FINAL REPORT

DEVELOPMENT OF AN INTEGRATED PEST MANAGEMENT STRATEGY FOR CITRUS IN WESTERN AUSTRALIA

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Horticulture Australia Limited
and
Department of Agriculture and Food
Western Australia

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PURPOSE OF THIS REPORT:

This report contains the results of a project to develop an integrated pest management program for citrus growers in Western Australia. The project has proved successful in identifying the main insect pests in citrus in WA. The results have been used to develop IPM programs for WA growers.

FUNDING PROVIDERS:

WAFGA Citrus Council
Horticulture Australia Ltd.
Department of Agriculture and Food WA through the Horticulture Program

July 2006

MEDIA SUMMARY

The Western Australian (WA) citrus industry placed as a high priority, the adoption of Integrated Pest Management (IPM) techniques to reduce reliance on pesticides as part of their adoption of best management practices. In WA, the major impediment to the adoption of IPM has been the use of cover sprays for control of Mediterranean fruit fly (*Ceratitis capitata)*, the primary insect pest of citrus. However, a project funded by HAL (CT98009) demonstrated that Medfly can be controlled using IPM-compatible bait sprays.

This study shows that WA has fewer pests than other states, making an IPM program simple to implement. Mediterranean fruit flies are the most important economic pest, but are easy to control with foliar baits. Other economically important pests include red scale (*Aonidiella aurantii*) and black scale (*Sasseita oleae*). Pests such as black citrus aphid (*Toxoptera citricada*) and citrus leaf-miner (*Phyllocnistis citrella*) are problems only for young trees (less than 5 years old).

TECHNICAL SUMMARY

Industry significance of the project

- The project "Development of an integrated pest management strategy for citrus in Western Australia" was initiated in January 2004 for a period of three years.
- The aim of the project was to develop an integrated pest management program for WA growers.

Brief description of the science undertaken

- Monitoring was carried out on a fortnightly (spring/summer/autumn) or monthly (winter) basis to identify the main pests of citrus present in WA, and their parasites and predators.
- This information was used to determine when to monitor for pests and adopting suitable methods to control them.
- An insecticide trial was also carried out to assess compatibility with an IPM program.

Key outcomes

- This project has shown that WA has fewer insect pests than other states making IPM much easier for growers to implement.

Recommendations to grower groups

- By adopting an integrated pest management program, growers are able to use fewer insecticides whilst maintaining economic control of pests.
- The project established an effective technology transfer program by making presentations to grower groups at meetings, field days and national venues. This work has been well received by growers.
- There are multiple benefits in adopting IPM including lower production costs; reduction in environmental pesticide load; low to no pesticide residues in fruit; reduction in skin blemish; and improved packout.
- Growers need to monitor their orchards for pests at the key times and learn how to identify the main insect pests in their area.

Recommendations to industry, research peers and Horticulture Australia

- By adopting the results of this project, citrus growers will be able to effectively manage insect pests whilst reducing pesticide use.
- Lower pesticide use means that beneficial insects are conserved and other insect species do not become serious pests, such as has occurred with the use of broad spectrum insecticides to control pests such as red scale and Mediterranean fruit fly. This will increase the saleability of the crop as pest and pesticide free.
- The use of insecticides such as Confidor is recommended for the control of citrus pests in young trees, where natural enemies are unlikely to become established. However, the long withholding period (20 weeks) and long activity (greater than 1 year) needs to be taken into consideration when deciding whether to use Confidor. Use of Confidor in mature trees is not recommended because other effective options are available.

Recommendations for future R & D

- The effect of commercially available beneficials on pests such as mealybug and cottony cushion scale needs to be further evaluated, including methods to enhance their survival in the field in WA.

- Further releases of natural enemies of citrus leafminer into WA should be considered. Monitoring results suggest that parasitism levels in WA are very low.
- The effect of insecticides such as Confidor needs to be evaluated against beneficial insects including predators (ladybirds, lacewings) and parasites (wasps such as *Aphytis melinus).*

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PART 1: Insect and other pests present in WA citrus

1. INTRODUCTION

The Western Australian citrus industry has placed as a high priority, the adoption of Integrated Pest Management (IPM) techniques to reduce reliance on pesticides. Previously, the main obstacle to the adoption of IPM in Western Australia had been the use of cover sprays to control Mediterranean fruit fly (Medfly, *Ceratitis capitata).* Cover sprays consisting of broad-spectrum insecticides killed Medfly and non-target insects such as parasitic wasps and ladybirds which kept other pest populations under control. This frequently resulted in secondary pest outbreaks. A project funded by Horticulture Australia (CT98009) from 1998-2001 demonstrated to growers that Medfly can be controlled using IPM-compatible foliar bait sprays. Most citrus growers now use foliar baits, reducing the impact on beneficial insects and making IPM a reality.

IPM: the multi-pronged approach to pest management

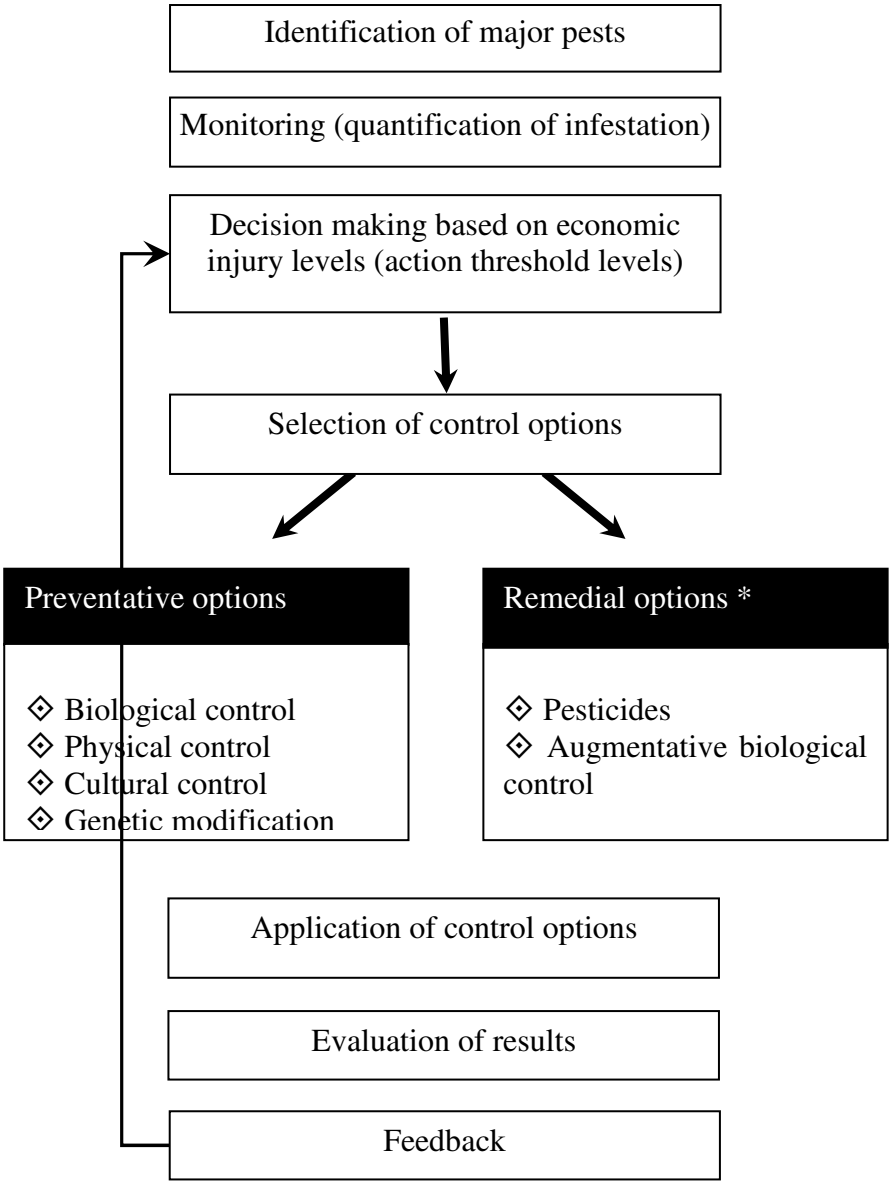
IPM is a strategy that utilises a range of different tactics to manage pests so that pest populations remain below economically damaging levels. Tactics that can be employed in an IPM program include biological control (use of predators, parasites and pathogens), cultural control (e.g. leaving fallow periods, removing insect hosts), physical control (e.g. windbreaks, insect proof mesh), genetic modification (eg. resistant varieties, sterile insects) and insecticides (chemicals used to kill insects).

Although citrus IPM programs have been developed for Queensland, New South Wales and South Australia, an IPM program needed to be specifically developed for WA. WA has a different climatic and cropping pattern from the other states, and little was known of the pest, parasite and predator complex present. Also, the pest threshold levels and controls developed for other states could not be transferred to WA without supporting data. For example, the thresholds may not be relevant or may require modification for local conditions.

Development of an IPM program for WA

Using figure 1 (next page) to illustrate the framework used to develop the IPM program for WA growers, the first step was to identify the major insect pests. Surveys of orchards over three years were used to determine what insect pests, predators and parasites are present, their phenology (when they are present and active) and their distribution within WA. The second part of the program, monitoring, was taught to growers through workshops and the provision of an IPM information guide and farm notes to enable growers to accurately monitor and identify pests. Step 3, decision making based on economic injury levels (action threshold levels), was tested on grower properties by using published action threshold levels. Steps 4 and 5, the selection and testing of control options, included commercially available biocontrol agents and an IPM compatible insecticide.

Figure 1. Main components of an IPM program (adapted from Dent 2005). *Options used to restore pest populations to below economically damaging levels



1.1 Materials and methods

1.1.1 Study Sites

- Most of the citrus grown in WA is produced to meet local demand, with the main growing areas in south western WA, from Gingin 85 km north of Perth to Burekup, 160 km south of Perth (Fig. 1). Climate ranges from tropical in the north to a Mediterranean-type climate in the southwest.
- To collect data on pests and beneficials, monitoring sites were established at Gingin (lemons), Bindoon (grapefruit), Harvey (mandarins, oranges) and Burekup (grapefruit) in January 2002.
- These sites were chosen because they represented the conditions under which most WA citrus is currently grown.
- Sites differed from each other in terms of soil type and citrus variety. Citrus in Carnarvon and Kununurra could not be monitored on a regular basis due to cost and time constraints. Instead, surveys were carried out once at Kununurra (October 2004) and three times at Carnarvon (September-October 2003, 2004, 2005) to collect pest and distribution data. In addition, citrus growers in all areas were asked which pests were present in their orchard.
- The pest and information database maintained at the Department of Agriculture and Food WA was also searched for information on citrus pests present in WA.

Figure 1. The main citrus growing areas in Western Australia

1.1.2 Sampling

Citrus was monitored for pests and beneficials such as ladybirds and lacewings once per fortnight from spring to autumn, and once per month in winter when insect activity was lower. The number of trees sampled depended on the size and varieties present on the property, but a minimum of 10 trees were sampled at each site. Trees were randomly selected and the leaves, branches, trunk, flowers and fruit were visually inspected for insects, snails and pest damage. Data recorded including the phenological stage of the citrus (i.e. flowering, fruit set, fruit size) and the life stage of the insect (e.g. adult, nymph, crawler).

Pest Identification

Insects and other pests were identified using the descriptions provided by Smith *et al.* (1997). When required, identifications were provided by Andras Szito (Entomology Branch, Dept. of Agriculture and Food, South Perth). Voucher specimens were deposited at the Entomology Branch, South Perth, and details including date, collector, locality and host were recorded onto the pest database. All common and scientific names used in the report follow CSIRO's nomenclature (http://www.ento.csiro.au/aicn/name_c/a_1.htm).

Economic Threshold Level

Economic, or action threshold levels (the pest level at which economic damage occurs) were taken from "*Citrus pests and their natural enemies: integrated pest management in Australia"* by Smith *et al.* (1997). These were used as guidelines to advise growers of the action they should take depending on the sampling results.

Red scale

Sampling for red scale was carried out at Gingin (lemons), Burekup (grapefruit), and Bindoon (grapefruit from August 2005) since growers at these sites had large red scale populations that they were having difficulty controlling. Five fruit were randomly chosen from each tree. The numbers of red scale were estimated on each fruit and classified into one of five categories: 0 (no scale on fruit), 1-5 scale per fruit, 6-10 scale per fruit, 11-20 scale per fruit, > 21 scale per fruit. A minimum of ten trees were sampled per property, giving a minimum sample of 50 fruit per site per sampling occasion. If the action threshold was exceeded (10% or more of fruit infested with 3 or more adult females), fruit samples were taken back to the laboratory to determine if parasites were present.

Day-degree models

The day-degree model was used to determine the best times for growers to release parasites for control of red scale. The day degree model is based on the relationship between insect growth and temperature, which increases with temperature until an optimum temperature is exceeded; at this point insect development declines. If the upper and lower temperatures for development of a particular insect species are known, a model can be developed to predict insect activity. Day degree information was available for red scale (Yu & Luck 1988).

The most commonly used bioclimatic model is based on day degrees (DD). A degree-day is each degree of temperature by which the average temperature on a given day exceeds the threshold temperature for development. The formula for the day degree model is given as:

$$\text{Day Degrees (DD)} = \frac{(\text{Min} + \text{max daily temperature})}{2} - \text{threshold temperature}$$

Temperature data collected over 10 years for Gingin and Harvey were used to develop the day degree models for red scale. Data were obtained from the WA Bureau of Meteorology.

1.2 Pests present in WA citrus

- The following table (Table 1.1) presents a summary of the main pests and beneficials found in WA orchards.
- The table can be used to identify insects occurring in citrus by first examining the insect (or animal) for legs, then determining their size (in mm from 'tip to toe'). Please note that for insects such as mealybugs and scale, legs are present but can be very difficult to see. For this reason they have been classified into the 'appears to lack legs' category.
- This report contains information on most, but not all of the insects found in citrus including beneficial insects.
- Noteable exceptions include Mediterranean fruit fly (Broughton *et al.* 2004; Broughton & De Lima 2002), garden weevil (Fisher 2003), and snails (Davis *et al.* 1994). All these pests are covered in farmnotes available on-line from the WA Department of Agriculture and Food (see bibliography).

Table 1.1. Main pests present in WA citrus orchards.

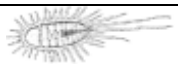
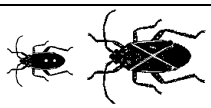
Size	Description	Species	Where found/damage	Type of damage
Hard shell or no shell				
>10 mm	 Entire lower surface modified as a 'gliding foot'.	Snail or slug	Leaves, branches, trunk, fruit;	Holes in leaves; rasping holes in fruit
Appears to lack legs				
1-5mm	 Yellow 'grub' or larva contained within a silvery mine in the leaf.	Citrus leaf miner	Leaves, green twigs and fruit (rarely)	Activity in leaves causes the leaf or green twig to twist and curl.
2-10 mm	 White 'grub' or maggot in fruit.	Mediterranean fruit fly /Drosophila (ferment fly)	Fruit	Larvae feed on fruit, causing decomposition. Drosophila tends to attack fallen fruit only.
10 mm	'Grub' or maggot in flower.	Lemon bud moth	Flower	Eats flowers and young fruit.
<10 mm	 Insect covered in a white powdery material, may have long tuft of white wax or 'tail'. Legs (6) present, but magnification may be required.	Mealybug	Leaves, fruit (under calyx).	Sooty mould on leaves and fruit; contamination of fruit (for export)
<20mm in size.	 Appears to lack legs and eyes; covered with a waxy coating.	Scale insect	Leaves, branches, trunk, fruit	Sooty mould; fruit contamination
Legs present				
<1mm	 Animals with 8 legs (magnification may be required to see feature). Mites range in colour from red, brown to yellow.	Mites	Leaves, fruit and leaf buds.	Varies: some species cause speckling on leaves, some damage developing fruit

Table 1.1. Main pests present in WA citrus orchards (continued from previous page).

Size	Description	Species	Where found	Type of damage
1-2mm in size	 White 'moth-like' insect. Found on undersides of leaves amongst their immobile immature stages; fly in spiral pattern when disturbed.	Whitefly	Leaves	Sooty mould on leaves and fruit
2mm	 Minute black or dark brown beetle covered with short hairs. Some species have brown-red patches .	Mite eating ladybird.	Leaves and fruit among their prey	Beneficial - feeds on mites, scale and aphids
2-7 mm	 Looks like an 'alligator'. Black body with orange stripes; some species can have spikes.	Ladybird larva (various species)	On leaves and fruit among their prey	Beneficial – feeds on aphids, mealybugs, scale and mites
3.5-5 mm	 Black thorx with silver markings; abdomen brown; some markings on wings.	Mediterranean fruit fly	Leaves and on fruit (adults).	Fruit: (1) female lays eggs into fruit causing oviposition scars; (2) eggs may develop into larvae.
4-10 mm	 Brown-grey with prominent 'pincers'; larva may disguise itself by carrying prey remains on its back.	Lacewing (beneficial)	Leaves, fruit.	Beneficial – feeds on scale, leafminer and aphids
<10 mm in size	 Long and slender insect; black - light yellow in colour	Thrips (various species)	Leaves, fruit, flowers.	Bleaching of fruit where fruit is touching; silvery scars on rind ('halo')
>12 mm	 Adult brown or green with lacy wings.	Lacewing (adult)	leaves, branches and fruit	Beneficial – feed on nectar, pollen & honeydew
5-8 mm	 Beetle grey-brown, darker on the sides with a short white line halfway along the body.	Fuller's Rose Weevil	Leaves	Feeds on leaf margins; can be a problem for exports
4-6 mm	 Beetle with a shiny shell, often brightly coloured (orange, red, black); often has spots or patches of white or red on back.	Ladybird (adult); various species	Leaves, branches	Beneficial – feeds on aphids, scale
5-10 mm in size	 Nymphs brown with two small spots on back. Adults brown with distinct white cross on back.	Crusader bug	Leaves, green twigs.	Wilt and die back of young shoots

1.2.1 SCALE INSECTS

- Scales are unusual insects, appearing to lack legs and eyes.
- Scale classification is based on the presence of a protective covering: soft scales do not have a separate protective covering whereas armoured scales do.
- The covering of soft scales cannot be removed without killing the insect; armoured scales cast skins that protect the underlying soft body of the insect and the cover can be lifted off. Examples of soft scale include black and hard wax scale; examples of armoured scale include red and circular black scale.
- Feeding between the two groups also differs: armoured scales have mouth parts that invade the mesophyll (the part of a leaf located between the upper and lower epidermis), enabling them to suck out the rich cell contents. No honeydew is produced. Any sooty mould or ants near armoured scales are associated with other honeydew-excreting insects that are nearby, such as soft scales, mealybugs or aphids.
- Soft scales feed from the phloem (the layer of tree tissue just inside the bark that conducts food from the leaves to the stem and roots) and produce copious amounts of honeydew that subsequently becomes infected with black sooty mould.

Scales occurring in Western Australia

- Of the 13 soft and seven armoured scale species listed in Smith *et al.* (1997) as occurring in Australian citrus, 7 soft and 2 armoured scale species were recorded in WA. Some species such as circular black scale and coffee scale were found only in Carnarvon.
- Three species (red, soft brown and black) are considered to be occasionally important to major pests of citrus in WA.
- Summary information including biology, distribution within WA, phenology, action thresholds and beneficials is provided separately for each scale species.

Monitoring for scale

- At a minimum, check for the presence or absence of scale on 5 randomly selected green twigs (5-10 leaves per twig) per tree.
- For red scale, check 5 randomly selected fruit per tree.
- The total number of trees you need to sample depends on block size.

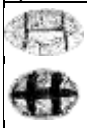
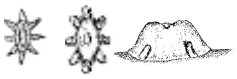
How to identify scales

- Scale identification is based on shape and colour.
- Squashing scales to determine the texture of the wax and to observe the colour of the body of the insect (which may be hidden under the wax) is used to provide additional information.
- A quick guide to scale species occurring in WA is provided in Table 2.

Control

- Scales are best controlled when crawlers and newly settled young scales are present.
- Biological control options are provided in the text for each scale species.
- Chemical control using oils work well with IPM programs and can give very good control of most scale insects when timed and applied well.
- Oil does kill some beneficial wasps and suppresses beneficial mite populations. However, residues do not persist.
- Oil sprays can damage trees, particularly when applied in hot weather when trees are water stressed (>40°C).
- Always check the label before spraying as not all oils are registered for use in citrus.

Table 1.2. Summary of scale species occurring in WA citrus

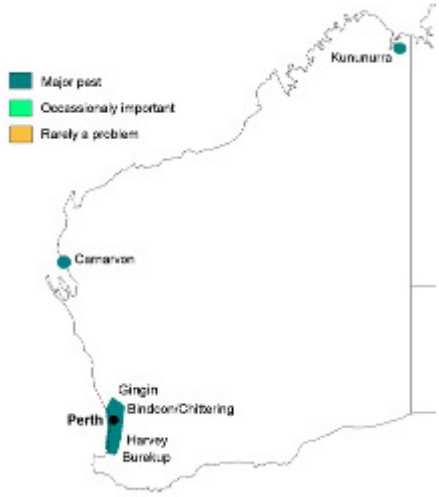
Shape	Colour and description of juvenile and adult stages	Species	Sooty mould?	Location on plant	Growing areas in WA
Mobile stage					
 Crawler. Oval in shape when viewed from above.	Only mobile stage of many scale species. Pale-yellow to yellow in colour and 1mm or less in length, legs and dark eye spots just visible to naked eye. Most commonly found under or near body of mature female.	All	N/A	May be found on any plant part.	N/A
Sedentary stage					
 Armoured scales. Round, flattened.	 Red, sometimes orange depending on host (eg. on lemon, scale may appear to be orange). Female has a round cover, male oval. If cover lifted off, a white, horseshoe shaped female is seen underneath.	Red scale*	No	Fruit, trunk, twigs, leaves.	all
	 Dark brown, black-dark red. Similar to red scale in size and shape. Female has a round cover, male oval. Cover if lifted off will reveal white, horseshoe shaped female underneath.	Circular black	Yes	Mainly leaves, fruits and stem.	Carnarvon
 Soft scales. Oval. Covering cannot be removed without killing insect.	 Reddish brown-brown. Juveniles flecked with irregular dark brown spots. Mature scale domed shape when viewed in profile. No 'H' on mature adults.	Soft brown scale*	yes	Fruit, green twigs, leaves.	all
	 Brown, reddish-brown to black. Juveniles range in colour from grey to dark brown and may appear 'rubbery'. Mature scale domed shape when viewed in profile. An 'H' may be seen on immature and mature scale.	Black scale*	Yes	Fruit, trunk, twigs, leaves.	all
	Greyish brown. Juveniles appear transparent, yellow.	Citricola scale.	Yes	Twigs, leaves.	Bindoon
	 Pale green with a brown or blackish irregular, U-shaped, internal marking. Marking (gut of insect) is visible to the naked eye.	Coffee scale	yes	Twigs, leaves.	Carnarvon
	 Red-pink to white. Juvenile white in colour and star-shaped (far left), with body (red-pink) becoming visible as insect matures (middle). Adult with hard, dirty white waxy coating, red body underneath wax.	Hard (Chinese) wax scale	Yes	Twigs, leaves.	Southern (Harvey, Burekup, Capel)
	 Pink. Adult similar in appearance to Hard (Chinese) wax scale. Squash insect – if body underneath is pink, scale is a pink scale. If red, Hard wax scale.	Pink wax scale	Yes	Twigs, leaves.	Southern (Harvey, Burekup, Capel).
	 Juveniles red, with cottony tufts on body. Adult has a distinctive egg sac: fluted, white and 'cushiony'. Body underneath is pink-red.	Cotton cushiony scale	Yes	Twigs, leaves.	all
 Soft scales. No particular shape.	 White with soft waxy covering. Juveniles appear as small blobs of wax on leaves or twigs. Females are white, with stripes of harder, whiter wax on the side of the body.	White wax scale	yes	Twigs	Southern (Harvey, Burekup, Capel).

Armoured Scales

Red scale (*Aonidiella aurantii* (Mercett))

- **Size:** 2 mm
- **Nymph:** red, thin, circular
  Adult: female – red-brown circular, male - elongated, paler than female
- Red Scale is the most damaging scale species occurring in WA citrus, attacking all citrus varieties in all growing areas.
- The severity of attack varies: lemons, grapefruit, navel oranges, Valencia oranges and mandarin (in descending order of attack).
- Trees of all ages may be attacked.
- Origin: South east Asia

From top: Female red scale. Photo: Jack Kelly Clark. Red scale on branch.



Importance and distribution of red scale within WA

Monitoring

J	F	M	A	M	J	J	A	S	O	N	D

Life Cycle

Egg ⇨ crawler (=1st instar nymph) ⇨2nd/3rd instar nymph ⇨adult

Immature stages

- Each female can produce 100 - 150 eggs. Crawlers hatch and emerge from under the female cover at a rate of 2-3 per day over a 6-8 week period (Smith *et al.* 1997).
- Crawlers are the only mobile stage of the life cycle, settling in small depressions on twigs, fruits, or leaves.
- With each moult, a concentric ring develops around the nipple shaped centre.
- Midway through the second instar, females and males start to develop differently.

Adult

- Males form an oval cover. Underneath the cover the male develops through additional stages to form a pupa. When it emerges from the pupa, the male is wasp-like in appearance and highly mobile.
- Male emergence often takes place in the afternoon and males live for about 6 hours - their sole purpose is to mate. Males follow the pheromones that unmated females produce to locate a mate.
- Females develop through three developmental stages. When the female scale has been mated, the body and the cover of the scale become attached together.

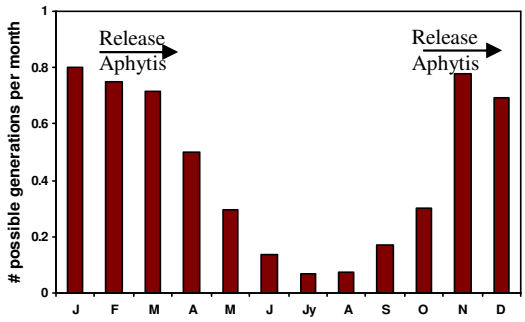
Damage

- Red scale was found on fruit, leaves, twigs, and branches on both the exterior and interior of the tree all year.
- Of the 25 fruit examined on each sampling occasion at orchards in Bindoon, Gingin and Burekup, red scale infested at least 20% of all fruit examined. Infested fruit were found year round.

- Fruit with greater than 10 scales is regarded by Woolworth's produce specifications as a major defect in fancy grade fruit (grapefruit, lemons, mandarins, oranges) varied between sites (Woolworths 2004). At Burekup, on 30 of 56 sampling occasions at least 10% of all grapefruit examined exceeded this threshold. On two occasions, 80% of the grapefruit examined had at least 10 scale/fruit (November 2003, December 2004). At Gingin, the threshold was exceeded on 42 of 57 sampling occasions.

Seasonal abundance

- Field monitoring shows that red scale has overlapping generations (ie. scales of various ages) occurring throughout the year at all sites in WA.
- Between October to March, the abundance of red scale on leaves and stem increases. This suggests that there is movement of crawlers at this time onto different parts of the tree including the fruit.
- The day-degree model based on average daily temperatures shows that red scale should be most abundant from November-March, which agrees with the field data.



Day degree calculations for red scale (Bindoon). The higher the number of possible generations that can be completed in a month, the higher the possible red scale population.

- The lower development threshold of 11.5°C (Yu & Luck 1988) for red scale is never reached in WA, though scale development slows down when the temperatures are cooler – July-September.

Biological control

- In 1905, the West Australian Department of Agriculture released the wasp *Aphytis chryomphali* (Mercet) (probably *A. lignanensis* Compere) (Waterhouse & Sands 2001). More parasitic wasps were released for control of red scale in the 1940s including *Comperiella bifasciata* Howard (1943-1947; 1947-1949) and in the 1960s (*Aphytis melinus* DeBach; Smith *et al.* 1997).
- All three species have established in Western Australia. However supplementary releases of *Aphytis* are often required in spring and autumn to boost the local population (see *Aphytis* section below). *C. bifasciata* was only found at Bindoon during this study.
- Predators of red scale recovered include green lacewings (*Mallada* species); and the ladybirds *Harmonia conformis* and *Rhizobius lophanthae*. These predators also attack other citrus pests.
- The ladybird *Chilocorus circumdatus* was released to control red scale in Burekup in 2005. However it was not recovered in subsequent surveys of the orchard and has not been found in other areas surveyed in WA.

Aphytis species

- *Aphytis lingnanensis* and *A. melinus* are regarded by Waterhouse and Sands (2001) to be the most important parasites of red scale.
- Both are available commercially to citrus growers*: A. lignanensis* is suited to tropical conditions and *Aphytis melinus* is suited to temperate conditions.

Identification of wasp parasites

Adult wasps of both *Aphytis* species are similar in appearance – pale yellow to yellow in colour. *A. melinus* is lightly larger – 0.8-1.2mm compared to 0.7-1.0 mm for *A. lingnanensis*

(Malipatil *et al*. 2000). *Comperiella bifasciata* is 0.7-0.9 mm long, with a black body and head.

- Use pupae to identify wasp species: *A. lingnanensis* has a dark streak extending down the entire length on the underside of the pupa, *A. melinus* has a black thorax. *C. bifasciata* has a black pupa about 1.5 mm long (Smith *et al.* 1997).

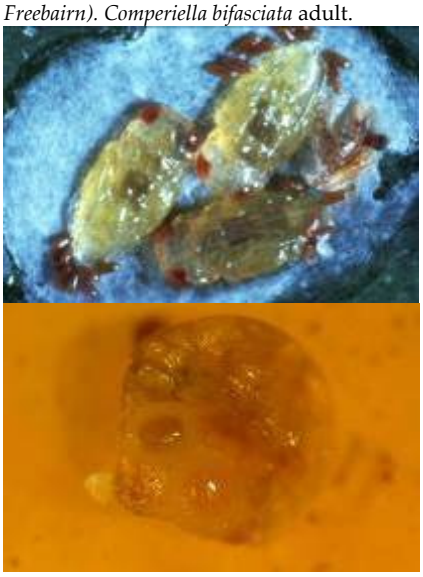
From top: Aphytis lignanensis adult (photo C. Freebairn). Comperiella bifasciata adult.

Biology

- Both species of *Aphytis* are ectoparasites, meaning that they lay eggs on the body of the host rather than laying eggs inside the host.
- *Aphytis* can complete about three generations for each scale generation.
- At 26.6° C, *A. melinus* takes 13-17 days to develop from egg to adult. Adults live about 10-15 days (up to 24 days), depositing 6-7 eggs/day.

What stages do they attack?

- *Aphytis* will only attack certain stages of red scale and it is important to monitor for this reason. The wasps attack large female second and third instars and male second instars.
- Mated females (lift up the scale cover with a needle – the scale cover and the body of female cannot be separated in mated females) are not suitable hosts.
- The female wasp lays eggs under the scale cover on the scale body and may lay more than one egg in larger scale.
- *Aphytis* can also kill red scale without laying eggs by probing the scale body with its ovipositor (egg laying organ). The wasp may then feed on the body of the scale (host feeding). Host feeding occurs on all stages except second moult females, mature and crawler-producing females and male pupal stages (Yu 1986).



From top: *A. melinus* pupae (photo C. Freebairn). Two *Aphytis* larvae feeding on a female red scale.

Releasing Aphytis

- *Aphytis* should be released before red scale reaches damaging levels.
- In WA, booster releases are often required and should be made if very high summer temperatures are experienced, or if scales are still at high levels late in the season.
- For *A. lignanensis*, releases are recommended from March-April. For *A. melinus*, release from November-March. More than one release may be required.
- The wasps are released as adults and should be released into the shade. The *Aphytis* will fly out of the tube or cup and begin to search for scale.
- High ant activity on trees will interfere with effectiveness of *Aphytis*. Ants should be controlled by selective spraying or treatment of ant nests.
- Parasites should be used within one day of arrival. If absolutely necessary, they can be stored in a cool (approx. 15.5° C), dark place until use.

Aphytis and pesticides

- *Aphytis* can be released a week after applying oils.
- Avoid using harsh pesticide applications after releases.

Comperiella bifasciata

- *C. bifasciata* is not available commercially.
- *C. bifasciata* is an internal parasite: the females lay eggs inside the body of the scale, one larva developing per scale.
- The life-cycle is completed in 3-6 weeks depending on the stage of development of the host. For example, the wasp develops more slowly if the scale is a first instar than if the scale is mature.

Exit hole made by parasitic wasp as it emerges from a female red scale (Photo Jack Kelly Clark).

Deciding when to release more parasites

- Parasitized scales look dried out and may have dark spots if pupae are present when examined closely.
- Look for exit holes made by the wasps as they emerge from the scale.
- Rubbing infested fruit and noting the amount of scales removed can give a quick assessment of parasitism.
- A detailed method for assessing percentage parasitism is given in Appendix 1, and will require a microscope.
- Releases are required if the parasitism rate is less than 20 % by January and 50% by March (Smith *et al.* 1989).

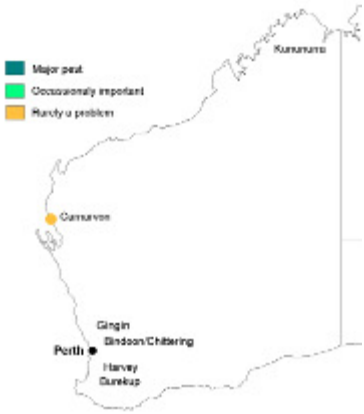
Circular black scale, *Chrysomphalus aonidum* (Linnaeus)

- *C. aonidum* is a polyphagous species (has a wide host range) with a preference for citrus, particularly navel and Valencia oranges and grapefruits (Bedford 1989).
- *C. aonidum* is more suited to tropical conditions. It was only found in Carnarvon on grapefruit in this study.
- Origin*:* Asia

Top: circular black scale female (round) and males (oval). Note Aphytis holoxanthus wasp also in photo (F. Freebairn). Bottom: damage to fruit and leaves.

Life cycle

- Reproduction in *C. aonidum* is sexual; no evidence of parthenogenesis has been recorded.
- Each adult female lays about 50-150 oval eggs under the scale over a period of 1-8 weeks, depending on the part of the plant infested.
- Eggs hatch under the scale and the first-instar nymphs or crawlers walk about to find a suitable feeding site before settling.
- Males form an oval cover. Underneath the cover the male develops through additional stages to form a pupa. When it emerges from the pupa, the male is wasp-like in appearance and highly mobile.
- Adults can live for 3-4 weeks and each female can lay more than 100 eggs (Brewer 1971).



Distribution and importance of circular black scale in Western Australia.

Damage

- *C. aonidum* tends to prefer the lower and central parts of mature citrus trees and rarely infests green wood (Rose & DeBach 1978).
- In Carnarvon, scales were found on grapefruit leaves and fruit. Infested fruit are not suitable for sale.

Aphytis holoxanthus pupae. Pupae were sheltering under the scale cover.

Biological control

- *Aphytis holoxanthus* was released for the control of *C. aonidum* in Queensland in 1974.
- *holoxanthus* was found in Carnarvon in 2003 and 2004. Local growers suggest that it was released to control circular black scale on banana.
- *holoxanthus* is regarded to be a very efficient parasite of circular black scale (Waterhouse & Sands 2001), quickly bringing populations of *C. aonidum* under control when released in Queensland and NSW.

Identification of *A. holoxanthus*

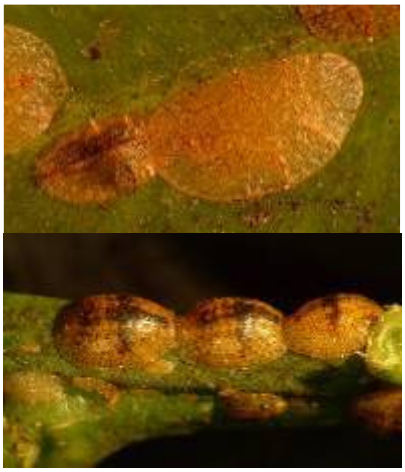
- Parasites will leave small circular holes in the scale cover as they emerge.
- The adult wasp is similar in appearance to other *Aphytis* species (yellow, 0.9-1.2mm long, male smaller).
- You are more likely to see the pupa, which has black pigmentation extending down the entire length of the underside of the body (see photo).

Soft scales

- All soft scales produce similar damage:
- Heavy feeding reduces tree vigour, kills twigs, and reduces yields.
- Sooty mould grows on excreted honeydew and may affect fruit grade.
- The honeydew also attracts ants, which interfere with the biological control of a number of citrus pests.

Soft brown scale, *Coccus hesperidum* Linnaeus

- Size: 3-4 mm
- Nymph: green-yellow, yellow-brown, flat & oval.
- Adult: 4mm, brown, sometimes mottled, flat & oval.
- Origin: probably South Africa
- In WA, soft brown scale tends to be more of a problem on young (> 3 years old) trees.



Top: nymph. Bottom: mature soft brown scale female.

Life cycle

- Unlike other scale species, all stages are capable of movement (Waterhouse & Sands 2001).
- Female brown soft scales lay a few eggs at a time. Eggs hatch almost immediately.
- Crawlers move around until they find a place on the leaves or green twigs on which to settle.
- The young moult twice and reach maturity on leaves or twigs; they rarely move onto fruit.

Distribution and importance of soft brown scale in WA

Seasonal abundance

- Field monitoring indicates that soft brown scale are present throughout the year.
- Crawlers and eggs were found from November to February.
- There are likely to be 2-5 overlapping generations occurring in WA a year.

J	F	M	A	M	J	J	A	S	O	N	D

Biological Control

- Over 20 species of parasite have been released into Australia to control soft brown scale since 1901 (Waterhouse & Sands 2001).
- Projects (CT98038, CT2051) were funded by HAL to introduce the wasp *Metaphycus luteolus* (Timberlake) from California into Australia for soft brown scale control.
- Releases of *M. luteolus* were made in Gingin, Bindoon, Harvey and Dardanup in 2004 as part of project CT2051. *M. luteolus* appears to have established in WA, with results varying from good (Gingin, Bindoon, Harvey) to poor control (Dardanup).
- However, *Metaphycus* may be unable to spread from the release sites and for this reason, the wasp may only become locally established. Further releases may be

Exit hole made by wasp in scale. Outline of Metaphycus pupae just visible under scale cover.

- required should the parasite become commercially available.
- Useful predators include ladybirds (*Cryptolaemus montrouzieri*, *Harmonia conformis*, *Rhyzobius lophanthae* (Blaisdell)) and lacewing (*Mallada* species).

Parasite Identification

- Look for exit holes in the scale – this indicates that parasites were present.
- Adult male and female *M. luteolus* are lemon-yellow, 0.7-0.9mm long (Malipatil *et al.* 2000).
- Pupae are black and are found under the scale cover.

Top: Metaphycus lounsburyi adult (Photo: C. Freebairn). Bottom: Metaphyus luteolus female (Photo C. Freebairn).

Black Scale, *Saissetia oleae* (Olivier)

- Size: 2-5 mm
- Nymph: brown, flat & oval, becoming darker with age with an 'H' on the top of the scale.
- Adult: 5mm, dark-brown-black, hemispherical in shape when viewed from the side, with a distinct 'H' on top of the scale. The 'H' may disappear as the female matures and becomes more rounded.
- Origin: Africa
- In WA, black scale tends to be more of a serious problem on young (> 3 years old) trees.

From top: nymph, mature female (photo J. Kelly Clark)

Seasonal abundance

- Field monitoring indicates that black scale are present throughout the year.
- In WA more than two hatching periods per year are likely, depending on temperature.
- Crawlers and eggs were found from November to January, and at other times of the year e.g. August.

Life cycle

- Each female lays between 150 to 2000 pink eggs.
- The eggs remain under the female scale, hatching after 15-20 days.
- Crawlers emerge from under the female and move around until they find a place on the leaves or green twigs on which to settle.
- The young moult twice and reach maturity on leaves or twigs; they rarely move onto fruit.

Biological Control

- 22 species of parasite and 2 predators have been released into Australia to control black scale since 1902 (Waterhouse & Sands 2001).

Distribution and importance of black scale in WA

J	F	M	A	M	J	J	A	S	O	N	D

Monitoring

From top, S. caerula adult feeding on crawlers (photo C. Freebairn), exit holes made by S. caerulea (photo J. Kelly Clark), M. helvolus (photo C. Freebairn).

Metaphycus

- *Metaphycus* species are efficient parasites of black scale (Waterhouse & Sands 2001, UC IPM guidelines 2006).
- *Metaphycus luteolus* released for soft brown scale control will also attack black scale.
- *Metaphycus helvolus* (Compere) (from California) was introduced to Queensland in 2002/03 for the control of soft brown scale and black scale in citrus. *M. helvolus* was released into citrus in WA in 2004 and established on some orchards.
- *Metaphycus* are not available commercially. Parasites either move into the orchard on their own or must be located in nearby citrus orchards and relocated. *M. helvolus* are currently being reared for commercial release into olive groves in WA and SA for control of black scale.

Scutellista caerulea

- The wasp, *Scutellista caerulea,* which originates from Africa, was introduced into Australia in 1903 via the USA. It is a predator of the eggs of several scale species (Smith *et al*. 1997).
- The female lays eggs amongst the scale eggs, or between the bottom of the scale and the leaf or branch surface before the scale has started to lay eggs. The larvae hatch in 4-5 days and feed on the scale eggs.
- Approximately 200 scale eggs are required for the larvae to complete development (15 to 20 days, longer if scale eggs are absent).
- After 14-21 days, the adult emerges through a hole that it cuts in the top of the scale.

Predators

- Useful predators include ladybirds (*Cryptolaemus montrouzieri*, *Harmonia conformis*, *Rhyzobius lophanthae* (Blaisdell)) and lacewings (*Mallada* species).
- *Parapriasus australiae*, a native ladybird that is known to feed on black scale (Smith et a. 1997), was found on olives in WA. It may also be present in citrus.
- The scale-eating caterpillar (*Catoblemma dubia*), is a native species, feeding on first and second instars and adults of black scale and other scales (Waterhouse & Sands 2001; Smith *et al*. 1997). Though found in olives in WA (Broughton & Learmonth 2006), it was not found in citrus during this study.
- The larva is distinctive, moving beneath a protective cover that it builds from scale remains. The larvae require high densities of the scales to complete development (Waterhouse & Sands 2001).

Parasite Identification

- The adult of *Scutellista caerula* is black, 1.3-1.8 mm with bluish reflections, and appears beetle-like in profile. The pupa is black and is often found under the mature female black scale cover. Exit holes in mature black scale are the most obvious form of *S. caerula* activity.
- Adult male and female *M. luteolus* are lemon-yellow, 0.7-0.9mm long (Malipatil *et al.* 2000). Pupae are black and are found under the scale cover.
- *M. helvolus* is similar in size and appearance, though the body colour can vary. The antennae are banded.

Green coffee scale, *Coccus viridis* (Green)

- Size: 3-4 mm
- Nymph: green, flat & oval.
- Adult: pale green with a brown or blackish irregular, U-shaped, internal marking.
- Similar in appearance to other *Coccus* species and may be confused with them.
- Origin: probably Africa
- In WA, green coffee scale was only found in Carnarvon.

Life cycle

- Each female produces up to 200 crawlers.
- Crawlers find a place on the upper surfaces of leaves or green twigs on which to settle. Fruit may become infested when populations are very high.
- All larval instars and adults are capable of movement.

Biological Control

- Parasites have been released in Queensland for the control of green coffee scale (Waterhouse & Sands 2001). No parasites were recovered during surveys of Carnarvon.
- The ladybird *Cryptolaemus montrouzieri,* is reported by Waterhouse & Sands (2001) to be an important predator.

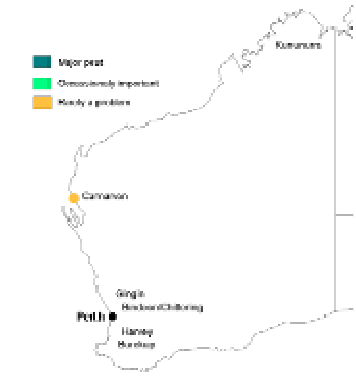
Citricola scale, *Coccus pseudomagnoliarum* (Kuwana)

- Size: 3-4 mm
- Nymph: almost transparent, yellow-green, flat & oval.
- Adult: greyish brown.
- Similar in appearance to other *Coccus* species and may be confused with them.
- Origin: probably Africa
- In WA, citricola scale was only found in Bindoon during this study and is considered to be rare in WA. Waterhouse & Sands (2001) indicate that it is found in southern WA.

Life cycle

- Each female produces up to 1500 eggs which hatch within 2-3 days.
- Crawlers find a place on the upper surfaces of leaves or green twigs on which to settle. Fruit may become infested when populations are very high.
- There is probably only one generation per year in southern Australia (Waterhouse & Sands 2001).

Photo: adult green coffee scale



Distribution of green coffee scale in WA

From top: nymph, adults. Photos: J. Kelly Clark.

Distribution & importance of citricola scale in WA

Biological control

- In California, *Metaphycus* species released for the control of soft brown and black scale also provide control of citricola scale.
- Useful predators include ladybirds (*Cryptolaemus montrouzieri*, *Harmonia conformis*, *Rhyzobius lophanthae* (Blaisdell)) and lacewings (*Mallada* species) (see section 1.2.8).

White Wax Scale, *Ceroplastes destructor* Newstead

- Size: 6 mm long, 8 mm wide and 7 mm high.
- Nymph: white and star-shaped, similar to Hard wax scale nymphs.
- Adult: white, soft moist wax, body underneath wax may be pink, red or brown.
- Origin: Africa
- White wax scale was only found in Burekup and Harvey during this study. Waterhouse & Sands (2001) indicate that it is present in southwest WA.

From top: nymph, adult.

Life cycle

- Parthenogenic (females do not need to mate with males, and produce only female offspring). Females produce up to 300 pinkish eggs under the body.
- There is only one generation of white wax scale in WA per year. Field data suggests that mature scale is abundant between March-June.
- Crawlers appear to settle on the veins of leaves for a short period in February-March.
- The scale moves onto the woody part of the tree where it overwinters and begins to secrete a 'peak' stage – the wax piles up on top of the scale.
- Biological control
- Six species of parasite and one predator were introduced for the control of white wax scale between 1968-1974.

Distribution& importance of white wax scale in WA

J	F	M	A	M	J	J	A	S	O	N	D

Monitoring

- The wasp *Anicetus communis* (Annecke) is regarded by Waterhouse & Sands (2001) as the most effective biological control agent for *C. destructor*, attacking 3rd instar nymphs. It was introduced into Western Australia in 1973 and 1974 and has established. It probably exercises good control of this pest since white wax scale is now much less common than it was in the past.
- The wasp, *Scutellista caerulea* is a predator of the eggs of several scale species (Smith *et al*. 1997) including white wax scale. It is unlikely to control the scale.

Hard wax scale (Chinese Wax Scale) *Ceroplastes sinensis* Del Guercio

- 6-7 mm long and 5 mm high.
- Nymph: white and star-shaped, similar to white wax scale nymphs.
- Adult: white, soft moist wax, body underneath wax may be pink, red or brown.
- Origin: South America
- Hard wax scale was only found in Burekup and Harvey during this study.
- Waterhouse & Sands (2001) indicate that it is present in southwest WA.

From top: star-shaped nymphs. Bottom: adults

Distribution & importance of Hard wax scale in WA

J	F	M	A	M	J	J	A	S	O	N	D

Monitoring

Life cycle

- Parthenogenic (females do not need to mate with males, and produce only female offspring), though males have been found. Females can lay up to 3800 eggs.
- There is only one generation of hard wax scale in WA per year. Field data suggests that crawlers emerge and settle on the leaf veins and mid-ribs in November-March, but may also emerge in August.
- The scale moves onto the woody part of the tree and the body becomes visibly pink or red. In the 3rd instar or as an adult, half the wax becomes pale pink and the other half white. Adults may retain this colour or become white.

Biological control

- No parasites or predators have been specifically released for the control of hard wax scale in Australia (Waterhouse & Sands 2001).
- In WA, a parasitic wasp *Scutellista caerula,* which attacks up to 50 per cent of Chinese wax scales (Bill Woods pers. Comm.). It lays its eggs under the scales, and the larva feed on the eggs of the scale but is unlikely to provide effective control.
- Useful predators include ladybirds.

Cottony cushion scale, *Icerya purchasi* Maskell

- Size: 5 mm (10-15 mm with egg sac)
- Nymph: orange-red bodies with dark legs and antennae partially covered with tufts of yellowish or white wax.
- Adult: body bright orange-red, yellow, or brown. Body is partially or entirely covered with yellowish or white wax. Fluted egg sac distinctive, 2.5 times longer than the body.
- Origin: native to Australia

Life cycle

- Parthenogenic (females do not need to mate with males, and produce only female offspring). Males are rare and females can reproduce without mating. Females can lay up to 1000 eggs.
- Nymphs are found mainly on twigs and leaves. Adult females settle on the branches and trunk and begin to form the white, elongated egg sac. They are rarely found on fruit.
- Populations are found all year round, with abundance increasing from December.

Biological control

- No parasites or predators have been specifically released for control of cottony cushion scale in Australia.
- Native predators include the ladybird, *Rodalia cardinalis*.

From top: cottony cushion scale nymphs, bottom: egg sac and nymph.

Distribution & importance of cottony cushion scale in WA

J	F	M	A	M	J	J	A	S	O	N	D

Monitoring

1.2.2 Aphids

- Aphids are pear shaped, soft-bodied insects. Four aphid species are recorded on citrus in Australia (Smith *et al.* 1979).
- Only two species occur in WA: black citrus aphid, *Toxoptera citricada* (Kirkaldy) and the spiraea aphid, *Aphis spiraecola* Patch. Spiraea aphid was found twice during this study at one orchard in Harvey and is regarded to be rare.

Damage

- Aphids have a piercing-sucking mouthpart that they insert into the plant tissue to feed on leaves, green shoots and flowers. Distortion as a result of feeding can occur.
- Overseas, black citrus aphid has been associated with the spread of citrus viruses such as citrus tristeza virus.
- Large quantities of honeydew are also produced which often turns black with the growth of the sooty mould fungus.
- Aphids are not usually a problem in citrus, except on young trees.

Black citrus aphid (also called brown citrus aphid), *Toxoptera citricada*

- Nymph: pear shaped, red-brown, brown to black, 1-2mm long.
- Adult: shiny black, 2mm long. May be winged or wingless.
- Origin: probably Asia

Black citrus aphid, *Toxoptera citricada. From top: heavy infestation in citrus, adult.*

Life cycle

- Females can produce live young (females do not need to mate and no eggs are laid).
- An entire generation can develop in one week. Nymphs mature in 6-8 days at temperatures of 20 ºC or above (Komazaki 1988).
- There can be 25 – 30 generations per year (Smith *et al.* 1989).

Distribution & importance of black citrus aphid in WA

Chemical Control

- Natural enemies normally keep aphid populations under control and chemical control is rarely needed. If required use horticultural spray oil first (if possible).

Biological Control

- A number of predators, parasites, and fungal diseases attack aphids and occur naturally in the orchard. The honeydew produced by the aphids provides a good food source for many natural enemies.
- Aphid predators include syrphids, ladybird beetles and lacewing larvae. These are described in more detail in the natural enemies section.
- Aphid parasites include the wasp species *Aphidius* and *Aphelinus*. Neither is available commercially.

J	F	M	A	M	J	J	A	S	O	N	D

Monitoring

- The female wasp lays her eggs individually inside the lower part of the abdomen in young nymphs. The parasitised nymphs appear bloated and bronze in colour.
- When the wasps emerge from the aphid, they cut a hole in the tail region (see photo).

Mummified aphids that have been attacked by wasp parasites.

Spiraea aphid, *Aphis spiraecola* Patch

- Nymph: pear shaped, apple green to bright yellow, 2mm long.
- Adult: apple green, 2mm long. May be winged or wingless.
- Found only on two occasions during this study at one orchard in Harvey and regarded to be rare.

Life cycle

- Females produce up to 60 live young (females do not need to mate and no eggs are laid).
- An entire generation can develop in one week.
- There can be up to 25 generations per year (Smith *et al.* 1989).

Chemical Control

- Natural enemies normally keep aphid populations under control and chemical control is rarely needed. If required use horticultural spray oil first (if possible).

Biological Control

- A number of predators, parasites, and fungal diseases attack aphids and occur naturally in the orchard.
- See previous entry under black citrus aphid.

Spiraea aphid. From top: nymphs, infestation on young stem (photo D. Cousins)

Distribution & importance of Spiraea aphid in WA

J	F	M	A	M	J	J	A	S	O	N	D

Monitoring

1.2.3 Whiteflies

- 'Whiteflies' or 'snow flies' (Aleyrodidae) resemble small moths but belong to the group (Hemiptera) closely related to aphids and scales.
- Like these insects, they have sucking mouth parts and when present in large numbers, their feeding may affect plant growth. .
- Two species of whitefly are recorded as pests of citrus in Australia (Smith *et al.* 1997), but only one species was recorded from WA: the Australian citrus whitefly, *Orchamoplatus citri* (Takahashi), first recorded in Western Australia in 1950, on lemon trees at Maddington

From top: whitefly on grapefruit leaves, whitefly adult with eggs in a circular egg-laying pattern, pupae.

Damage

- Lemon trees are the favourite host of the whitefly, but all types of citrus are liable to attack.
- Whiteflies have a piercing-sucking mouthpart that they insert into the plant.
- Large quantities of honeydew are also produced which often turns black with the growth of the sooty mould fungus.
- Sooty mould on the fruit causes the most concern.
- Whiteflies are not usually a problem in citrus orchards in WA.

Australian citrus whitefly, *Orchamoplatus citri* (Takahashi)

- Origin: described from New South Wales and is thought to be native.
- Adults 2.5 mm long. Both pairs of wings and the body are covered with a white, waxy,wool-like secretion. The adults cluster on young shoots and leaves. Adults will fly off in clouds when disturbed.

Distribution & importance of whitefly in WA.

Life cycle

- Yellow, oval-shaped eggs are laid on the underside of mature young leaves in horseshoe shaped or circular patterns.
- Eggs often appear as if they have been dusted with white powdery wax. From these the larvae or 'crawlers' emerge.
- The larvae settle in groups on the underside of the leaf and look like small scales. After a few weeks the outer coverings of the larvae harden and form pupal cases.
- Adults later emerge from the pupae to continue the life cycle.
- All growth stages can often be found on citrus trees at any one time.
- As many as 4-5 generations of whitefly a year (Smith *et al.* 1997). Greatest populations occur in spring and autumn, coinciding with growth flushes.

J	F	M	A	M	J	J	A	S	O	N	D

Monitoring

Control

- White oil sprays will help control whitefly. In most cases however, action is rarely required.

Biological control

- Several predatory insects are associated with the whitefly. These include small beetles belonging to the family Nitulidae. The beetle larvae have been observed destroying the whitefly eggs and using the empty shells to decorate their pupal covering.
- Naturally occurring beneficials including ladybirds, lacewing and syrphid (hoverfly) larvae also feed upon the whitefly.
- If ants are present, control them to enhance biological control of the whitefly.

Syrphid pupa – has been decorated with whitefly shells.

1.2.4 Mealybugs (Hemiptera: Pseudococcidae)

- Mealybugs are oval shaped, soft-bodied insects covered with a white, mealy wax.
- Five species occur in Australian citrus (Smith *et al.* 1989) of which three occur in WA: citrus mealybug (*Planococcus citri*), longtailed mealybug (*Pseudococcus longispinus*) and spherical mealybug (*Nipaecoccus filamentosus*; Kununurra only).
- Mealybug species differ in the thickness and length of the waxy filaments (spines) along the body margin and the posterior end.
- Citrus mealybug has a pinkish body that is visible through the powdery wax. There are 18 pairs of short filaments around its margins, the pair at the posterior end are up to ¼ the length of the body.
- Longtailed mealybugs have long filaments at the posterior end.
- Spherical mealybugs have a purplish body that is visible trough the wax. The filaments around its margins are not appreciably longer at the posterior end.

Damage

- Mealybugs have piercing sucking mouthparts that they insert into the plant to feed.
- Feeding weakens and stunts plants, causes leaf distortion and in the case of spherical mealybug, twisting of shoots if the infestation is heavy.
- Large quantities of honeydew are also produced which often turns black with the growth of the sooty mould fungus. The presence of honeydew and sooty fungus is one way to detect infestations mealybugs.
- Mealybugs can also hide under the calyx of the fruit, which can cause export problems.

From top: citrus mealybug nymph and crawlers, mealybugs on grapefruit

Lifecycle

- Citrus mealybug species have a similar lifecycle and the males undergo an additional stage (pupa).
- Female: Egg ⇨ crawler (=1st instar) ⇨ 2nd/3rd/instar
- nymph (looks like the adult) ⇨ adult female
- Male: Egg ⇨ crawler ⇨ 2nd/3rd/instar ⇨ male pupa (=cocoon) ⇨ adult male

Citrus mealybug, *Planococcus citri* (Russo)

- Adult female 3-4 mm long, male is usually smaller. There is a dorsal line (barely visible) running the length of the body).
- Newly hatched nymphs are light yellow and free of wax. Immature males and all stages of females are similar in appearance.

Distribution & importance of citrus mealybug in WA

Lifecycle

- Eggs are laid in a white cottony mass behind the female.
- Females can lay between 300-600 eggs and die soon after laying eggs.
- Eggs hatch in 3 -10 days, depending on temperature (Waterhouse & Sands 2001).

J	F	M	A	M	J	J	A	S	O	N	D

Monitoring

- Newly hatched nymphs are light yellow and free of wax, but soon start to excrete a waxy cover.
- An entire life cycle can take 20-40 days and there can be up to 3-4 generations per year (Smith *et al.* 1989). There are 3-4 overlapping generations per year (Smith *et al.* 1989).

Control

- Mealybugs are primarily managed by conserving their natural enemies and reducing ant populations.
- Treatment is rarely required and oil sprays are effective on young stages only.

Biological Control

Parasites

- Mealybug parasite, *Leptomastix dactylopii* Howard
- considered to be a useful mealybug parasite. The wasp (honey-coloured, 3mm long) parasitises third instar and adults.
- It was released into Queensland from Brazil in 1980 and 1987 (Waterhouse & Sands 2001) and became established.
- It was not found in WA during this study and is not commercially available.

Other parasites

- Other mealybug parasites include *Anagyrus* sp. (third instar), *Leptomastidea abnormis* (second instar) and *Coccidoxenoides peregrina* (first instars).
- None were not found during this study and are not commercially available.
- *Predators*
- Native predators include lady beetles, lacewings, and syrphid flies.
- An efficient predator of the citrus mealybug, the native ladybird, *Cryptolaemus montrouzieri*, introduced from NSW to WA in 1902 feeds on both larval and adult stages.
- The larvae resemble a mealybug, but are generally much larger than a mealybug (see photo).
- *Cryptolaemus* can be purchased from commercial insectaries in early spring and released in orchards where citrus mealybugs were a problem the previous year. Release about 500 *Cryptolaemus* per acre (see section 1.2.8 for more information).

From top: female Leptomastix dactylopii, Cryptolaemus montrouzieri larva feeding on long tailed mealybug

Longtailed mealybug – note the long tail filaments.

Distribution & importance of longtailed mealybug in WA

J	F	M	A	M	J	J	A	S	O	N	D

Monitoring

Longtailed mealybug, *Pseudococcus longispinus* (Targioni)

- Adult female 3-4mm long covered with a thin coating of white wax. Tail filaments are longer than, or as long as the body. Side filaments are also long compared to the other two species.
- Crawlers are minute and pink. Later stages are similar in appearance to females.

Life cycle

- Females produce up to 200 live young (crawlers) over 2-3 weeks.
- The entire life cycle takes 6 weeks in summer and 12 weeks in autumn.
- There are 3-4 overlapping generations per year (Smith *et al.* 1989).

Control

- See entry under citrus mealybug.

Spherical mealybug, Nipaecoccus viridis (Newstead)

- Adult female 2.5-4 mm long, slightly flattened in shape, and covered with creamy white wax.
- The body just visible under the wax is a purplish colour and is usually almost hidden by the large white domed egg sac.
- Unlike other mealybugs, spherical mealybugs cluster in colonies on leaves and shoots (see photo)
- Origin: exotic

Lifecycle

- Little information is available on the spherical mealybug.
- