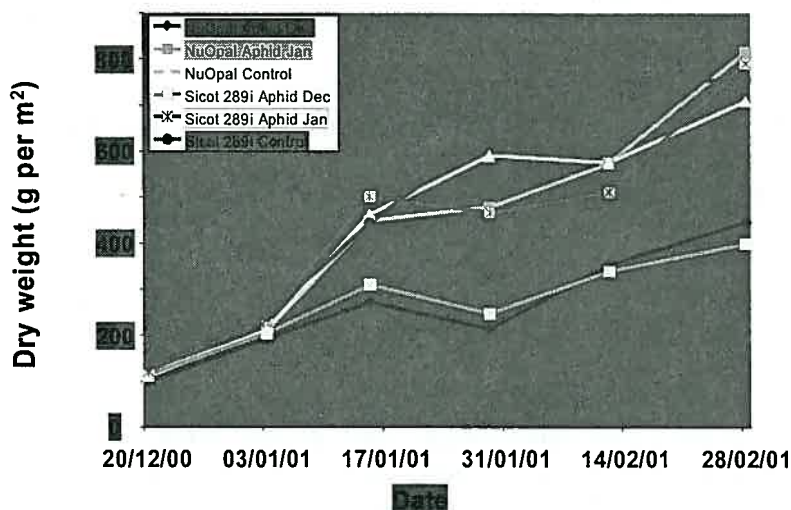


Figure 2. Aphid populations can eventually effect crop growth, here shown by plant dry weight (g/m^2 or meter of row), if left uncontrolled for long periods at very high densities. December infestations reached about 1200 aphids per leaf. However, later infestations did not affect growth.

Our results show that aphids can significantly affect cotton yield if left uncontrolled (Table 1). The earlier the aphid population begins to increase the greater the reduction in yield. Later populations often reached quite high levels but didn't affect yield (Table 1). Over the last two years, different timings of control have also been imposed to better define thresholds. This involved having uncontrolled aphid populations or controlling them earlier or later in their population growth cycle and keeping them at low densities thereafter (shown in Figure 1 in the legend a treatments ending in EC or LC). When we intervened at about two weeks after infestations had reached 100% of plants infested we found no effects on yield (look at EC treatments). It should be noted that this control was implemented when aphids were at far higher densities than the current 90% of plants infested. When control was implemented about 4 weeks after populations had reached 100% infestation (look at LC treatments) it was too late and irretrievable yield loss occurred. Putting these data together with the aphid density information should give us a much better idea of thresholds for control of aphids to prevent yield loss.

Table 1. Effect of aphid populations beginning at different times and controlled at different times on yield of cotton (bales / ha). Yield with a * are significantly different from the 'no aphid' treatment.

Time of infestation	Control	Variety	
		NuOpal	Sicot 289i
No aphids		10.1	11.5
December	No control	8.2*	8.6*
	Early control	10.3	
	Late control	7.8*	
January	No control	8.7*	8.4*
	Early control	10.2	
	Late control	8.1*	
February	No control	11.4	11.7

The effects of aphids on yield are a product of timing of infestation and duration of infestation – the damage is cumulative. In terms of thresholds, one concept being considered is to use aphid days. One aphid day is one aphid on the third or fourth mainstem leaf below the terminal for one day. Aphid days can be accumulated across the season as a way of capturing both density and duration. Figure 3 shows that across two seasons there seems to be a fairly good relationship between aphid days and yield loss (yield is shown as relative yield to allow for differences between experiments). Note that this figure includes both early and late infestations, further analysis to allow for time of infestation would probably further improve the relationship. An approximation of the probable shape of the relationship between aphid days and yield has been added. The data suggests that the yield of plants is unaffected by small aphid populations, but is increasingly affected as aphid numbers increase past a critical point then a drop off once this level is exceeded. This point occurs at about 6500 aphid days, which may be a good indication for a future threshold.

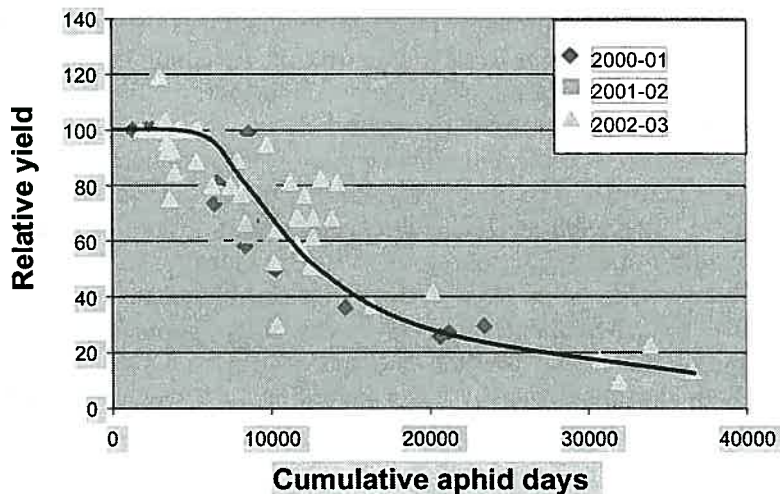


Figure 3. Potential relationship between the number of accumulated aphid days and yield for cotton.

Our research into the effects of aphids on yield is almost complete and some further data in 2004-05 should allow the development of valid thresholds for management of aphids.

Alternative hosts of aphids.

Over the past 3 years, collaborative research at Narrabri and Toowoomba has been monitoring the hosts of aphids through the year. This has involved regular surveys of crops, weeds and native hosts, both in the Namoi and Darling Downs regions. We now have a good knowledge of the main weed hosts for cotton aphid, green peach aphid and cowpea aphid as well as knowledge of the hosts of other aphid species that are in the area and a preliminary list of hosts is shown in Table 2.

Monitoring has continued through winter although aphid numbers have been low due to dry conditions. We have expanded sampling to embrace a number of gardens, both on commercial farms and in Narrabri itself. We have found cotton aphids on some ornamentals (Hibiscus, Chrysanthemum, Murraya, *Impatiens* New Guinea, Liliun sp., *Verbena* sp., *Cuphea lavea*, and Sunflower) in farm gardens and in town and these may be year round refuges for aphids. Samples have been collected and sent to Dr Grant Herron to test for resistance and this will continue as we find hosts with suitable numbers of aphids (see below).

To clarify the role of some crops as hosts for cotton aphid we initiated pilot experiments to see if aphids will even survive on particular crops. We germinated woolly-pod vetch, faba bean, canola, lupins, and lucerne in pots in the glasshouse. Each pot was enclosed in an aphid-proof mesh cover and about 50 aphids introduced onto each plant. Observations show that aphids survived and reproduced slowly on faba bean and lupins, but have failed to survive on lucerne, vetch or canola. In the field aphid proof bags were placed over individual plants in crops of faba bean and vetch and aphids were introduced. After several weeks aphids have persisted on the faba bean plants but not on vetch.

Table 2. Hosts of cotton aphid, cowpea aphid and green peach aphid recorded in the Namoi Valley. Note that although winged forms of aphid may land on a host and be recorded on it, in many cases they have not produced young (no wingless nymphs) and therefore the plant is probably not a host.

