



**CSIRO Plant Industry
Cotton Research Unit**

FINAL REPORT

**Project title: Improving understanding of the
ecology and management of cotton
aphid**

Project code: CSP145C

A final report prepared for the Cotton Research and Development Corporation

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Part 1 - Summary Details

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Final Report Executive Summary

Improving understanding of the ecology and management of cotton aphid

Cotton aphid (*Aphis gossypii* Glover) is a late season pest of cotton, with the potential to reduce the value of lint by contaminating it with sticky honeydew secretions. Recently, cotton aphid emerged as a threat during the early and mid season – due to its potential to cause yield loss and its role as a vector of the disease ‘Cotton Bunchy Top’(CBT). This project aimed to improve understanding of the ecology of this pest, especially season abundance and overwinter host use, and of its distribution on cotton, which is important in developing sampling techniques. This project was complemented by two other CRDC funded projects; ‘Aphid bio-control’ (DAQ119C), and ‘Incorporating aphids, insecticides and early season plant compensation in IPM’ (CSP147C). Key outcomes are:

1. Cotton aphid is a mid-late summer pest. A wide range of summer and winter hosts were identified and included a range of broad leaf weeds, crops and garden plants. Among the winter crop hosts are faba beans and lupins, although aphid do poorly on them. Aphids failed to persist on vetch, canola or lucerne. In particular ratoon cotton will carry-over aphid populations, which is a problem for resistance management and for carry-over of CBT. This led to recommendations for good overwinter field hygiene.
2. It is likely that winter conditions affect the size of the overwintering populations, with drier conditions supporting fewer hosts and lower overwinter aphid populations.
3. Cotton aphid uses hosts in farm and urban gardens through winter. Farm gardens in particular can serve as reservoirs for insecticide resistant cotton aphids and are particularly important in dry years when other hosts are scarce.
4. The seasonal abundance and host range of cowpea aphids was documented. This species has two peaks in abundance, in early spring and autumn. It also uses a wide range of hosts, but is particularly noticeable on medics.
5. Green peach aphid is a cool season specialist. It has a narrower host range than cotton aphid and cowpea aphid, but uses some brassicaceous hosts that are widespread.
6. A wide range of other aphid species and their hosts was also recorded. This information has proven valuable, for instance in warning industry of influxes of *Rhopalosiphum* spp. which settle on seedling cotton, but which will not establish and breed. This led to the recommendation not to treat aphid populations unless it is clear they are breeding.
7. Cotton aphids show a preference for the upper canopy leaves of plants. However, at higher numbers there is a significant population found in the lower canopy. This population is difficult to reach with insecticides and may be a major source of recolonisation of plants following insecticide application.
8. Cotton aphid shows a highly clumped distribution, a product of their biology, whereby females produce live young that do not move far away from the parent. This makes sampling more difficult as populations may be missed.
9. There is a curvilinear relationship between the proportion of plants infested with aphids and the mean number of aphids per leaf. This may be useful if it can be linked effectively with the thresholds being derived in another project.

Outcomes of this research have been widely reported to industry. Future research on aphids could emphasise selective control, improved understanding of colonization and spread in cotton, contribution of trap crops or relay crops as hosts and link with spread of CBT.

Part 3.3 – Final Reports (due 3 months after completion of project)

2. Outline the background to the project.

Aphids are emerging as major problems in cotton. Cotton aphid, *Aphis gossypii* predominates, but there have also been occasional early season infestations of green peach aphid, *Myzus persicae* and cowpea aphid, *Aphis craccivora*. Over the past three seasons there has been a trend toward earlier and more widespread development of aphids in cotton crops, possibly caused by a number of related factors including:

- (i) Reduced early season applications of endosulfan, which is a moderately effective aphicide.
- (ii) Unwanted effects of spray drift from conventional cotton onto Bollgard II® /Ingard® may cause reductions in beneficial insect abundance without affecting the resistant aphids, allowing populations to develop rapidly.
- (iii) Resistant aphids survive in situations where formerly they would have been easily and economically controlled.
- (iv) The perceived risk associated with Cotton Bunchy Top disease (CBT) which is spread by cotton aphid, has caused many growers to use lower thresholds for aphids, accelerating selection for insecticide resistance.

Unfortunately our current understanding of the ecology of aphids and the role of biotic and abiotic factors in their population dynamics is poorly understood. Furthermore, our understanding of the distribution of aphids within cotton crops is poorly understood, hampering development of effective sampling strategies. This project was designed to address these needs by studying the population dynamics of aphids on alternative hosts to cotton, including crops and weeds and by studying the within and between plant abundance of aphids in cotton fields. This project was partnered with another project (DAQ119C), which was looking at biocontrol of aphids. In this collaboration Dr Franzmann's group undertook sampling of weeds and cotton in the Darling Downs on behalf of this project and we completed a range of experiments looking at the biocontrol of aphids at Narrabri for Dr Franzmann.

An additional side benefit of this project was that cotton aphids collected off a range of alternative hosts would be sent to Dr Grant Herron at EMAI for resistance testing. This provided additional information on the distribution and survival of resistant cotton aphids.

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

1. To determine the annual abundance of aphids and their natural enemies on alternative hosts (uncultivated, cultivated, cotton regrowth and volunteers).
2. To determine the season abundance of aphids on cotton and their within plant and between plant distribution to improve sampling recommendations.
3. To evaluate the role of biocontrol agents in influencing aphid populations. (This will be reported as part of DAQ119C).

4. Detail the methodology and justify the methodology used.

1. To determine the annual abundance of aphids and their natural enemies on alternative hosts (uncultivated, cultivated, cotton regrowth and volunteers).

The use of cotton and alternative hosts throughout the year was approached in several ways;

a) A range of sites was selected across the Namoi valley at which the abundance of aphids on the succession of weed and native species was studied through regular sampling. This included categorising the abundance of each plant species, its growth phase, the abundance of aphids on it, the species of aphids and the presence of predators or parasites. All aphid species were identified, not just those affecting cotton as this provided a broader understanding of which aphid species were using which hosts. Dr Franzmann's group conducted similar studies in the Darling Downs.

b) Crop hosts were surveyed for the presence of aphids and beneficials during summer and winter. Additionally, to clarify if particular winter growing crops would host cotton aphids we caged groups of cotton aphid on these hosts in the field and monitored their population growth. These crops included woolly-pod vetch, faba bean, canola, lupins, and lucerne

c) Due to the dry winters at the start of this project data on overwinter survival of aphids was scant due to the scarcity of suitable hosts. During the winter of 2004 therefore we placed groups of cotton aphids onto various winter hosts and monitored their survival.

d) In 2004, in addition to the sampling described in (a) above plants at these sites that were infested with aphids were marked and returned to on successive visits. For these plants the presence or absence of aphids was scored as an indication of the persistence of aphid populations over winter.

2. To determine the season abundance of aphids on cotton and their within plant and between plant distribution to improve sampling recommendations.

The distribution of aphids within plants and within fields was studied by assessing the abundance of aphids on each mainstem node leaf for a range of plants in a given area of a cotton field. The sampling processes used a grid pattern where a plant was sampled every 5 metres along the row and every fifth row. Usually 30 – 50 plants were sampled on each date with samples taken weekly during the last half of the cotton season. Data were obtained for four unsprayed cotton fields in 2002-03 and a further two in 2004-05, including fields in both the Namoi Valley and the Darling Downs. Attempts were made to obtain data from commercial cotton fields but these failed as the growers usually controlled the aphids before after only one or two sampling events.

5. Detail and discuss the results including the statistical analysis of results.

A. Alternative hosts of aphids and seasonal patterns of abundance.

This study focussed on the three species of aphids most commonly found on cotton, cotton aphid, cowpea aphid and green peach aphid. However during the course of the

study we recorded all species that were encountered. This information is useful as it provides information on the aphid species that are likely to be found at certain times of the year. Many of these aphids will not attack cotton but may settle on the crop temporarily to test feed.

i) Seasonal abundance of on weed and native hosts.

This study was aimed to identify the hosts used by the three cotton-attacking aphids. An emphasis was placed on the over-winter hosts as these aphid species do not have a diapause stage under Australian conditions and must have plant hosts on which to survive. Further, knowledge of winter host species can help with on farm management by allowing growers to identify those weeds that need to be eliminated to reduce overwinter survival of aphids.

Control of overwinter hosts is particularly important if the aphids are resistant. Under Australian conditions cotton aphids reproduce asexually, with adult female aphids giving birth to live young (see life cycle Appendix 1). As such there is no mating, so there is no opportunity for dilution of resistance by matings between susceptible and resistant individuals (as there is for instance with *Helicoverpa armigera*). Some clones of cotton aphid have developed resistance to organophosphates and pirimicarb, though there are some clones that are still susceptible. If resistant aphids are allowed to overwinter on farms then this increases the chance that aphid populations encountered in the next season will also be resistant. Eliminating the hosts of these aphids will reduce survival, at least giving the chance that aphids that enter the farm subsequently may be susceptible.

Cotton Aphid seasonal abundance

We have been able to follow populations of cotton aphid through the winter on a range of hosts. The most complete data set is for ratoon cotton, grown as part of a resistance-screening project for Cotton Bunchy Top Disease. Aphids, both alates (winged) and apterae (wingless), were present on a succession of hosts throughout the year. This is illustrated in Figure 1, which shows the numbers of apterous aphids found on all weed hosts and ratoon cotton across all sites in the Namoi Valley (about 3900 individual samples). Numbers generally peaked in late summer and declined through winter. This is expected due to the slower growth of aphids during winter months. Another clear trend is the number of recordings of aphids over time, despite their being a generally even sampling effort over time. In the first year 2002 the winter was very dry and there were fewer aphids found, the winter of 2003 was slightly wetter and there were more recordings of aphids and in the winter of 2004 where there were regular moderate rains the recordings of aphids on weed hosts was consistently more frequent. This highlights the strong effect of season conditions, particularly winter rainfall and temperatures, on aphid population levels through winter and their build up in spring.

The numbers of alate aphids was much lower than aptera as expected, as alates are only produced when aphid populations become stressed due to crowding, poor food quality or shortening daylength. Alate populations tended to build from late summer and peak in March and April, possibly corresponding to the finish of the cotton crop. Alates were generally rare in winter, probably reflecting the generally low populations of apterae found during this period. The alates showed the same general increase in abundance from 2002 to 2004 as seen for the apterae.

Cotton aphid - apterae

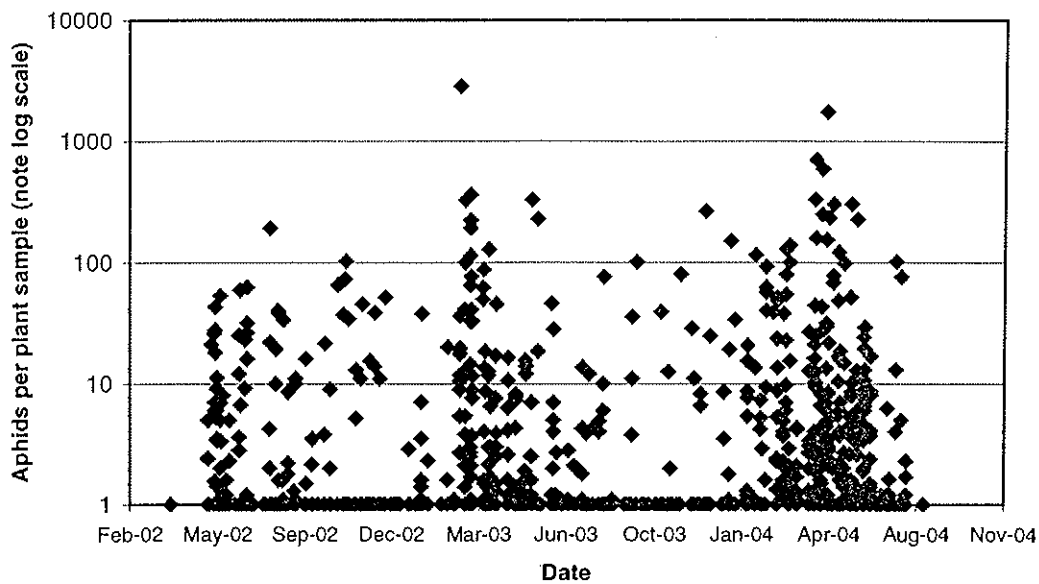


Figure 1. Number of cotton aphid (*Aphis gossypii*) apterae recorded for each individual weed sample at sites across the Namoi Valley. Points aligned at '1' represent zeros.

Cotton aphid - alates

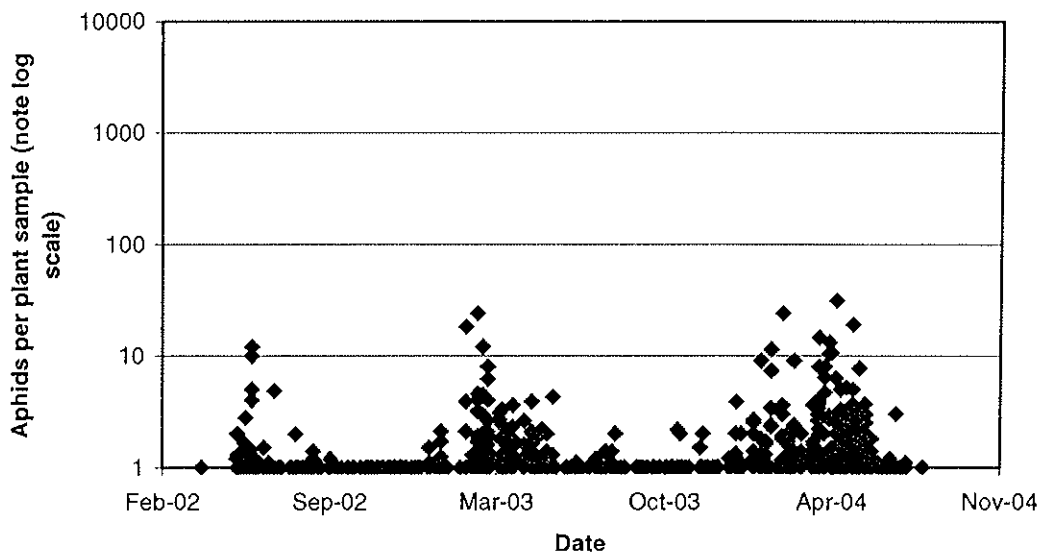


Figure 2. Number of cotton aphid (*Aphis gossypii*) alates recorded for each individual weed sample at sites across the Namoi Valley. Points aligned at '1' represent zeros.

Cowpea Aphid season abundance

This aphid species is often found on young cotton but rarely establishes. It will breed on cotton, however population growth is very low and in the field populations on cotton generally die off. Looking at the overall season abundance of this species it can be seen for both apterae (Figure 3) and alates (Figure 4) that abundance was generally much lower than cotton aphid on the hosts sampled and that populations tended to be higher in the winter

months, in contrast to cotton aphid where they were highest in summer. This may in part reflect the preference of this species for the winter growing legumes as hosts.

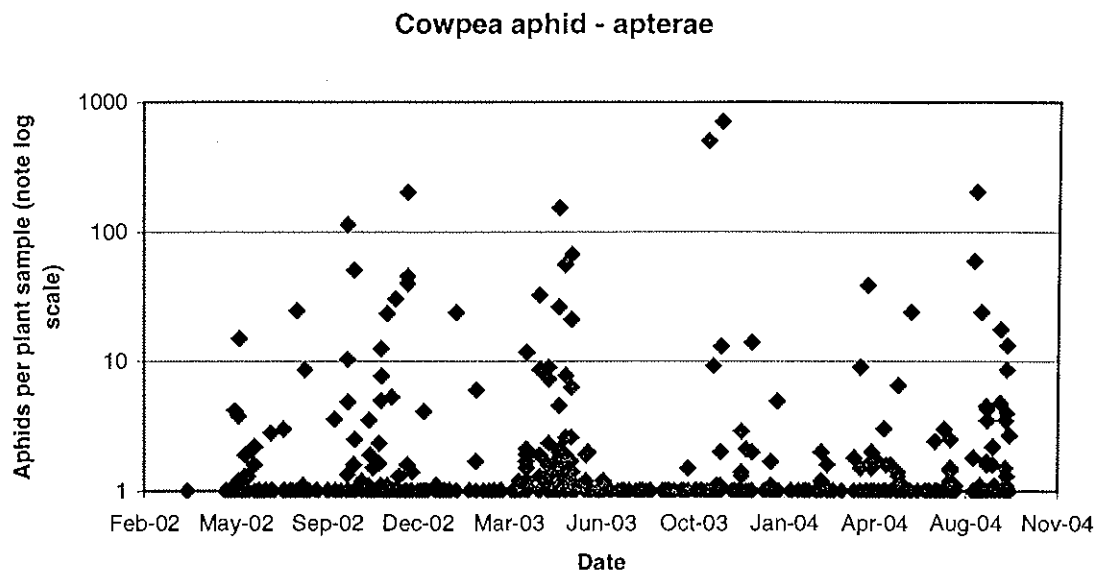


Figure 3. Number of cowpea aphid (*Aphis craccivora*) apterae recorded for each individual weed sample at sites across the Namoi Valley. Points aligned at '1' represent zeros.

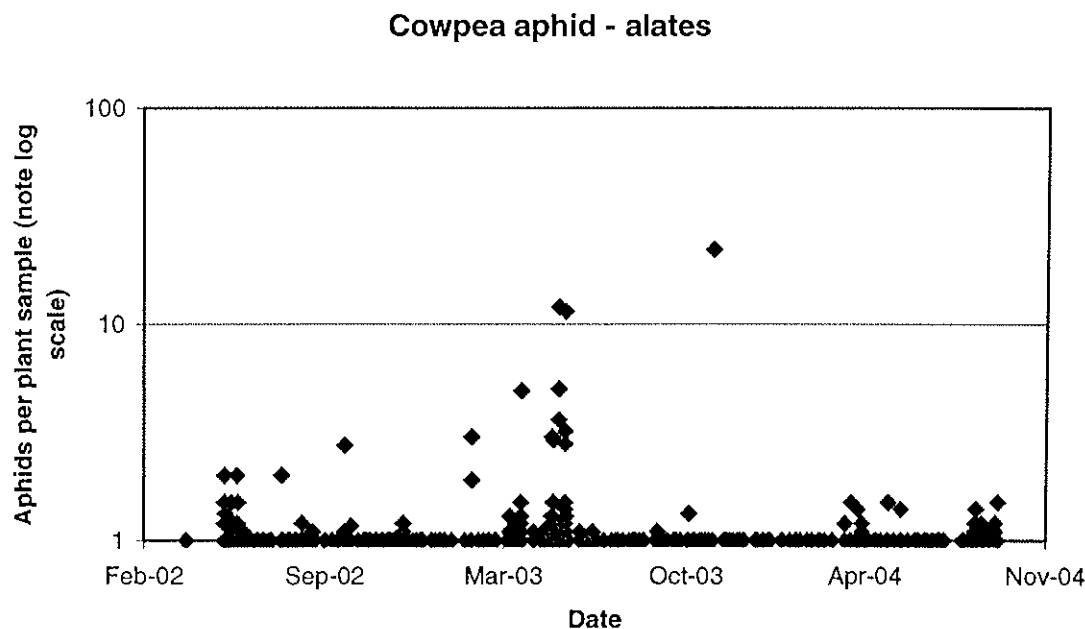


Figure 4. Number of cowpea aphid (*Aphis craccivora*) alates recorded for each individual weed sample at sites across the Namoi Valley. Points aligned at '1' represent zeros.

Green Peach Aphid seasonal abundance

This aphid species will colonise cotton crops, mainly early or very late in the season. It prefers cooler temperatures and tends to die drop in abundance as the weather becomes hotter through summer. Figures 5 and 6 show quite clearly that this species is generally less abundant than cotton aphid. It also shows highest abundance through the minter months, both

for apterae and alates.

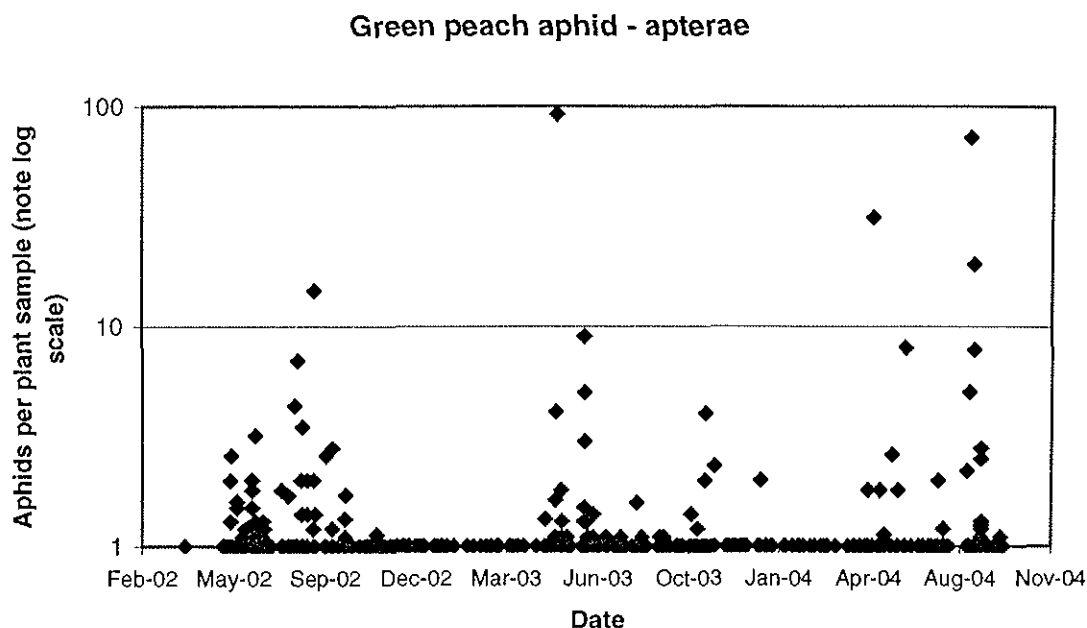


Figure 5. Number of green peach aphid (*Myzus persicae*) apterae recorded for each individual weed sample at sites across the Namoi Valley. Points aligned at '1' represent zeros.

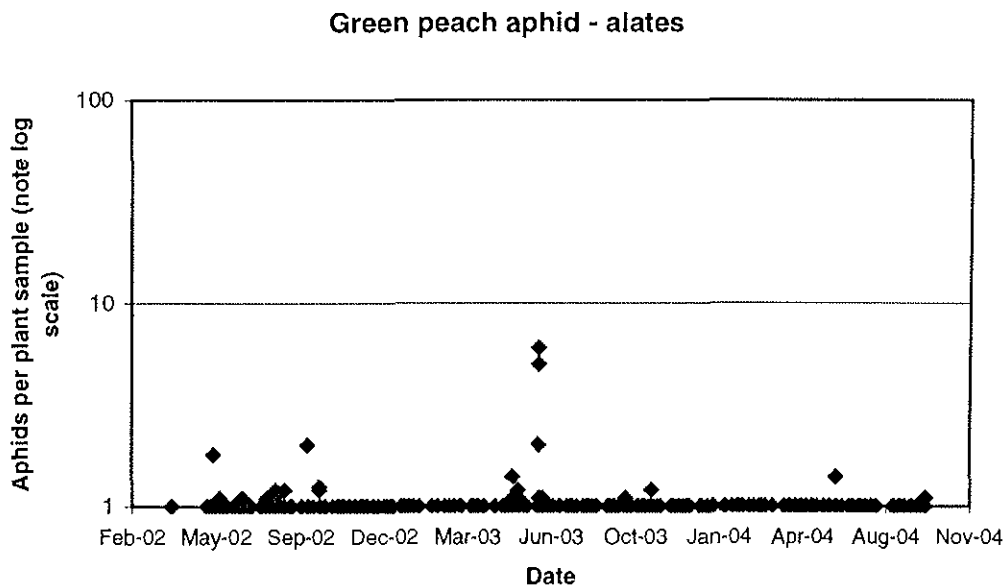


Figure 6. Number of green peach aphid (*Myzus persicae*) alates recorded for each individual weed sample at sites across the Namoi Valley. Points aligned at '1' represent zeros.

ii) *List of key hosts for aphids attacking cotton in the warmer and cooler months*
As part of the surveys of alternative hosts we compiled a list of host for the three key species that attack cotton. For convenience we divided the year into the warmer months and the cooler months, and the hosts are listed accordingly. A plant was only classified as a host if apterae were recorded. This is because the alates can settle and test feed on a wide range of hosts without being able to reproduce on them.

Cotton aphid hosts and links with resistance

This species is able to feed and reproduce on an enormous range of host species, with 44 plant species recorded as hosts in this study (Table 1). This species is most abundant through summer, as indicated by the wide range of summer hosts. Through winter populations contract to a smaller subset of available hosts, and population growth slows.

Of particular note also is that cotton aphid is also able use a wide range of plant species commonly found in town and farm house gardens (Table 2). This has important implications for both their abundance on cotton farms and for resistance management. During the first two years of this study the winters were very dry, and the availability of host for aphids was low. We initiated the sampling of farm gardens as these are generally well watered, even in a drought. We found aphids on a range of hosts in farm Gardens. Where there were sufficient numbers we sent samples down to Dr Grant Herron at NSW DPI, Elizabeth McArthur Agricultural Institute, Camden.

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, but the samples from farmyards highlight that resistant clones do over winter on farms and therefore farm hygiene id very important.

Table 1. Hosts of cotton aphid (*Aphis gossypii*) recorded from regular sampling on cotton farms and weedy areas in the Namoi Valley, between May 2002 and September 2004.

Plant Species	Common name	Warm Oct-May	Cool Jun-Sept
<i>Bidens pilosa</i>	Cobblers pegs	xxx	xxx
<i>Bidens subalternans</i>	Beggars ticks	xxx	
<i>Boerhavia diffusa</i>	Tarvine	x	
<i>Cajanus cajan</i>	Pigeon pea	xx	
<i>Chamaesyce drummondii</i>	Caustic weed	xxx	xx
<i>Chenopodium pumilio</i>	Small crumbweed		x
<i>Chrysanthemum sp.</i>	Chrysanthemum	xxx	
<i>Citrullus lanatus</i>	Camel melon/watermelon	xxx	
<i>Citrullus vulgaris</i>	watermelon	xx	xxx
<i>Convolvulus erubescens</i>	Australian bindweed		x
<i>Conyza bonariensis</i>	Flax leaf fleabane	x	x
<i>Cucumis myriocarpus</i>	paddymelon	xxx	
<i>Cucumis pepo</i>	pumpkin	xx	
<i>Cucumis sativus (cucumber)</i>	cucumber	xx	
<i>Cucurbita maxima (pumpkin)</i>	Winter squash	xx	
<i>Cucurbita pepo(zucchini)</i>	zucchini	xx	x
<i>Echium plantagineum</i>	Paterson's curse		xx
<i>Datura ferox</i>	Fierce thornapple	xxx	
<i>Fallopia convolvulus</i>	Black bindweed	xx	
<i>Glycine max</i>	Faba bean	xx	
<i>Gossypium hirsutum</i>	Cotton	xxx	xxx
<i>Helianthus annuus</i>	Sunflower	xxx	xx
<i>Hibiscus esculentus</i>	Okra	xxx	
<i>Hibiscus rosa-sinensis</i>	Hibiscus	xxx	
<i>Hibiscus sabdariffa</i>	Rosella	xxx	xx
<i>Hibiscus trionum</i>	Bladder ketmia	xxx	xx
<i>Impatiens hawkeri</i>	Impatiens	x	
<i>Lamium amplexicaule</i>	Deadnettle	xx	xx
<i>Malva parviflora</i>	Marshmallow	xx	xx
<i>Malvastrum coromeliandrum</i>	Malvastrum	xx	xx
<i>Medicago polymorpha</i>	Burr medic	x	xxx
<i>Physalis ixiocarpa</i>		xxx	
<i>Portulaca oleracea</i>	Pigweed	xx	
<i>Rapistrum rugosum</i>	Turnipweed	xx	xx
<i>Silybum marianum</i>	Variegated thistle		x
<i>Sida rhombifolia</i>	Paddy's lucerne	xx	x
<i>Solanum nigrum</i>	Blackberry nightshade	xx	
<i>Sonchus oleraceus</i>	Milkthistle	xx	xx
<i>Trianthema portulacastrum</i>	Giant pigweed	xxx	
<i>Triticum aestivum</i>	Wheat		x
<i>Tribulus terrestris</i>	Cat-head	xx	
<i>Urtica urens</i>	Small nettle	x	x
<i>Verbena bonariensis</i>	Purpletop	x	x

X, more than one aphid found on a plant on one sampling occasion

XX, more than one aphid found on one plant on more than one sampling occasion, but never more than 100/plant

XXX, more than one aphid found on one plant on more than one sampling occasion, and more than 100 aphids found on a plant at least once

Table 2. Hosts of cotton aphid (*Aphis gossypii*) recorded from town and farm gardens in the Namoi Valley, between May 2002 and September 2004.

Plant species	Common name	Warm Oct-May	Cool Jun-Sept
<i>Abutilon sp.</i>	Abutilon		XX
<i>Argyranthemum</i>	chammomile		X
<i>Begonia sp.</i>	Begonia	X	
<i>Calibrachoa</i>	Calibrachoa	X	
<i>Chili</i>	Chili	XX	
<i>Chrysanthemum sp.</i>	Chrysanthemum		XXX
<i>Citrus (lemon)</i>	Lemon		XX
<i>Citrus (Lime)</i>	Lime		XX
<i>Citrus (orange)</i>	Orange		X
<i>Cuphea llavea</i>	Tiny mice	XX	X
<i>Gazania sp.</i>	Gazania		XX
<i>Hypoestes phyllostachya</i>	Polka dot plant		X
<i>Lagenaria siceraria</i>	Bottle gourd	X	
<i>Lantana spp.</i>	Lantana	X	XX
<i>Melissa officinalis</i>	fennel	X	
<i>Mentha sp.</i>	Mint		X
<i>Nerium</i>	Nerium		X
<i>Origanum marjorana</i>	Marjoram	XX	
<i>Ozothamnus sp.</i>			X
<i>Rosa sp.</i>	Rose	X	X
<i>Salvia sp.</i>	Salvia	XX	X
<i>Solanum melongera</i>	Eggplant/aubergine	X	X
<i>Zinnia peruviana</i>	Zinnia		X
<i>Zinzibar</i>	Ginger		X
<i>Citrus hystrix</i>	Kaffir lime		X
<i>Hibiscus rosa-sinensis</i>	Hibiscus		XXX
<i>Malus</i>	Apple	X	XX
<i>Vinca</i>	Vinca		X

X, more than one aphid found on a plant on one sampling occasion

XX, more than one aphid found on one plant on more than one sampling occasion, but never more than 100/plant

XXX, more than one aphid found on one plant on more than one sampling occasion, and more than 100 aphids found on a plant at least once.

Table 3. Percent of cotton aphids (*Aphis gossypii*) controlled by each chemical tested for aphids collected from a nursery, farm gardens and weeds. Resistance can be calculated by subtracting the number below from 100. Numbers in bold indicate resistant strains.

Location	Sample no.	Plant sp.	Common name	Pirimor	Rescue	Pegasus	Confidor	Talstar	Endo
				2002-03					
Welshman's Nursery	-	<i>Hibiscus</i>	Hibiscus	100	100	100	100	100	100
Narrabri Waverly Farm garden	-		Chrysanthemum	99	81	100	100	92	100
Willawood Farm garden	-		Gazania	28	100	100	100	100	100
Brookstead (Darling Downs)	-	<i>Hibiscus trionum</i>	Bladder ketmia	16	68	100	100	100	100
				2003-04					
Adam St, Narrabri, domestic backyard	-	<i>Pandorea jasminoides</i>	Wonga Vine	8	74	100	100	100	100
Greenbah Farm Garden	-	<i>Lantana montevidensis</i>	Lantana	16	23	100	100	100	100
ACRI Field 18	1873	<i>Lamium amplexicaule</i>	Deadnettle	96	100	100	100	100	100
ACRI Field 18	1874	<i>Gossypium hirsutum</i>	Volunteer cotton	98	100	100	100	100	100
ACRI Field 18	1878	<i>Gossypium hirsutum</i>	Cotton	97	100	100	100	100	100
ACRI Field 18	1884	<i>Gossypium hirsutum</i>	Ratoon cotton	93	100	100	100	100	100
ACRI	1989	<i>Helianthus annus</i>	Sunflower crop	41	81	100	100	100	100
ACRI	1935	<i>Helianthus annus</i>	Sunflower crop	65	100	100	100	100	100
ACRI	1936	<i>Bidens subalternans</i>	Beggars ticks	36	73	100	100	100	100
ACRI	1939	<i>Datura ferox</i>	Fierce Thornapple	19	62	100	100	100	100
ACRI	1945	<i>Tribulus terrestris</i>	Caltrop/ Cathead	72	60	100	100	100	100
Narrabri RSL garden	-	<i>Hibiscus sp.</i>	Garden Hibiscus	85	91	100	100	99	100
Riverway Farm	2017	<i>Hibiscus trionum</i>	Bladder Ketmia	48	83	100	100	100	100
Riverway Farm	2024	<i>Datura ferox</i>	Fierce Thornapple	70	-	-	-	-	-
Collins Bridge, near WeeWaa	2065	<i>Xanthium occidentale</i>	Noogoora Burr	-	-	-	-	-	100

Cowpea aphid hosts

This species uses a wide host range (Table 4), and is more abundant in winter. Medic is an important host in both summer and winter for this species.

Table 4. Hosts of cowpea aphid (*Aphis craccivora*) recorded from regular sampling on cotton farms and weedy areas in the Namoi Valley, May 2002 to September 2004.

Plant Species	Common name	Cool Jun-Sept	Warm Oct-May
<i>Amaranthus macrocarpus</i>	Dwarf amaranth	xx	
<i>Arctotheca calendula</i>	Capeweed		x
<i>Aster subulatus</i>	Bushy starwort	x	
<i>Atriplex calcarata</i>			x
<i>Bidens pilosa</i>	Cobblers pegs	xx	
<i>Bidens subalternans</i>	Beggars ticks		xx
<i>Boerhavia diffusa</i>	Tarvine		xx
<i>Chenopodium pumilio</i>	Small crumbweed		xx
<i>Chamaesyce drummondii</i>	Caustic weed	xx	xxx
<i>Chrysanthemum sp.</i>	Chrysanthemum	x	
<i>Citrullus lanatus</i>	Camel melon/watermelon		xx
<i>Cucurbita maxima</i>	Winter squash		x
<i>Cucurbita pepo</i>	pumpkin		x
<i>Datura ferox</i>	Fierce thornapple		xx
<i>Echium plantagineum</i>	Paterson's curse	x	
<i>Einadia trigonos</i>	fishweed		xx
<i>Glycine max</i>	Faba bean		x
<i>Gossypium hirsutum</i>	Cotton		xxx
<i>Helianthus annuus</i>	Sunflower		x
<i>Hibiscus sp.</i>	Hibiscus	x	x
<i>Hibiscus esculentus</i>	Okra		x
<i>Hibiscus sabdariffa</i>	Rosella		x
<i>Hibiscus trionum</i>	Bladder ketmia	x	
<i>Lamium amplexicaule</i>	Deadnettle	x	x
<i>Malva parviflora</i>	Marshmallow	xxx	xx
<i>Medicago polymorpha</i>	Burr medi	xxx	xxx
<i>Medicago truncatula</i>	Barrel medic		x
<i>Murraya paniculata</i>	Orange jasmine	x	
<i>Polygonum aviculare</i>	Wireweed		x
<i>Persicaria decipiens</i>	Slender knotweed		x
<i>Rapistrum rugosum</i>	Turnipweed		xx
<i>Sclerolaena muricata</i>	Black roly poly	x	
<i>Senna barclayana</i>	Pepper leaf senna		x
<i>Sesbania cannabina</i>	Yellow pea bush		x
<i>Sonchus oleraceus</i>	Sowthistle		xx
<i>Trianthema portulacastrum</i>	Hogweed		xxx
<i>Tribulus terrestris</i>	Cat-head	xx	xxx
<i>Urtica urens</i>	Small nettle	xx	
<i>Verbena bonariensis</i>	Purpletop		xx
<i>Vicia faba</i>	Faba bean		x
<i>Xanthium occidentale</i>	Noogoora burr		xx

X, more than one aphid found on a plant on one sampling occasion

XX, more than one aphid found on one plant on more than one sampling occasion, but never more than 100/plant

XXX, more than one aphid found on one plant on more than one sampling occasion, and more than 100 aphids found on a plant at least once.

Green peach aphid

This species has a much narrower host range than either cotton aphid or cowpea aphid (Table 5). It also tends to use a wider range of hosts and to be more abundant on these hosts during the cooler months.

Table 5. Hosts of green peach aphid (*Myzus persicae*) recorded from regular sampling on cotton farms and weedy areas in the Namoi Valley, between May 2002 and September 2004.

Plant Species	Common name	Warm Oct-May	Cool Jun-Sept
<i>Ammi majus</i>	Bishops weed		x
<i>Amaranthus macrocarpus</i>	Dwarf amaranth	xx	
<i>Arctotheca calendula</i>	Capeweed		x
<i>Bidens subalternans</i>	Beggars ticks	x	
<i>Brassica napus</i>	Rape/Canola	x	
<i>Calibrachoa "selecta violet"</i>	Calibrachoa	xx	xx
<i>Datura ferox</i>	Fierce thornapple	x	
<i>Echium plantagineum</i>	Paterson's curse		xx
<i>Fallopia convolvulus</i>	Black bindweed	x	
<i>Lantana sp.</i>	Lantana	x	
<i>Malva parviflora</i>	Marshmallow	xx	xxx
<i>Medicago polymorpha</i>	Burr medic	x	
<i>Persicaria decipiens</i>	Slender knotweed	x	
<i>Polygonum aviculare</i>	Wireweed		xx
<i>Rapistrum rugosum</i>	Turnipweed	xx	xxx
<i>Rosa sp.</i>	Rose		x
<i>Sida rhombifolia</i>	Paddy's Lucerne	x	
<i>Solanum melongera</i>	Eggplant/Aubergine		xx
<i>Solanum nigrum</i>	Blackberry Nightshade		xx
<i>Sysbrium officinale</i>	London Rocket		x
<i>Urtica urens</i>	Small nettle		xxx

X, more than one aphid found on a plant on one sampling occasion

XX, more than one aphid found on one plant on more than one sampling occasion, but never more than 100/plant

XXX, more than one aphid found on one plant on more than one sampling occasion, and more than 100 aphids found on a plant at least once.

iii) List of aphid species recorded in the cotton regions and their hosts.

During the course of sampling for the three aphid species that attack cotton we also encountered a wide range of other aphid species. A knowledge of what plants are abundant in an area, especially crops, and of the aphids species that may be on those plants or crops can help in understanding the presence of aphids on cotton at certain times. For instance, *Rhopalosiphum maidis* and *R. padi* are often abundant of cereal crops late in the spring. As these crops mature alates of these aphids migrate seeking new hosts. Some will land on cotton and test feed, but not establish. A grower or consultant unaware of this may be tempted to spray these aphids. Hence knowing that they are alates, that these species are likely to be present at that time and waiting to see if the aphids actually reproduce on cotton is a strategy to avoid unnecessary spraying.

iv) Winter crop hosts of cotton aphid (*A. gossypii*)

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 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 had persisted on the faba bean plants but not on vetch. This suggests that faba bean is a host for cotton aphid, albeit a poor one.

v) *Weed sampling on the Darling Downs*

Weed hosts were surveyed monthly for two years from November 2001 to October 2003. Sampling was from four sites, two each from an area near the towns of Cecil Plains (27°32'S; 151°12'E) and Jimbour (26°58'S; 151°13'E). In each area a wet site (within 100m of permanent water) and a dry site (more than one km from permanent water) were sampled. Each site occupied approximately 1-2 ha. At monthly intervals we searched the sites for weeds. Grass weeds were not sampled. We attempted to collect off ten weeds at each site. Weeds were sampled by visual inspection and beating into a tray. Cotton aphids were counted. From November 2003 to January 2004 the sampling strategy was modified based on results from the previous years. Nine weed species, which had been recorded as hosts previously, were searched for in areas around the two town sites, at monthly intervals. Fifty plants were sampled as before. Cotton aphids were found on a wide range of hosts. Green peach aphids were never recorded in the surveys, indicating very low abundance, similar to the findings for the Namoi Valley (Table 6).

Table 6. Weed hosts of cotton aphid on the Darling Downs

Host	Species	Warm Oct-May	Cool Jun-Sep
Blackberry nightshade	<i>Solanum nigrum</i>	XX	
Bladder ketmia	<i>Hibiscus trionum</i>	XXX	XXX
Cobbler's pegs	<i>Bidens pilosa</i>	XXX	XXX
Curled dock	<i>Rumex crispus</i>	XX	X
Deadnettle	<i>Lamium amplexicaule</i>	X	XX
Marshmallow	<i>Malva parviflora</i>	X	XXX
Paddy's lucerne	<i>Sida rhombifolia</i>	XXX	XXX
Rhyncosia	<i>Rhyncosia</i> spp.	X	
Tarvine	<i>Boerhavia diffusa</i>		X
Variegated thistle	<i>Silybum marianum</i>		XX
Wild sage	<i>Salvia vebenaca</i>	X	X
Wild zinnia	<i>Zinnia peruviana</i>	X	

X - Cotton aphids found on one sampling occasion.

XX - Cotton aphids found on more than one sampling occasion but never more than 100 aphids per plant.

XXX - Cotton aphids found on more than one sampling occasion and at least once with more than 100 aphids per plant.

v). *Other aphid species*

~~A wide range of aphid species were recorded that are not pests of cotton. However these species are significant as they may settle on cotton to test feed and growers may mistake them for damaging species. Hence a knowledge, of which aphid species are present and the hosts they use is valuable in understanding when a particular species may be likely to settle on cotton (Table 7).~~

Table 7. Weed species and aphid species for which they are hosts. The aphid species are listed generally across the top of the table. In the 'Aphids recorded' column is more detail of particular aphid species found. (Summer, Autumn, Winter, Spring ; SAWS)

Aphid Species	Common name	Host species	Common name	Recorded			
				S	A	W	S
<i>Lipaphis pseudobrassicae</i>	Turnip aphid	<i>Chenopodium pumilio</i>	Small crumbweed				
		<i>Echium plantagineum</i>	Paterson's Curse				
		<i>Lamium amplexicaule</i>	Deadnettle				
		<i>Malva parviflora</i>	Marshmallow				
		<i>Polygonum aviculare</i>	Wireweed				
		<i>Rapistrum rugosum</i>	Turnip weed				
		<i>Sysbrium spp</i>	Rocket				
<i>A.kondoii</i>	Blue-green Aphid	<i>Lepidium bonariense</i>	Peppergrass				
		<i>Malva parviflora</i>	Marshmallow				
		<i>Medicago polymorpha</i>	Burr medic				
		<i>Sclerolaena spp.</i>	Roly poly				
		<i>Urtica urens</i>	Small nettle				
<i>A.Pisum</i>	Pea Aphid	<i>Medicago polymorpha</i>	Burr medic				
		<i>Malva parviflora</i>	Marshmallow				
		<i>Polygonum aviculare</i>	Wireweed				
		<i>Urtica urens</i>	Small nettle				
<i>Rhopalosiphum padi</i>	Oat or wheat aphid	<i>Sorghum halepense</i>	Johnson Grass				
		<i>Avena fatua</i>	Wild oats				
		<i>Echium plantagineum</i>	Paterson's Curse				
		<i>Medicago polymorpha</i>	Burr medic				
		<i>Triticum aestivum</i>	Wheat				
<i>Rhopalosiphum maidis</i>	Corn aphid	<i>Sorghum halepense</i>	Johnson Grass				
		<i>Sorghum bicolor</i>	Sorghum				
		<i>Avena fatua</i>	Wild oats				
<i>Hyperomyzus lactucae</i>	Blackcurrent/ Sowthistle Aphid	<i>Lactuca spp</i>	Wild lettuce				
		<i>Sonchus oleraceus</i>	Sowthistle				
<i>Brachycaudus rumexicolens</i>	Dock Aphid	<i>Persicaria spp.</i>	Knotweeds				
		<i>Polygonum aviculare</i>	Wireweed				
		<i>Rumex crispus</i>	Curled dock				
<i>Brachycaudus helichrysi</i>	Leaf-curling Plum Aphid	<i>Helianthus annuus</i>	Sunflower				
		<i>Urtica urens</i>	Small nettle				
<i>Brachycaudus sp.</i>		<i>Urtica urens</i>	Small nettle				
<i>Uroleucon sonchi</i>	Brown Sowthistle Aphid	<i>Lactuca spp</i>	Wild lettuce				
		<i>Sonchus oleraceus</i>	Sowthistle				
		<i>Biddens subalternans</i>	Beggars ticks				
<i>Aphis spiraeicola</i>	Spiraea aphid	<i>Malva parviflora</i>	Marshmallow				
		<i>Sonchus oleraceus</i>	Sowthistle				
<i>Aphis nerii</i>	Oleander aphid	<i>Gomphocarpus fruticosa</i>	Swanplant				
		<i>Nerium oleander</i>	Oleander				
<i>Dysaphis radicola</i>	Apple-dock Aphid	<i>Polygonum aviculare</i>	Wireweed				
		<i>Rumex crispus</i>	Curled dock				
<i>Dysaphis apiifolia</i>	Hawthorn-parsley Aphid	<i>Ammi majus</i>	Bishop's weed				
		<i>Medicago polymorpha</i>	Burr medic				
		<i>Silybum marianum</i>	Variiegated thistle				
<i>Therioaphis trifolii</i>	Yellow Clover aphid	<i>Medicago polymorpha</i>	Burr medic				
<i>Capitophorus eleagni</i>	Artichoke Aphid	<i>Arctotheca calendula</i>	Capeweed				
		<i>Silybum marianum</i>	Variiegated thistle				
<i>Capitophorus hippophyses</i>		<i>Persicaria spp.</i>	Knotweeds				
<i>Metopolophium dirhodum</i>	Rose-grain Aphid	<i>Sorghum halepense</i>	Johnson Grass				
		<i>Avena fatua</i>	Wild oats				
<i>Sitobion miscanthi</i>		<i>Sorghum halepense</i>	Johnson Grass				
		<i>Avena fatua</i>	Wild oats				
<i>Hysteroneura setariae</i>	Rusty plum Aphid	<i>Sorghum halepense</i>	Johnson Grass				
		<i>Avena fatua</i>	Wild oats				

B. Within plant and within field distribution of cotton aphid (*A. gossypii*)

i) Within plant distribution of aphids

The within plant distribution was assessed at several sites (Figures 7 to 11). At most sites aphids showed a bias toward the younger leaves of plants from mainstem node 1 - 6 below the plant terminal. As populations developed, however, there was a trend toward a second population abundance lower in the canopy, particularly at Kingsthorpe. This is significant, as insecticides applied to control aphids will have the greatest efficacy near the tops of plants with declining efficacy lower in the plant. This is primarily due to poor coverage of these lower leaves, due in part to their being 'shaded' by younger leaves. Hence populations lower down in the canopy will contribute to rapid reinfestation of upper plant parts. Furthermore, if sampling is only done in the upper canopy then these lower populations may be missed.

Cotton aphid - aptera per leaf

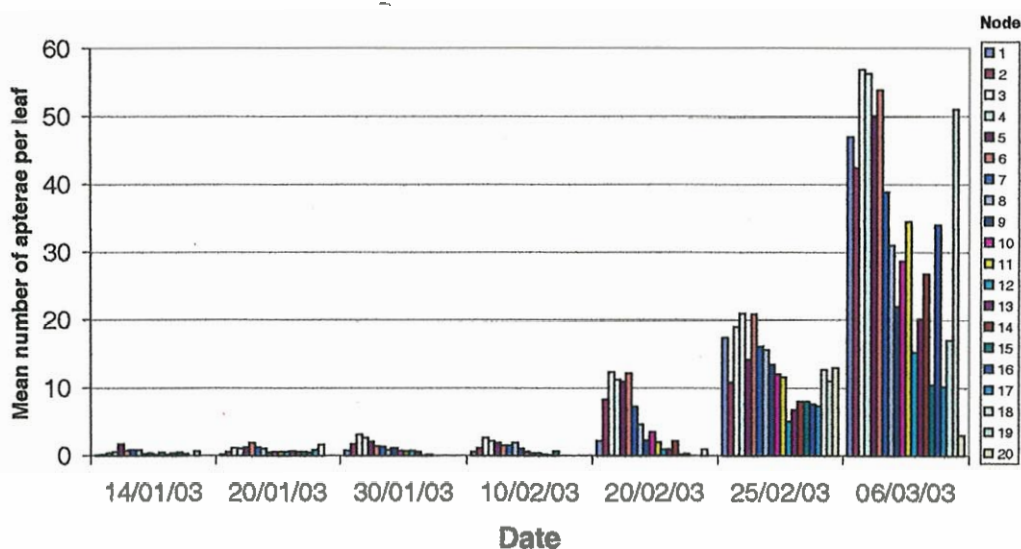


Figure 7. Distribution of cotton aphid aptera by mainstem node (1 is the top most unfurled mainstem node leaf), Block 17, ACRI, 2002-03.

Cotton aphid - alates per leaf

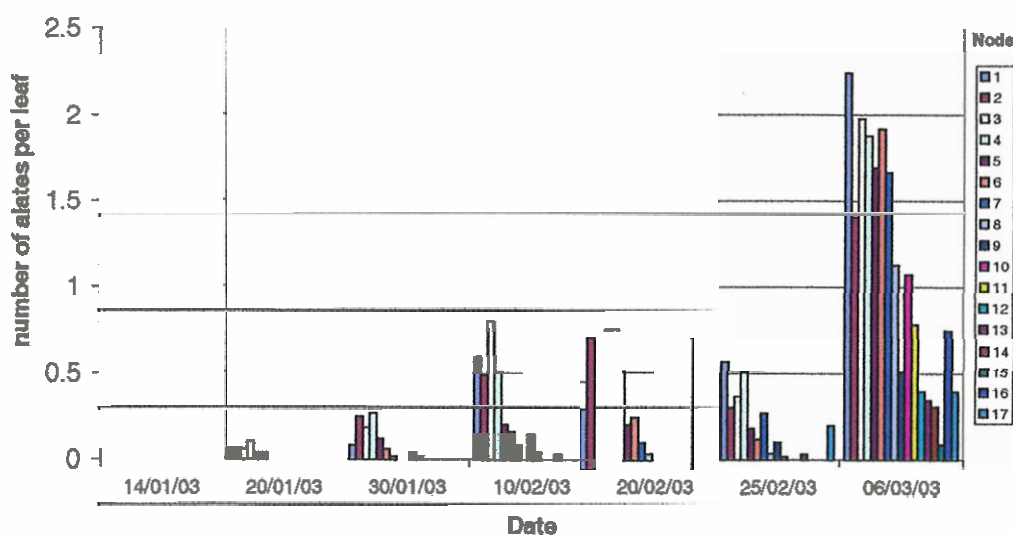


Figure 8. Distribution of cotton aphid alates by mainstem node (1 is the top most unfurled mainstem node leaf), Block 17, ACRI, 2002-03.

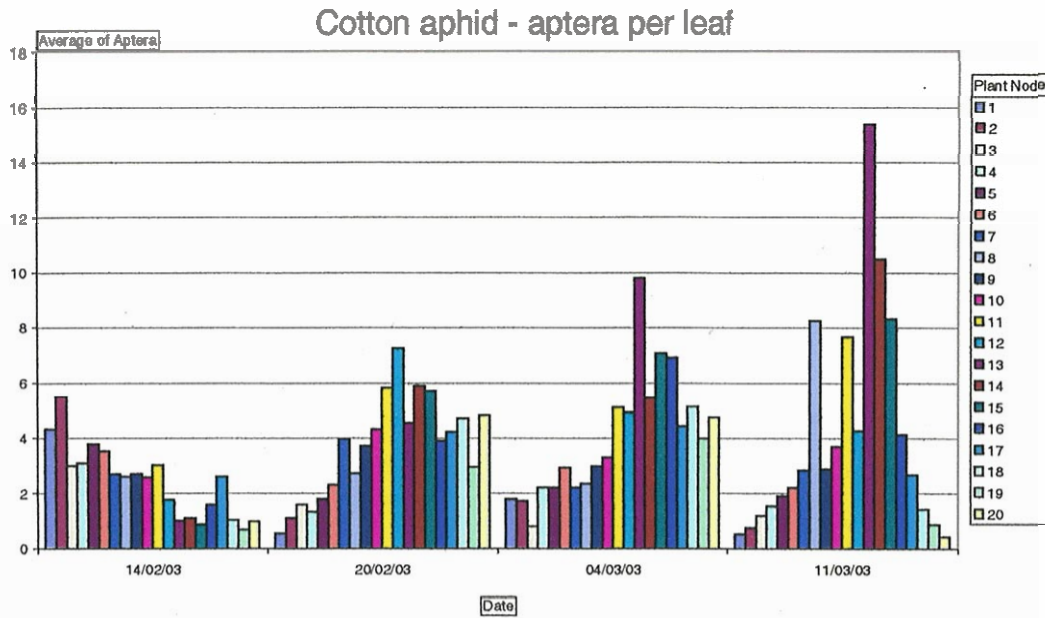


Figure 11. Distribution of cotton aphid aptera by mainstem node (1 is the top most unfurled mainstem node leaf), Kingsthorpe, Darling Downs, 2002-03.

ii) Within field distribution

An understanding of the within field distribution of aphids is important because it can influence the way in which a pest is most effectively sampled. For instance, if a pest is distributed very evenly (uniformly) then a small sample will be effective, whereas if the pest is highly clumped then a larger sample will be required to increase the chance of finding the pest. We used Taylor's Power Law to determine the distribution of aphids. This plots the log of the variance against the log of the mean.

The slope of this line indicates the type of distribution; a slope of 1 means that the distribution is random (the variance increases proportionally to the mean), a slope <1 means that the distribution is more uniform or even (this is because the variance is small because each sample contains about the same number of individuals), a slope >1 indicates a clumped distribution because the variance is large because there are a lots of samples with nothing and a few with very high numbers.

Data from three sampling locations was plotted and shows clearly that aphids have a highly clumped distribution. This is to be expected with a 'colony' forming species, where an individual female aphid will found a colony on a leaf, which will slowly spread to neighbouring plants as the population grows.

Cotton aphid - apterae per leaf

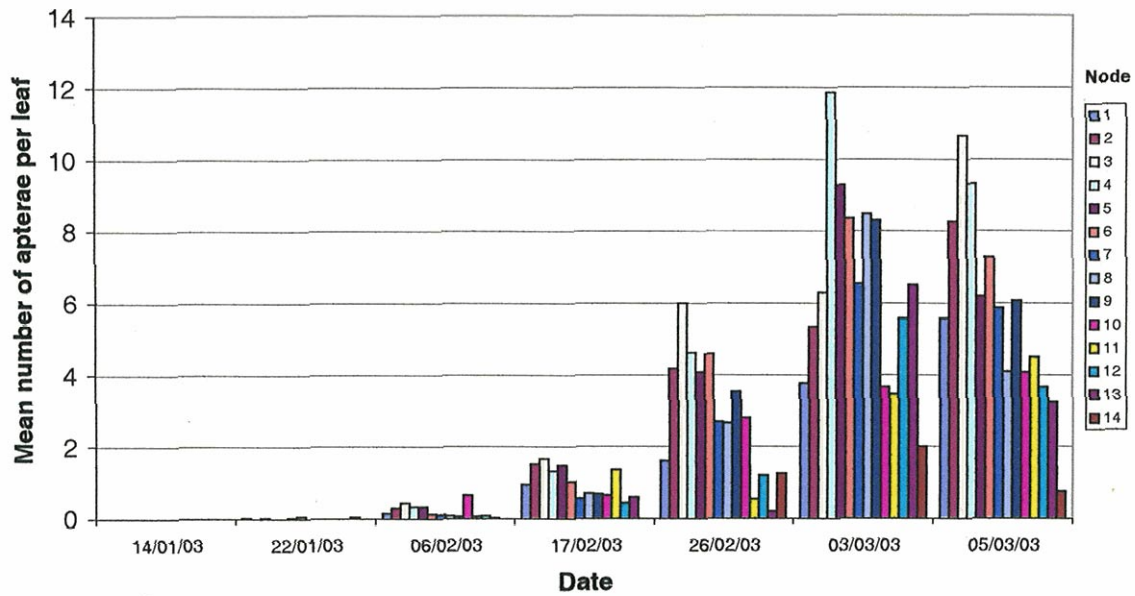


Figure 9. Distribution of cotton aphid aptera by mainstem node (1 is the top most unfurled mainstem node leaf), Leitches Block, ACRI, 2002-03

Cotton aphid - alates per leaf

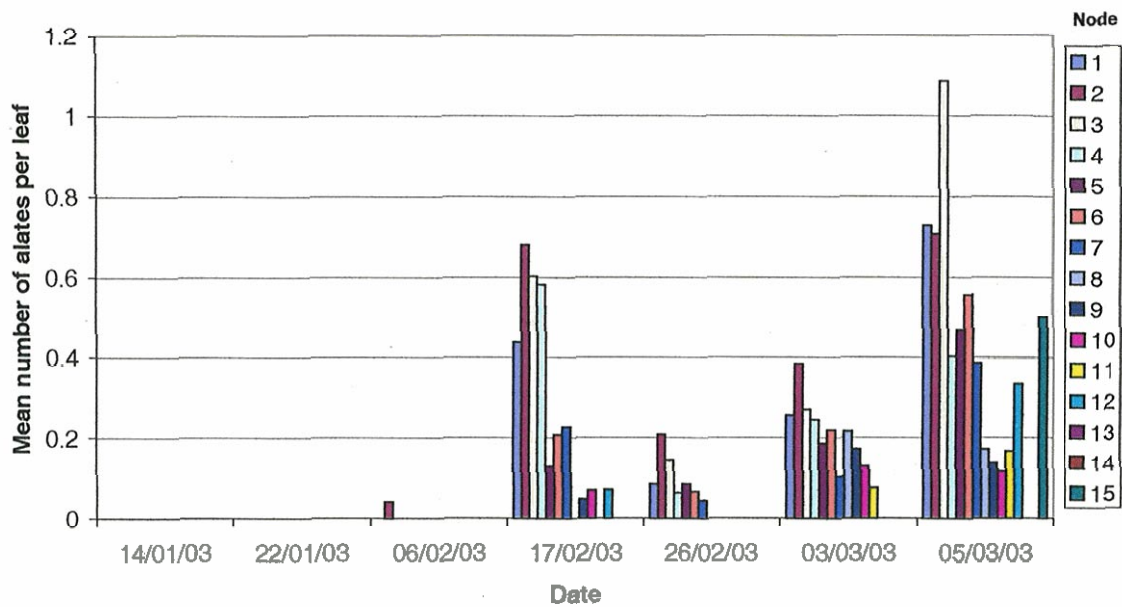


Figure 10. Distribution of cotton aphid alates by mainstem node (1 is the top most unfurled mainstem node leaf), Leitches Block, ACRI, 2002-03

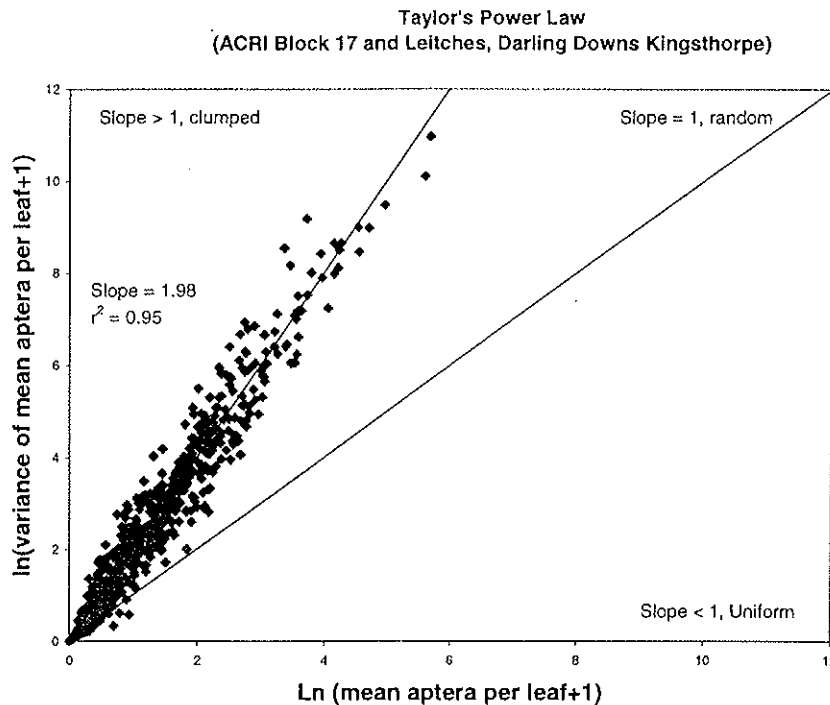


Figure 11. Relationship between the mean and variance showing that the distribution of aphids is highly clumped.

iii) Relationship between proportion of infested plant and mean aphid density per leaf.

Pests that have clumped distributions are often effectively sampled using a presence / absence sampling system. This avoids the need to count individuals, making sampling faster, so more leaves can be sampled which increases the chances of finding the pest if it is present. However it is important that the proportion of plants that are infested can be related back to a mean density of the pest so that this can be compared with threshold densities for control. Problems can occur if the pest distribution is so clumped that 100% of plants are infested well before or close to the density at which the economic threshold is reached.

We investigated this relationship both using natural infestations in 1-2 ha sections of fields. Initial analysis revealed a curvilinear relationship, but significantly this relationship appears different for different strata of the plant. Aphids in the upper (top 5 nodes) and mid (nodes 5-10 from the top) strata of the canopy show a fairly tight relationship between the percentage of plants infested and the mean number of aphids per leaf (Figure 12). However, aphids in the lower strata (node 11 – 15 below the top) showed a poor relationship.

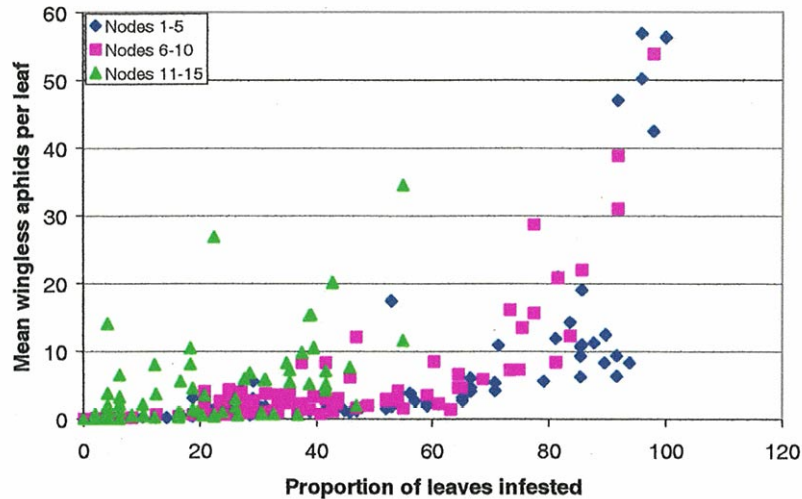


Figure 12. Relationship between mean number of aphids per leaf and proportion of leaves infested for different strata of the canopy; nodes 1 –5, 6-10, 11-15 from the terminal.

We fitted curves to these data so that we evaluate how well the mean number of aphids per leaf could be predicted by knowledge of the percentage of leaves infested. To linearise the data we transformed both axes;

$$\begin{aligned} \text{Aphids per leaf} & \dots\dots\dots \text{Ln}(\text{aphids}+0.1) \\ \text{Percentage infested} & \dots\dots \text{Ln}(((\% \text{ infested}/100)+0.05)/(1-(\% \text{ infested}/100)+0.05)). \end{aligned}$$

This transformation worked well, and the fitted lines are shown in Figure 13. Note the r^2 values for the top and middle strata are high compared with the bottom strata. This is possibly related to the way aphids spread. In the top strata aphids spread rapidly across the crop, by flying and by wind – initially at low densities but with many plants infested. In contrast in the bottom canopy it is difficult for aphids to move from plant to plant except by walking, so the rate of spread between plants is slower than the rate of growth of populations, and hence there are more aphids for any given percentage infestation.

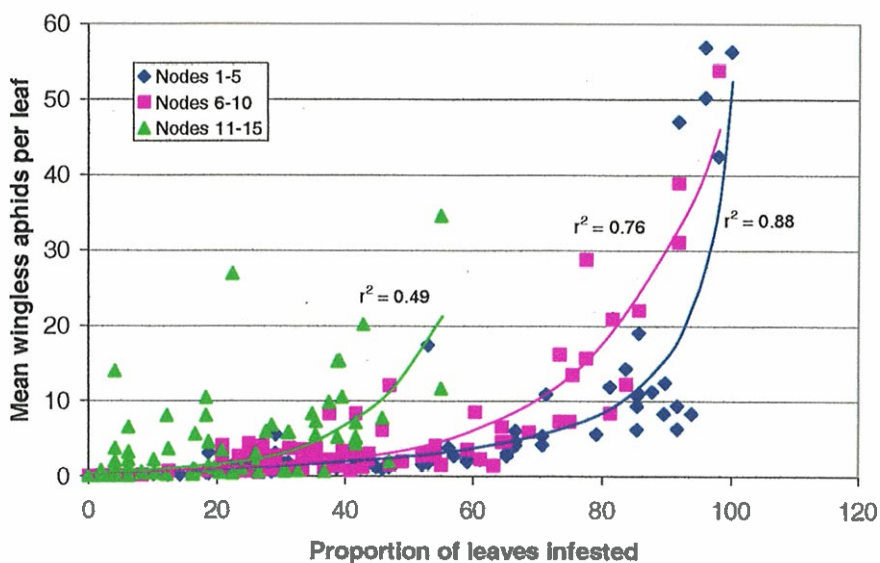


Figure 13. Fitted relationships between mean number of aphids per leaf and proportion of leaves infested for different strata of the canopy; nodes 1 –5, 6-10, 11-15 from the terminal.

Although there is a good relationship between the percentage of plants infested and the mean number of aphids per leaf in the upper canopy it is significant that the inflection point occurs at a relatively high percentage infestation. This is an issue because it means that in the range from about 85% of plants infested to 100% infested there is a dramatic increase in the number of aphids per leaf. This has two important implications. Firstly, presence absence sampling loses accuracy when it is most important – i.e. close to the threshold of 90% of plants infested. This means that consultants and growers need to be vigilant with sampling at this point, otherwise they run the risk of having far more aphids than they think they have, with an increased risk of yield loss. Secondly, data from another project (CSP147C) suggests the threshold for aphids for yield loss is probably in the range of 100 – 200 aphids per leaf. If so then the current threshold is too low and the presence/absence sampling technique will not be accurate at these densities. A solution, once the threshold has been resolved in CSP147C, will be to either use a ranking system to cater for the threshold or to change the definition of infestation, for instance a leaf is not classed as infested unless at least 10 aphids are present. These options are currently being explored.

6. Provide a conclusion as to research outcomes compared with objectives. What are the “take home messages”?

This project has provided a good basic knowledge of the ecology of aphids in cotton regions and of their seasonal abundance and distribution in cotton fields. Such knowledge did not exist before. Key points include:

- i. Cotton aphid is predominantly a mid-late summer pest. A wide range of summer and winter hosts were identified and included a range of broad leaf weeds, crops and garden plants. Among the winter crop hosts are faba beans and lupins, although aphid do poorly on them. Aphids failed to persist on vetch, canola or lucerne. In particular ratoon cotton will carry-over aphid populations, which is a problem for resistance management. This led to recommendations for good overwinter field hygiene.
- ii. It is likely that winter conditions affect the size of the overwintering populations, with drier conditions supporting fewer hosts and lower overwinter aphid populations. Cotton aphid uses hosts in farm and urban gardens through winter. Farm gardens in particular can serve as reservoirs for insecticide resistant cotton aphids and are particularly important in dry years when other hosts are scarce.
- iii. The seasonal abundance and host range of cowpea aphids was documented. This species has two peaks in abundance, in early spring and autumn. It also uses a wide range of hosts, but is particularly noticeable on medics.
- iv. Green peach aphid is a cool season specialist. It has a narrower host range than cotton aphid and cowpea aphid, but uses some brassicaceous hosts that are widespread.
- v. A wide range of other aphid species and their hosts was also recorded. This information has proven valuable, for instance in warning industry of influxes of *Rhopalosiphum* spp. which settle on seedling cotton, but which will not establish and breed. This led to the recommendation not to treat aphid populations unless it is clear they are breeding.
- vi. Cotton aphids show a preference for the upper canopy leaves of plants. However, at higher numbers there is a significant population found in the lower canopy. This

population is difficult to reach with insecticides and may be a major source of recolonisation of plants following insecticide application.

- vii. Cotton aphid shows a highly clumped distribution, a product of their biology, whereby females produce live young that do not move far away from the parent. This makes sampling more difficult as populations may be missed.
- viii. There is a curvilinear relationship between the proportion of plants infested with aphids and the mean number of aphids per leaf. This may be useful if it can be linked effectively with the thresholds being derived in another project.

7. Detail how your research has addressed the Corporation's three Outputs - Economic, Environmental and Social?

This research has provided a basic knowledge of aphid ecology and distribution, of the species present in cotton regions and the hosts they used and of the link between aphid ecology and resistance. Such information has been useful in providing the cotton industry with improved guidelines for managing these pests. This helps reduce insecticide resistance, loss of yield and reductions in fibre quality. Ultimately, improved management of aphids helps, in a small way, to allow sustainable cotton production, which is important for the regional communities that depend on this crop.

ix. Future opportunities

Application and publication of outcomes

Publication of outcomes has been hampered as data was being collected up until the end of the project. It is intended to publish this research in the next year. This entails publications to industry as well as publications in scientific journals.

The application of outcomes has already been initiated (see publications below and Appendix 2 – Selected publications); growers have been advised of hosts of cotton aphids, of their overwintering and the importance of weed control, of the potential role of farm gardens in resistance carry-over, the within plant distribution of data and of the need to check that aphid species found on young cotton are actually breeding on cotton before deciding on the need for control. This information and other components of this work needs to be brought together for publication as a

CRC	Research	Review.
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Future research

This research should be continued in two main areas;

Firstly using the information generated in this project to help improve management of aphids. This would include (i) investigating selective options for control of aphids, especially in Bollgard II crops where supplementary control may be all that is required given likely higher numbers of beneficials, (ii) further refining the overwinter survival and colonization of cotton, including trap crops and crops potentially used in relay crop systems, which may enable development of predictive capacity for the risk of aphid outbreaks.

Secondly, aphids are vectors of the disease Cotton Bunchy Top. It would greatly help our understanding of this disease if we knew more about the transmission of this disease and its potential rate of spread within cotton fields. This would be driven by the transmission characteristics of the disease and the rate of spread of

aphids across fields. If this could be predicted than it could lead to improved recommendations for managing this disease in future by allowing development of thresholds that incorporated the risk of CBT. At present it is difficult to provide a logical recommendation for management of early aphid populations, given the need to balance risk of CBT against risk of resistance selection and negative effects on the beneficial fauna. Further, good progress has been made in screening for varieties that are resistant to CBT and a new variety should be available in 2005-06. This work needs to continue. The dry winters of the past few seasons have hidden the aphid / CBT problem, but a return to more typical or wetter winters could see this situation change quickly.

Wetter, milder winters where there is adequate rainfall to induce good weed growth may lead to higher carry-over of aphids and earlier build up in spring, with subsequent migration onto young cotton. This scenario is well illustrated by the wet mild winter of 1998 and the high abundance of aphids on young cotton in the following cotton crop. The risk of aphids infecting cotton with CBT is also probably higher in such years as it is likely that alternative hosts for the disease such as marshmallow may also be more abundant. Even in the drought years we have been able to find CBT affected plants near the centre of aphid outbreaks when conducting surveys in early March, indicating that the disease is not 'rare' in aphid populations. Fortunately in recent years the low overwinter survival of aphids and late build-up in cotton has limited infection with this disease and potential to affect yield. A new project based around these issues was developed and has been funded by the CRDC.

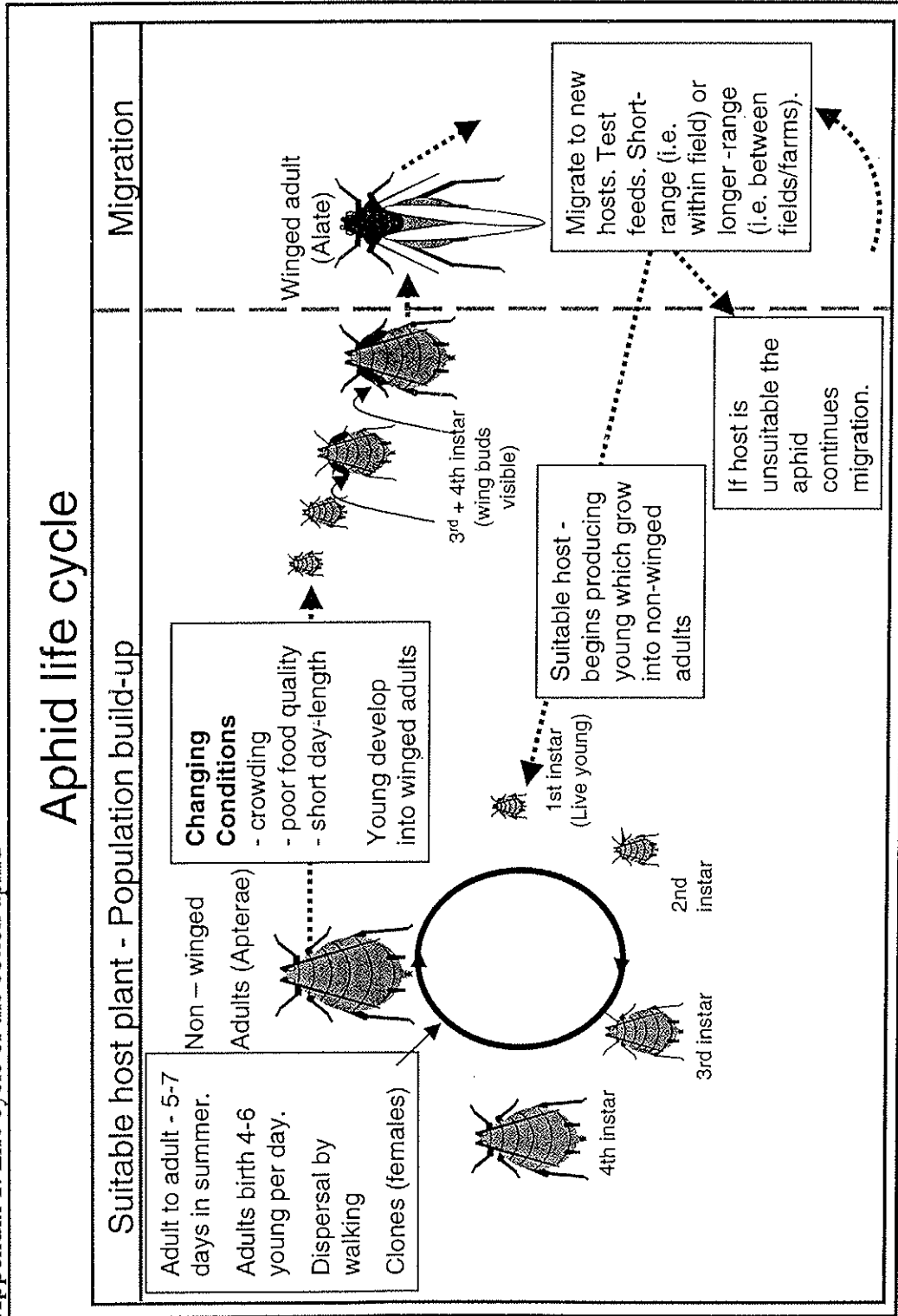
**8. List the publications arising from the research project and/or a publication plan.
(NB: Where possible, please provide a copy of any publication/s)**

1. Wilson, L. and Spora, A. (2001) Aphids in cotton *Australian Cotton CRC Research Review No. 10*
2. Wilson, L. and Spora, A. (2001) Strategies to manage aphids in cotton. *Australian Cotton CRC Research Review No. 11*
3. Franzmann, B., Wilson, L. and Smith, T. (2002) Two new bio-control agents for cotton aphid. *Proceedings of the 11th Australian Cotton Conference*. Brisbane, August 2002.
4. Herron, G., Gullick, G. and Wilson, L. (2002) Insecticide resistance in cotton aphid (*Aphis gossypii*): Results and management options after seasons 1999/2000, 2000/2001 and 2001/2002. *Proceedings of the 11th Australian Cotton Conference*, Brisbane, August 13-15, 2002, pp. 221-227
5. Wilson, L., Herron, G. and Heimoana, S. (2004) Secondary Pests in the Bollgard II era. CCA AGM Narrabri, 18-19 May, 2004
6. Wilson, L., Herron, G. and Heimoana, S. (2004) Aphids and mites in the Bollgard II era. CSD Variety trial results – 2004. pp 81-83
7. Wilson, L., Heimoana, S., Smith, T., Herron, G. and Franzmann, B. (2004) Research on aphid ecology and management. *Proceedings of the 12th Australian Cotton Conference*, Broadbeach, August 10-12, 2004, pp. 523-531
8. Herron, G., Cottage, E., Wilson, L. and Gunning, G. (2004) Insecticide resistance in cotton aphid (*Aphis gossypii*): Results and management options after seasons 2003/2003 and 2003/2004. *Proceedings of the 12th Australian Cotton Conference*, Broadbeach, August 10-12, 2004, pp. 533-539.

9. Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. Where possible include a statement of the costs and potential benefits to the Australian cotton industry or the Australian community.

This project provides basic information with which to improve the management of aphids in cotton. Information of the seasonal abundance and host range is important as it identifies a time period (winter) and the species that should be controlled to help reduce overwinter survival. The studies with crop hosts suggest that common rotations such as wheat or vetch are unlikely to contribute to aphid survival through winter, unless these crops were infested with host weeds. However, other species such as lupins or faba beans presents a greater risk. Information on the other aphid species present in the region and the hosts they use provides information that is important in helping growers and consultants to understand that different aphid species have preferred hosts, and although they may settle on cotton and test feed most will fail to establish. The information on aphid within plant and within field distribution will be crucial when thresholds are developed. The threshold can be linked with the sampling information to provide an efficient package to assess and evaluate the risk of loss from aphid populations. Most of these findings have been extended to industry already and, judging by feedback at grower meetings and field days, the level of knowledge and understanding of aphid biology, ecology and management has increased significantly through the industry.

Appendix 1. Life cycle of the cotton aphid



Appendix 2 – Selected Publications

Research on aphid ecology and management. Proceedings of the 12 Australian Cotton Conference, Broadbeach, August 10-12, 2004, pp. 523-531

Lewis Wilson¹, Simone Heimoana¹, Tanya Smith¹, Grant Herron² and Bernie Franzmann³
Australian Cotton CRC and ¹ CSIRO Plant Industry, ² NSW Agriculture, ³ Qld DPI&F.

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).

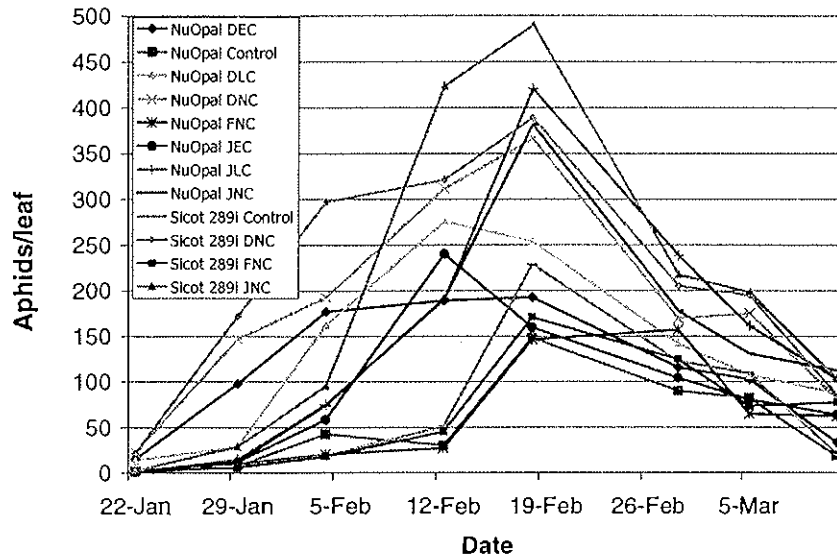


Figure 1. Aphid populations on the 3rd or 4th mainstem node leaf below the terminal in different experimental treatments, ACRI, 2001-02. Each line represents a different treatment, which vary in their starting dates and peak populations levels.

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.

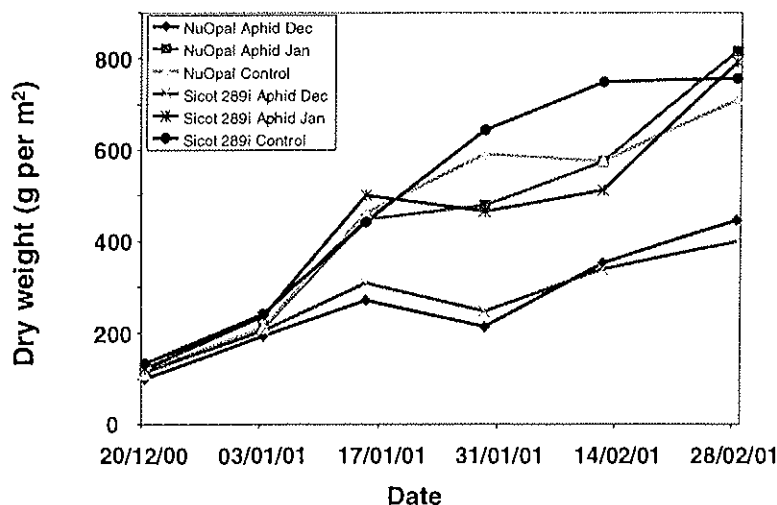


Figure 2. Aphid populations can eventually effect crop growth, here shown by plant dry weight (g/m² or meter of row), if left uncontrolled for long periods at very high densities. December infestations reached about 1200 aphids per leaf. However, later infestations did not affect growth.

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 that 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.

<i>Time of infestation</i>	Control	<i>Variety</i>	
		<i>NuOpal</i>	<i>Sicot 289i</i>
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.

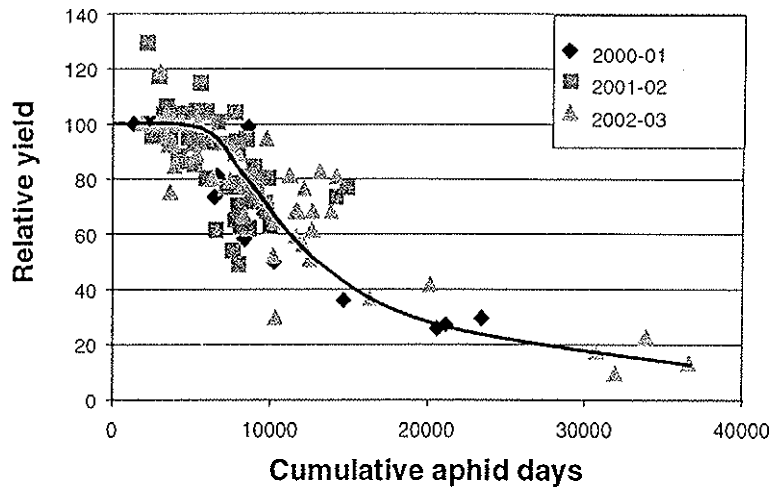


Figure 3. Potential relationship between the number of accumulated aphid days and yield for cotton.

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, *Lilium* 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.

	Cotton aphid	Cowpea aphid	Green aphid	peach
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Host species	Common name	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				
<i>Brassica (cauliflower)</i>	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>	Variiegated 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.

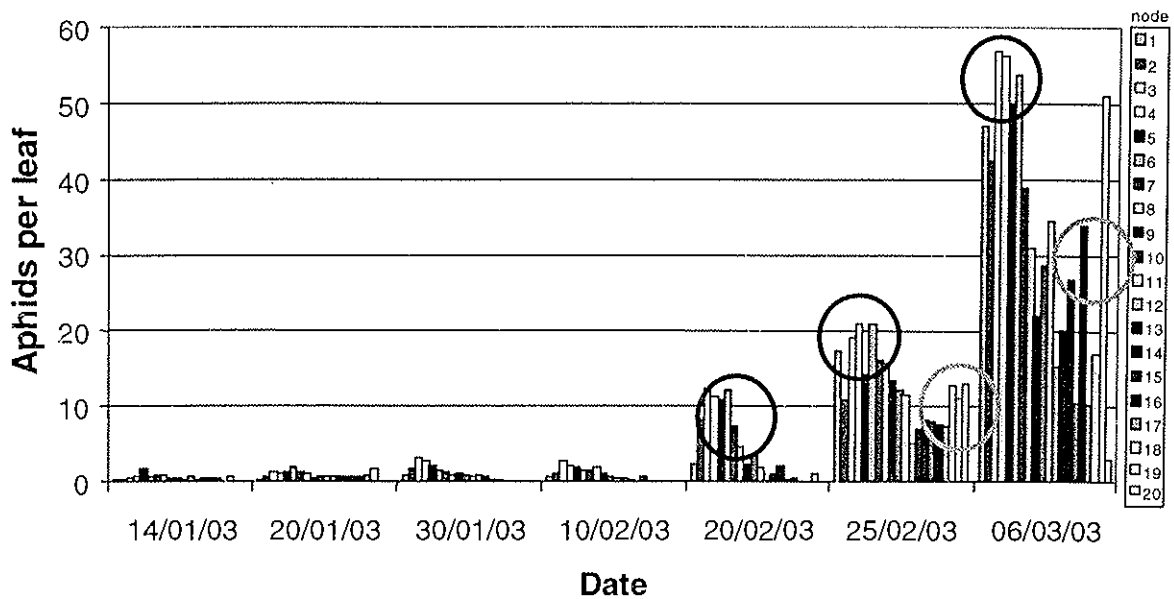


Figure 4. Distribution of aphids on cotton plants. For each date nodes near the top of the plant are on the left, near the bottom on the right. Dark circles indicate the bias of aphids toward younger leaves (node 2-5 below the terminal), while light circles indicate significant populations lower down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

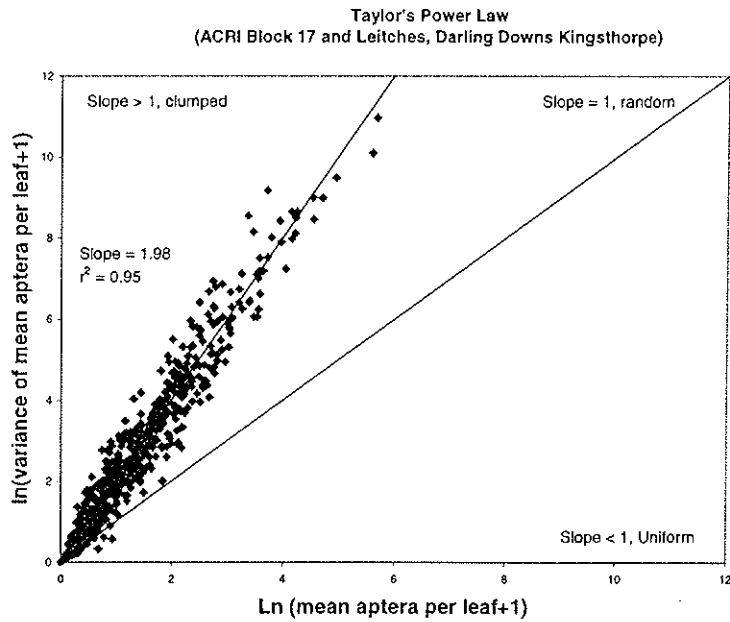


Figure 5. Analysis of mean / variance relationship for cotton aphids on cotton, showing slope of 1.98 indicating a highly clumped distribution.

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.

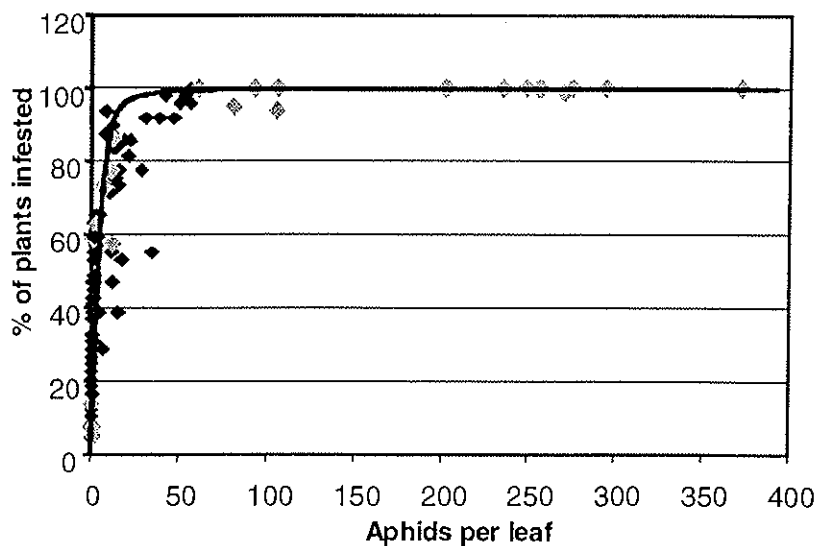


Figure 6. Relationship between mean density of aphids per leaf and % of leaves infested. The dark points are from large scale sampling and light from small plots.

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.

Cotton Aphid Cage Trial 1, 2002-03

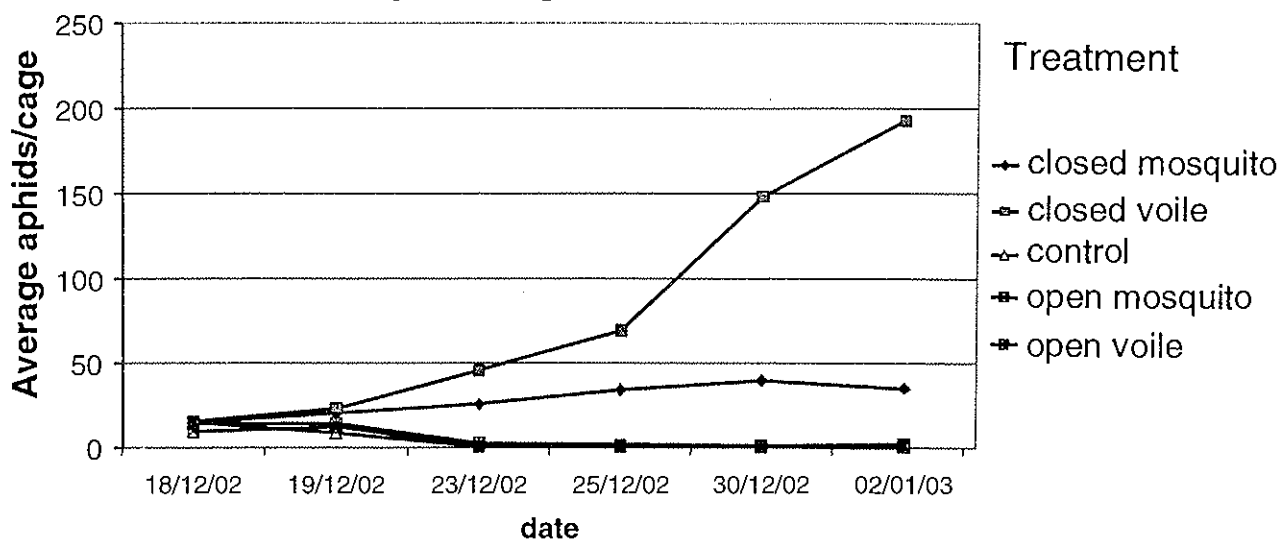


Figure 7. Effect of protecting aphids on cotton plants from all beneficials (closed voile), some beneficials (closed mosquito gauze) or exposed to beneficials (all other treatments).

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.

Acknowledgements

CRDC provided funding for much of this research (CSP103C, CSP145C, CSP147C, DAN163C, DAQ119C). Thanks to Dee Hamilton, Deon Cameron, Lex Cameron, Nemrod Mor, Mark Strahle, Lawrence Smith, Kelli Trackson and Melissa McDougall who all provided excellent assistance at various times.

Aphids in Cotton

Reviewer: Lewis Wilson¹, Annie Spora²

Research: Lewis Wilson¹ Grant Herron², Simone Heimoana¹ and Bernie Franzmann³

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Introduction

Aphids, once considered only a secondary pest in cotton are now a major problem for growers in some regions. Three species are commonly found on cotton, the cotton aphid (*Aphis gossypii*), green peach aphid (*Myzus persicae*) and cowpea aphid (*Aphis craccivora*). The cotton aphid is the most commonly found, but there are occasional early or late season infestations of green peach aphid, which die off during hot periods. Cowpea aphid is sometimes found on seedling cotton in late spring after legume crops die off, but rarely establishes effectively in cotton plants.

Damage

Aphids insert their stylets into the leaf or terminal tissues of plants and probe until they contact a phloem vessel. The phloem is the tissue that distributes the photosynthetic products (assimilates) required for plant growth throughout the plant. The sap in the phloem is under pressure and is basically 'forced' into the aphids, which regulate the flow. Phloem sap is rich in sugars, but poor in acids which insects need for growth. To accumulate enough amino acids for growth the aphids 'pass' a lot of excess sugar, which is excreted onto plants as a shiny sugar-rich deposit known as 'honeydew'. Honeydew encourages the growth of sooty moulds on leaf surfaces.



Picture 1. Aphids excrete sugary honeydew which has a shiny appearance on leaves (honeydew left, normal leaf right).
Photo: L. Wilson

Aphids cause damage to cotton in three ways.

1. Aphids compete with young growth and developing fruit (squares and bolls) for assimilates. If the plant is unable to compensate then some reduction in growth is likely.
2. The presence of aphids on leaves reduces photosynthesis. The cause of this effect is not well understood but could be due to a number of factors including the damage caused by insertion of stylets (especially when there are many aphids), the effects on assimilate depletion or the effects of saliva secreted in to the plants by the aphids.
3. Secretion of honeydew (Picture 1) The presence of honeydew on leaves can reduce photosynthesis. Furthermore, late season

aphid infestations result in honeydew contaminating lint, making the lint sticky and discoloured. Severe downgrading of sticky lint may result because of the difficulties of processing it in high speed spinning machinery.

Cotton aphids generally prefer to feed on the terminals, young leaves and fruit, sites where the supply of assimilate is high.

Damage symptoms from cotton aphids initially appear as crinkled and curled leaves, with the margins of the leaves curling downwards (Picture 2). Prolonged high populations of cotton aphid will lead to a dra-

matic shortening of internodes, severely reduced leaf size, leaf / fruit loss and obvious yellowing or mottling of young leaves. This yellowing or mottling often occurs on areas of leaves heavily damaged by aphids or can occur evenly around the margins of leaves and should not be confused with the angular mottling found with Cotton Bunchy Top (CBT). Pre-squaring cotton appears to be able to fully compensate for aphid damage as long as the aphid feeding ceases. However, prolonged high population levels up to cut-out (when fruit production slows or stops) can cause substantial damage and reductions in yield. Populations in excess of 90% of plants infested with aphids for 3 or more weeks are likely to result in economic loss.



Picture 2. Severe aphid damage results in wrinkling, stunting and cupping of leaves. Younger leaves may show a yellow margin and reddened patches may appear on leaves. Photo: L. Wilson

The green peach aphid causes far more severe effects on plant growth at much lower densities when compared with cotton aphid. Symptoms include yellowing of young leaves and the terminal and severe reductions in internode length and leaf / fruit size. Plants generally recover quickly if the green peach aphid numbers decline due to hot weather, beneficial insect activity or insecticides. Fortunately this pest rarely establishes well on cotton.

Increasing problem

Over the past three seasons there has been a trend

toward earlier and more widespread development of aphids in cotton crops, possibly caused by a number of related factors:

1. Reduced early season applications of endosulfan, which is a moderately effective aphicide. In the past application of endosulfan to control *Helicoverpa* spp. co-incidentally controlled any aphid populations present.
2. Cotton production using Ingard®, has reduced insecticide suppression of aphids because of fewer early season insecticide sprays. However there is also an improved survival rate of beneficial insects that will help control aphids. Unfortunately, the unwanted effects of spray drift from conventional cotton onto Ingard® may cause reductions in beneficial insect abundance without affecting the resistant aphids, allowing populations to develop rapidly.
3. Resistant aphids survive in situations where formerly they would have been easily and economically controlled. Australia-wide surveys of cotton aphid populations has identified various levels of resistance to pirimicarb, organophosphates, endosulfan and pyrethroids.
4. The perceived risk associated with Cotton Bunchy Top (CBT) disease has caused many growers to use lower thresholds for aphids, accelerating selection for insecticide resistance and reducing beneficials. Cotton aphids have been shown to effectively transmit CBT. Nevertheless, the presence of aphids does not always mean that CBT will develop in a crop, but a crop with CBT has usually had high levels of aphids at some time.

Biology and Ecology

In Australia, the life cycle of aphids is quite different to that of other cotton insects. Aphids of the species found in cotton are all females, there are no males and therefore no sexual reproduction. Females give birth to live female young which are clones of themselves, inheriting all of their characteristics including insecticide resistance. A female aphid can produce live young at the rate of 4 - 6 per day, which in summer can mature into adults in 4 - 7 days and immediately begin producing live young. Aphids are all female and have within them several live young at various stages of development. These cloned offspring already have clones developing within them before they are born. This is how so many generations can be produced in

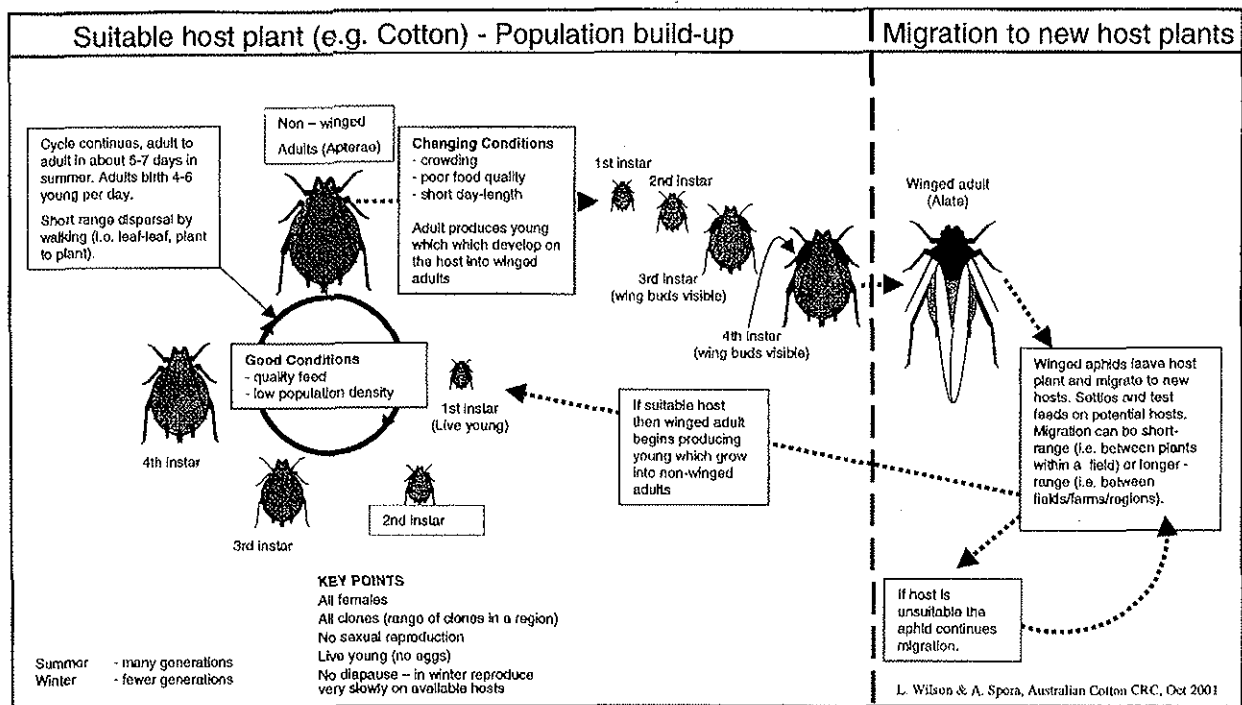


Figure 1: Life cycle of cotton aphid

such short periods. Populations can explode if conditions such as food quality and climate are suitable.

Colonisation of a new host plant usually occurs by the winged (alate) adult. Aphids will settle on the plant and test feed. If the plant is unsuitable the winged adult will resume the flight settle, and test feed pattern, until it finds suitable food or dies. If the plant is suitable, production of live young commences quickly. These mature through four nymphal stages into wingless adults (apterae). The wingless cycle will continue until some aspect of their environment triggers the switch to the production of dispersing (winged) forms. This switch can be caused by poor food quality, for instance if the host plant is senescing, by overcrowding or by reduced day-length.

The female adult aphid then produces live young which develop wing-buds. These nymphs mature into winged adults, which then fly off to find a new host plant. This could entail only a short flight, to another uncolonised plant in the same cotton field, or depending on wind currents, a longer flight to a new crop or weed host further away.

In winter, cooler temperatures slow the growth rate of aphids dramatically. In Australian cotton regions, cotton aphids and green peach aphids do not have an overwintering form, instead they persist through winter at low levels on whatever suit-

able host plants are available. In spring as temperatures increase aphid populations begin to build rapidly again.

Beneficial insects often help to control aphid populations, though there is usually a lag between build up of aphids and build up of beneficials to the point that effective control occurs. Disruption of beneficial populations by some insecticides can lead to earlier, more severe aphid outbreaks

Cotton aphid

The cotton aphid varies widely in colour. The winged adults are typically black, but the wingless stages can vary from pale yellow through to dark green, brown and dull black (Picture3). The wingless forms have a typically bulbous round shape.

Cotton aphid is favoured by warm temperature and does well on cotton through the peak growing period.

Cotton aphid has a broad host range and has been recorded on members of the following families; Fabaceae (legumes, lucerne), Solanaceous weeds (datura, ground cherry, nightshades), Cucurbitaceae (paddymelon), Malvaceae (bladder ketmia, marshmallow) and Asteraceae (sunflower, capeweed, daisies, thistles, bathurst burr). A more complete host range can be found in the IPM Guidelines, available from the Australian Cotton CRC or the CRC website.



Picture 3. Cotton aphids on a leaf. Note wide variation in colour and globular shape. Centre left is a predatory larvae of a hoverfly. Photo: C. Mares

Green peach aphid -

The green peach aphid is a pale yellow-green and is more tear-drop shaped than the cotton aphid (Picture 4). Colonies tend to be uniform in colour compared with cotton aphid. Seen with a hand lens or microscope, green peach aphid had a small tubercle at the junction of the antenna and head, which is absent in cotton aphid and cowpea aphid. The area between these tubercles is 'U' shaped in green peach aphid whereas it is flat in cotton aphid. Also, the green peach aphid has a pair of long pale, tube-like siphunculi at the tip of its abdomen, whereas those of cotton aphid are quite short and usually dark (see Figure 2)



Picture 4. Green peach aphid, note pale green/yellow colour and tubercles with indented 'U' shape between them (see Figure 1). Photo: L. Wilson

The green peach aphid prefers cooler conditions. It is sometimes found on cotton early in the season but populations do not usually persist once hot conditions commence. Green peach aphid also has

a wide host range and is often found on members of the following families. Fabaceae (legumes, lucerne and lupins), Asteraceae or all Brassica sp. They are also often found on peach and plum trees.

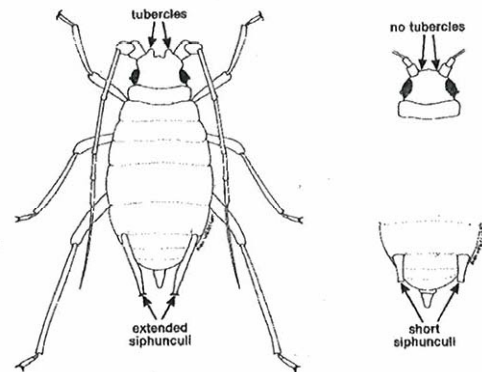


Figure 2. Green peach aphid (left) and cotton aphid (right). - extracted from Forrester and Wilson 1988.

Cowpea aphid

The cowpea aphid is very similar to the cotton aphid in appearance. However, the wingless adults of this species are a shiny black, in contrast to cotton aphid, which is always a dull colour (Picture 5)



Picture 5 Cowpea aphid showing shiny black wingless adults Photo J. Wessels

Cowpea aphid will colonise a range of hosts but prefers legumes and is often found on medic. This species is often found on cotton early in the season but seldom establishes, though it may sometimes produce a small number of offspring. More common hosts include the Cucurbitaceae, Asteraceae, and Fabaceae families, see above.

Other species of aphids on cotton

A range of other aphid species are occasionally found on young cotton. These are mostly the winged forms of species that have migrated from other hosts, especially leguminous weeds. These include Pea aphid (*Acyrtosiphon pisum*), Blue green

aphid (*Acyrtosiphon kondoi*) (Picture 6) and the spotted alfalfa aphid (*Therioaphis trifolii*).



Picture 6 : Winged adult of blue green aphid, (Photo NSW Agriculture)

These species can settle on cotton to test feed but will not normally establish. Populations of winged adults on seedling cotton may initially be high but will usually decline quickly over two or three weeks. A wide range of beneficial insects also enters cotton crops at this time.

Winged forms of the corn aphid (*Rhopalosiphum maidis*) and the oat or wheat aphid (*Rhopalosiphum padi*) may also migrate from grasses, cereals or sorghum into cotton but do not establish. *Aphis spiraeicola* (apple aphid) is also sometimes found on cotton, and probably originates from certain Asteraceae such as *Conyza* spp. (fleabane) or *Chrysanthemum*.

Soil aphids

Bean root aphid (*Smynturodes betae*) is rare aphid pest that feeds on the roots of cotton seedlings (Picture 7).

Death of seedlings can occur and may be mistaken for seedling disease. The aphids are small globular and wingless.

The presence of aphids can be detected by carefully separating the soil away from the roots of seedlings. Aphids can be found on the roots at a

depth of about 10 cm and they are tended by ants which construct small chambers to allow movement of aphids around the roots. The chambers are covered in a white, waxy dust from the aphids. Infestations so far have tended to occur in field previously heavily infested with burr medic

If infestations are discovered after seedling emergence there is no effective chemical control for the aphids. If planting cotton into seedbeds which have been infested with burr medic then granular insecticides applied to control other pests may coincidentally control bean root aphid.



Picture 7 : Bean Root Aphid on the roots of young cotton. Photo: M Cahill

How aphid biology affects resistance to insecticides

Aphid populations in a region will consist of a number of different clones. These clones will appear identical but as there is no sexual reproduction the clones are essentially separate sub-populations. Different clones may display differences in biological features, for instance a degree of specialisation toward a particular type of host plant. They can also vary in their resistance to insecticides.

It is likely that there is a range of resistant and susceptible clones in a region. Normally when resistance develops in an insect population there is some penalty in growth or reproduction in that population. In the absence of insecticide selection the resistant individuals are not favoured, though this is not always the case.

When aphids are treated with an insecticide (aphicide) the aphids of resistant clones survive and those of susceptible clones die. This leaves a popu-

lation that is highly resistant which can continue to develop rapidly in the field. Due to the clonal nature of aphid populations, one field can have resistant aphids while the adjacent field can have susceptible aphids.

Resistance management for aphids is different to that for other pests that reproduce sexually. There is no mating of susceptible aphids with resistant aphids to dilute the resistance in a population as is the case with *Helicoverpa*.

Acknowledgments

We thank Dr Amelia Reddall (CSIRO Plant Industry), Dr Neil Forrester and David Larsen (NSW Agriculture) for their input into this review, Dr Mary Carver, Dr Paul de Barro and Dr Owain Edwards (CSIRO Entomology) for assistance with aphid identification, ecology and life cycles and the CRDC and Australian Cotton CRC for funding.



Strategies to Manage Aphids in Cotton

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Introduction:

This is a companion document to the Australian Cotton CRC Research Review Number 10 December 2001 "Aphids in Cotton" and covers management issues to do with aphids.

Resistance in aphids in cotton

Cotton aphid

Cotton aphid resistance to older organophosphates (OP's) such as dimethoate/omethoate, pirimicarb and profenofos has been recorded in most regions with hotspots in the Namoi Valley and the Emerald area. Of particular significance is the strong cross-resistance between older organophosphates and carbamates (pirimicarb). This means that if a dimethoate spray fails then a pirimicarb spray will also fail. So far resistance in aphids is patchy within regions and inconsistent between years. In fact resistance can vary between fields within a farm and within a single field through the season. Cotton Aphid also shows low level resistance to endosulfan and pyrethroids, but to date does not have resistance to diafenthiuron (Pegasus®) or imidacloprid (Confidor®)



Picture1 : Effective sampling for aphids is critical for good management - Photo C Mares CSIRO

Green peach aphid

This species is widely resistant to dimethoate / omethoate, profenofos and pirimicarb. OPs will not control green peach aphids, but pirimicarb may provide partial control (about 50%) It is therefore important to distinguish between cotton aphid and green peach aphid in the field.

If there is a spray failure the follow-up spray should be from a group that does not have the same active ingredient.

Strategies to manage aphids

Aphids, cotton aphid in particular, are emerging as a difficult pest to manage due to resistance and possible role as a vector of Cotton Bunchy Top (CBT). In the light of the resistance results above, aphid management needs to be reviewed to ensure that sensible thresholds are used and that the efficacy of aphicides is maintained.

There are no silver bullets for managing aphids, instead a

number of integrated controls tactics are recommended to help reduce aphid numbers and manage resistance. It is important to manage aphids within an integrated pest management (IPM) system that takes into account the whole



Table 1: Chemical 'Mode of Action' groups available for rotation against aphids

Option	Chemical Group ¹	Chemical subgroup	Mode of action	Seed treatments or 'at planting' insecticides ²	Foliar insecticides ²	Withholding Period Foliar Insecticides (days before harvest)
1	1A	Carbamates	Acetyl choline esterase inhibitors	aldicarb	pirimicarb	21 days
	1B	Organophosphates	Acetyl choline esterase inhibitors	phorate disulfoton	profenofos dimethoate omethoate chlorpyrifos parathion methyl	28 days 14 days 21 days 28 days 14 days
2	4A	Chloronicotinyls	Acetyl choline receptor agonists/antagonists	imidacloprid (Gaucho [®]) thiamethoxam (Cruiser [®])	imidacloprid (Confidor [®])	91 days ⁴
3	12B	Diafenthiuron	Inhibitors of oxidative phosphorylation, disrupters of ATP formation		diafenthiuron (Pegasus [®])	35 days
4	2A	Cyclodienes	GABA-gated chloride channel agonists		endosulfan	28 days ³

¹ Chemical groups according to the Avcare Insecticides Resistance Action Committee, based on mode of action are highlighted on the front panel of product labels.

² Where only one commercial product containing a particular insecticide is available the 'Trade Name' as well as the active ingredient name is given and if there is more than one commercial product, only the active ingredient name is given.

³ See label for use restrictions.

⁴ Withholding period under review -- check label

year (see IPM Guidelines for Australian cotton - available in ENTOPak or from the Cotton CRC website, www.cotton.crc.org.au).

Managing Aphids

Control of overwintering hosts.

Variety selection.

Sowing treatments.

Sampling and thresholds.

Predators & parasitoids.

Rotation of insecticides.

Control of winter aphid hosts

Aphids are able to overwinter on a number of other crops and weeds. There is a risk of resistant clones persisting through winter. Growers and consultants should aim to reduce the availability of on-farm hosts over winter. Cotton regrowth in particular poses a high risk as a reservoir for CBT. Cotton regrowth and volunteer cotton are both potential overwintering aphid hosts

This may be a particular issue if legumes are planted following cotton and there is germination of cotton seed from fallen seed-cotton or regrowth on cotton stubs. If farm hygiene is adequate through winter it is possible that localised aphid survival will be low and that immigrant colonising aphid

clones will be susceptible in the following year. Growers on farms where resistance problems occurred in the last season could consider planting a 'non-host' rotation crop, such as a winter cereal and ensuring that on-farm control of weeds, cotton stubble and cotton volunteers is excellent.

Varieties

None of the current commercial varieties show strong resistance to aphids. There are a number of commercial varieties that do show resistance to CBT syndrome which can be spread by aphids. These varieties are still susceptible to aphids and aphid damage but do not develop CBT symptoms. This may help provide growers concerned with the risk of CBT with the confidence to tolerate higher numbers of aphids, and allow beneficials to survive thereby helping to reduce insecticide resistance selection.

Seed treatment or 'at planting' insecticide

This strategy will help prevent the early build up of aphid populations, therefore reducing the need for foliar aphicides which may disrupt beneficial populations. It may also reduce the risk of CBT for farmers who have concerns about this disease. However, care must be taken in selecting later insecticide sprays as some seed treatments and 'at

planting' insecticides are from the same groups as foliar sprays used for aphid control and there is the potential for prolonged selection with one insecticide group (see Table 1). Check the insecticide label to see that the first foliar insecticide is not the same group as the sowing treatment. Appropriate chemical alternation is still necessary late in the season even if aphids have not been targeted for control since the use of the 'at planting' insecticide. This is because resistant clones, in fields where they are present, are likely to persist at some level through the season.

Sampling

Aphid sampling should begin from seedling emergence and be done at least weekly (Picture 1). Aphids generally prefer younger growth so this is a good place to look. As mentioned earlier aphids have winged and non-winged forms. Score a plant as infested only if non-winged forms are present (winged forms could be just test feeding before moving on to another host). If a high proportion of plants do have winged forms then resample within a few days to check if they have settled and produced young. If reproducing aphids are found it is important to confirm the species, as green peach aphid causes more severe damage than cotton aphid and has a different resistance spectrum.

At the same time as sampling for pests, sample the crop for beneficial insects. See IPM Supporting Documents 7 and 9, available in ENTopak or on the CRC Website, for further details of aphid and beneficial sampling.

Thresholds.

Data from Australia and overseas suggests that cotton will generally recover from aphid damage provided infestations do not persist at high levels (> 90 % plants infested) for too long (< 10 days). The conventional threshold for aphids through the growing period (90% of plants infested) is still therefore appropriate in terms of cotton's capacity to tolerate aphid damage. At this level of infestation 10% of plants have no aphids, many plants have a few aphids and a few plants have many aphids. Control should be applied at this density or slightly earlier if it is clear that aphid populations will soon exceed threshold. Once cotton has open bolls, the threshold should be reduced to 10% of plants infested if honeydew is present to prevent contamination of lint.

However the recent advent of the CBT syndrome,

for which cotton aphid is a proven vector, means that some growers are unwilling to tolerate conventional aphid thresholds. Unfortunately, using reduced aphid thresholds increases insecticide selection pressure on aphids. This can result in resistance and aphid populations that are very difficult to control. Furthermore, early aphid control with broad-spectrum insecticides will reduce beneficial abundance. This will increase the risk of severe aphid outbreaks, especially if aphid sprays fail due to resistance. It is important to weigh-up the risk of CBT and frequent spraying against the risk of resistance when deciding if aphids need to be controlled.

It may also be possible to spot treat areas of the field with heavy aphid populations as soon as they are noticed to prevent them from spreading throughout the field. Unfortunately, until we have a better understanding of the causal agent for CBT and the epidemiology of the syndrome we cannot give a definite threshold for its prevention.

Predators and parasitoids.

A range of parasitoids and predators will help to reduce aphid survival. Cotton consultants have reported that where they were able to effectively conserve beneficials, through either not spraying or spraying only with very selective options (Gemstar or Bt), and where there was little drift risk, aphid populations were present but did not develop into a problem.

Predators of aphids include; lady beetle larvae, damsel bugs, big-eyed bugs, and the larvae of green lacewings and hoverflies. Wasp parasites (*Aphidius colemani* and *Lysiphlebus testaceipes* can mummify and kill aphids (mummified aphids appear as bloated pale brown aphids which do not move Picture 2).

When conditions are only moderately favourable to aphids, natural enemies may successfully limit populations. However under conditions favourable for mass dispersal and rapid aphid increase, natural enemies may not be effective quickly enough to prevent aphids causing economic damage.

Some insecticides can induce aphid problems because of their detrimental effect on natural enemies combined with their inherent poor efficacy against aphids (see IPM Guidelines Supporting

Document 1 available in ENTopak or at www.cotton.crc.org.au). The risk of adverse effects of drift of insecticides applied to nearby cotton on beneficial populations should be taken into account.



Picture 2: Aphid colony showing brown, bloated parasitised mummies (photo Peter M.Room)

Selection of insecticides should consider both the target pest and the type of beneficials that are present. For example, an insecticide can have little effect on one beneficial group, such as spiders, yet be disruptive to another, such as predatory beetles (See page 52 of the Insect Management in Cotton Pocket Guide).

Rotation of insecticides

It essential that we try to preserve the efficacy of existing aphicides. This will require a combination of resistance management and improved management of aphid populations.

Our current resistance management strategy for aphids hinges on four main points;

1. A maximum of 2 sprays of any registered aphicide against aphids, unless the product is otherwise restricted.
2. Rotation of chemistry, that is, do not use the same chemical group consecutively.
3. The first aphicide spray should not be from the same chemical group as any seed treatment or at planting insecticide used that also controls aphids.
4. There is cross-resistance between carbamate (group 1A) and organophosphates (group 1B) and therefore they should be considered as the same group for aphid control.

It is important not to follow a failure with a given product with another product from the same group. The current aphicides registered for use in cotton and their chemical groups are listed in the Cotton Pest Management Guide and can also be found on the Cotton CRC Website. If there is a spray failure the follow-up spray should be from a group that does not have the same active ingredient.

Acknowledgments

We thank Dr Amelia Reddall (CSIRO Plant Industry), Dr Neil Forrester and David Larsen (NSW Agriculture) for their input into this review, Dr Mary Carver, Dr Paul de Barro and Dr Owain Edwards (CSIRO Entomology) for assistance with aphid ecology and life cycles and the CRDC and Australian Cotton CRC for funding.

* Important Use of Pesticides

Pesticides must only be used for the purpose for which they are registered and must not be used in any other situation or in any manner contrary to the directions on the label.

Some chemical products have more than one retail name. All retail products containing the same chemical may not be registered for use on the same crops. Registration may also vary between States. Check carefully that the label on the retail product carries information on the crop to be sprayed.

This publication is only a guide to the use of pesticides. The correct choice of chemical, selection of rate, and method of application is the responsibility of the user.

Pesticides may contaminate the environment. When spraying, care must be taken to avoid spray drift or to adjoining land or waterways. Residues may accumulate in animals fed any crop product, including crop residues, which have been sprayed with pesticides. In the absence of any specified grazing withholding period(s), grazing of any treated crop is at the owner's risk.