Host species	Common name	Cotton aphid		Cowpea aphid		Green peach aphid	
		wingless	winged	wingless	winged	wingless	winged
<i>Amaranthus macrocarpus</i>	Dwarf Amaranth	y	y	y			y
<i>Amaranthus viridis</i>	Green Amaranth		y				
<i>Atriplex sp</i>	saltbush		y				
<i>Atriplex velutinella</i>	Sandhill Saltbush		y		y		
<i>Bidens pilosa</i>	Cobblers Pegs	y	y				
<i>Bidens subalternans</i>	Beggars Ticks	y	y				
<i>Boerhavia diffusa</i>	Tarvine		y				
Brassica (cauliflower)	Brassica (cauliflower)					y	
<i>Brassica napus</i>	Canola					y	y
<i>Chamaesyce drummondii</i>	Causticweed	y	y	y	y		
<i>Cicer arietinum</i>	Chickpea		y				
<i>Citrullus lanatus</i>	Bitter melon	y	y				
<i>Commelina cyanea</i>	Wandering Jew		y				
<i>Convolvulus arvensis</i>	Field bindweed	y					
<i>Convolvulus erubescens</i>	Australian bindweed	y	y			y	
<i>Datura ferox</i>	Fierce Thornapple	y	y	y	y	y	y
<i>Echium plantagineum</i>	Paterson's curse					y	y
<i>Hibiscus rosa-sinensis</i>	Hibiscus	y					
<i>Hibiscus trionum</i>	Bladder ketmia	y	y			y	y
<i>Ipomea lonchophylla</i>	cowvine	y	y			y	
<i>Lamium amplexicaule</i>	Deadnettle	y					
<i>Malva parviflora</i>	Marshmallow	y	y	y		y	y
<i>Medicago polymorpha</i>	Common Burr Medic	y		y	y		
<i>Melilotus indica</i>	Hexham Scent				y		
<i>Phyla nodiflora</i>	Carpet Weed		y				
<i>Physalis ixiocarpa</i>	Annual Groundcherry	y	y	y			
<i>Physalis minima</i>	Wild Gooseberry	y	y			y	
<i>Polygonum aviculare</i>	Wireweed		y		y	y	
<i>Persicaria lapathifolia</i>	Knotweed			y	y	y	
<i>Portulaca oleraceae</i>	Common pigweed	y	y		y		
<i>Raphanus raphanistrum</i>	Wild Radish		y				
<i>Rapistrum rugosum</i>	Turnip weed	y	y		y	y	y
<i>Rumex crispus</i>	Curled Dock	y	y	y	y	y	y
<i>Salvia reflexa</i>	Mint Weed	y					
<i>Senna barclayana</i>	Pepperleaf Senna				y		
<i>Sida rhombifolia</i>	Paddy's Lucerne		y				
<i>Sinapis arvensis</i>	Charlock					y	y
<i>Solanum esuriale</i>	Quena		y				
<i>Solanum nigrum</i>	Blackberry nightshade	y	y				
<i>Sonchus oleraceus</i>	Sowthistle	y	y		y	y	y
<i>Silybum marianum</i>	Variegated thistle	y	y	y		y	y
<i>Trianthema portulacastrum</i>	Giant pigweed/ Black Pigweed	y	y		y		
<i>Tribulus terrestris</i>	Cathead	y	y	y	y		
<i>Urtica urens</i>	Small Nettle		y				
<i>Verbena bonariensis</i>	Purple Top		y				
<i>Verbena officinalis</i>	Common Verbena		y	y			

<i>Verbena rigida</i>	Veined Verbena		y				
<i>Verbesina encelioides</i>	Crown Beard	y	y				
<i>Vicia faba</i>	Faba beans	y	y	y	y	y	y
<i>Vicia sativa</i>	Vetch				y		
<i>Xanthium occidentale</i>	Noogoora Burr	y	y			y	

Distribution and abundance of aphids on cotton crops.

We monitored the within-plant and between-plant distribution of aphid population as they developed in fields at Narrabri and the Darling Downs. Sampling showed that aphid populations initially were biased toward the tops of plant. Once established and the population increases to high numbers, the aphids spread to lower nodes (Figure 4). This means control can be difficult because aphids at lower nodes may not be contacted by insecticides and so can recolonise the upper plant parts.

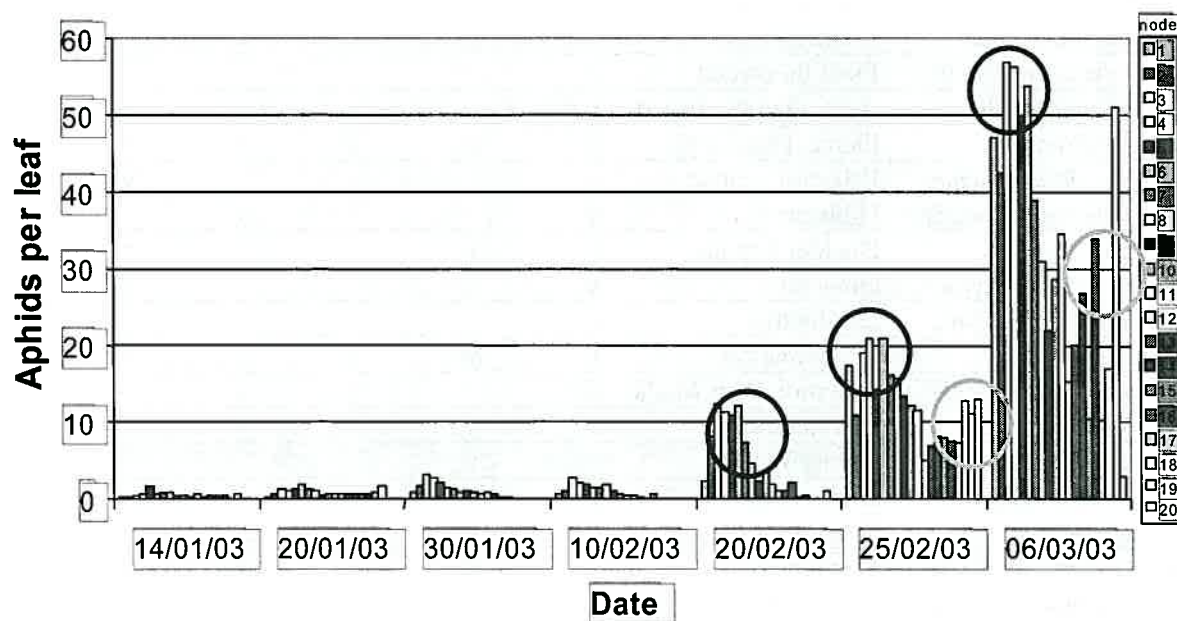


Figure 4. Distribution of aphids on cotton plants. For each date nodes near the top of the plant are on the left, near the bottom on the right. Dark circles indicate the bias of aphids toward younger leaves (node 2-5 below the terminal), while light circles indicate significant populations lower down on heavily infested plants.

Looking at the distribution of aphids between plants it is clear that they show a highly clumped distribution. This clumping is described well by Taylor's Power Law. The value of the slope of the line in Figure 5 is constant across sites and varieties and can therefore be used in the development of sampling equations that allow for the clumping of the pest.

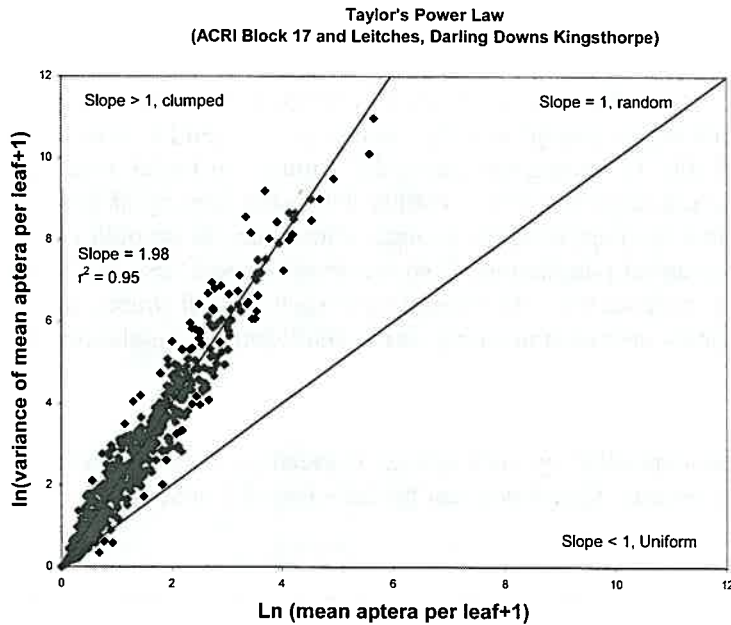


Figure 5. Analysis of mean / variance relationship for cotton aphids on cotton, showing slope of 1.98 indicating a highly clumped distribution.

The current aphid sampling system relies on presence-absence sampling. The basis for presence-absence sampling is the relationship between the mean number of insects per unit and the proportion of units infested. Our data show that the relationship between the mean number of aphids per leaf and the proportion of leaves infested is highly non-linear (Figure 6). The relationship obtained is similar for data from small-scale field plots experiments and larger scale commercial field scale sampling. The problem with the non-linear relationship is that it is at the threshold of about 90% of plants infested that the precision of presence absence sampling declines. For instance just below 90% of plants infested the mean number of aphids per leaf would be less than 15, but above 95% could easily reflect anywhere from about 20 to over 400 aphids per leaf. A rating system may be more reliable and just as quick. This concept is currently being explored.

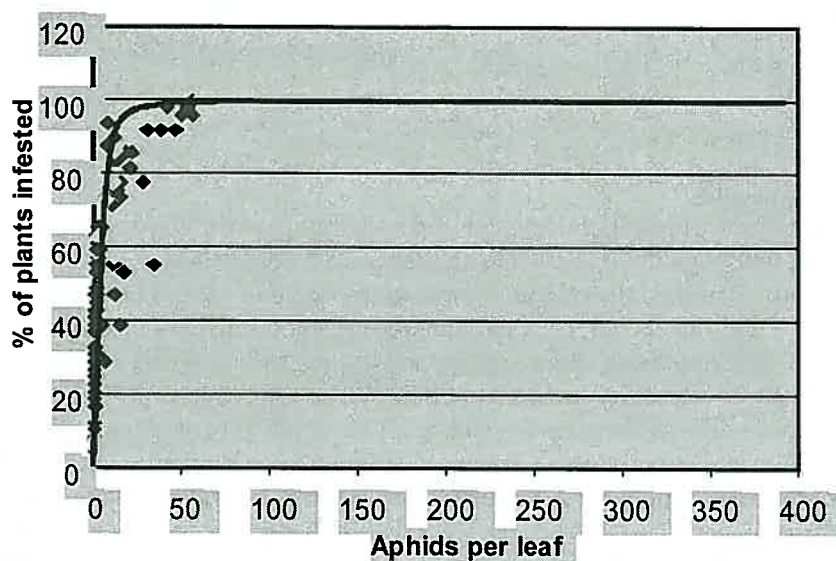


Figure 6. Relationship between mean density of aphids per leaf and % of leaves infested. The dark points are from large scale sampling and light from small plots.

Resistance

Samples collected from farm gardens and from some town backyards have shown high levels of resistance to pirimicarb and organophosphates. Resistance is very similar to field populations that cause control problems (Table 3). During the recent dry winters we found it very difficult to find breeding populations of aphids anywhere else – mainly due to the scarcity of hosts. Farmyards and backyards suitable hosts that are kept watered through winter may, in drought conditions, become the local nucleus for future aphid populations. If so we would expect very low numbers of cotton aphids on cotton in spring, because they are coming from such a small source, and consequently a slow or late build-up of aphids on cotton in spring due a small starting populations. Fortunately this is what has occurred.

Table 2. Percent of aphids controlled by each chemical tested for cotton aphids collected from a nursery, farm gardens and weeds. Resistance can be calculated by subtracting the number below from 100.

Population	Pirimor	Rescue	Pegasus	Confidor	Talstar	Endo
2002-03						
Narrabri; town nursery, Hibiscus	100	100	100	100	100	100
Farm Garden; ex Chrysanthemum	99	81	100	100	92	100
Farm garden; ex <i>Gazania</i> .	28	100	100	100	100	100
Weed, ex <i>Bladder ketmia</i>	16	68	100	100	100	100
2003-04						
Narrabri; garden ex <i>Pandorea jasminoides</i>	8	74	100	100	100	100
ACRI; ex <i>Helianthus annuus</i>	41	81	100	100	100	100
Farm garden; ex Lantana	16	23	100	100	100	100

Effect of beneficials

We considered the effects of beneficials on aphid population growth. We were mainly interested in the factors acting at low population levels i.e. are beneficials able to keep aphid populations at sub-economic levels if not disturbed. Once aphid populations begin to increase exponentially, they will generally reach very high levels before beneficials bring aphid numbers down. Experiments were done using cages of differing mesh size covering and sealing the terminals of plants. The different mesh sizes allowed access for different size beneficials. The fine voile kept virtually all beneficials out, the mosquito gauze allowed in parasites and small bugs, but kept out larger spiders, beetles and bugs and open plants were exposed to all beneficials. Plants with the voile and mosquito gauze on them but left open were also included as controls. The experiments gave varying results, but tended to be more consistent early in the season. In these experiments it was clear that excluding beneficials (voile) led to rapid aphid population increase (Figure 7). A similar but slower increase occurred with the mosquito gauze, but in all other instances aphid populations died off quickly, indicating effective control due to beneficials. Identifying which species of beneficials were

causing this mortality has been difficult, because the limited observation period meant that numbers of beneficials actually seen feeding on aphids was fairly low. In other work, Bernie Franzmann found that the most common and apparently important natural enemies were the white-collared ladybird, transverse ladybird, variable ladybird, red and blue beetle, and brown smudge bug. Though natural variability in predator abundance means that some will be more important in particular years. A new project starting in 2004 will use an ELISA technique to help identify key predators of aphids at low population densities. In this work a rabbit protein, which can be detected serologically will be used to 'mark' aphids. Predators can then be collected and tested for the presence of the rabbit protein in their gut, which indicates that they have eaten 'marked' aphids.

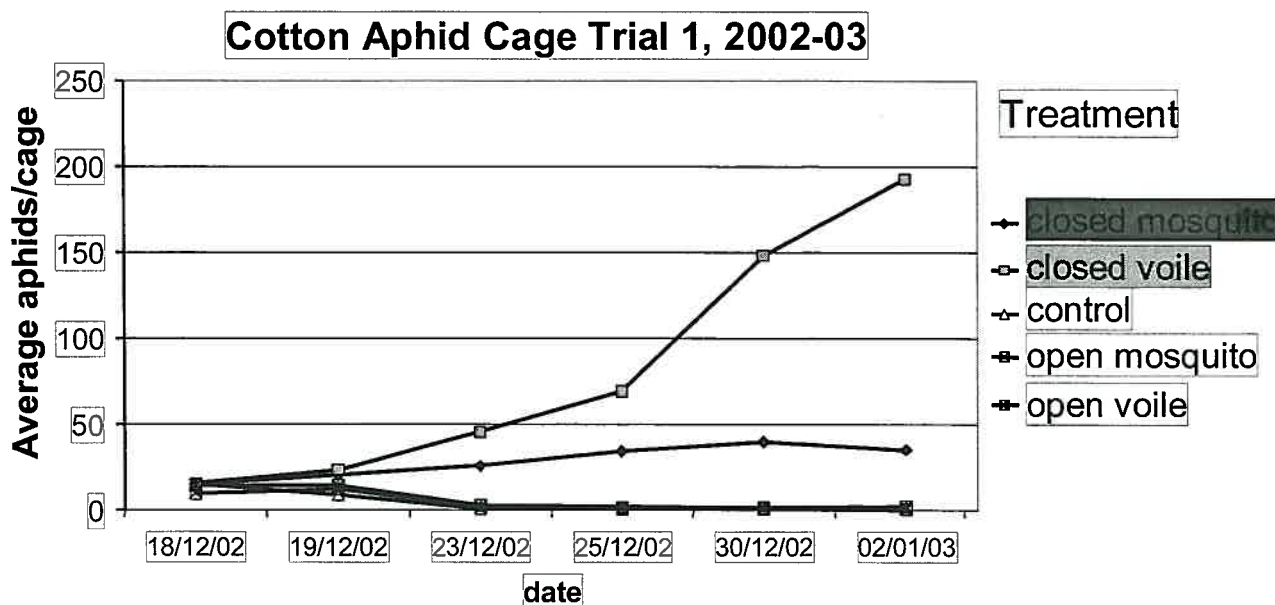


Figure 7. Effect of protecting aphids on cotton plants from all beneficials (closed voile), some beneficials (closed mosquito gauze) or exposed to beneficials (all other treatments).

Conclusions

Research is now providing us with a solid understanding of aphid ecology, damage and within-field distribution. This has already contributed to extension materials on aphids, available on the Australian Cotton CRC Website. As data are analysed fully, improved threshold and sampling recommendations will be developed.

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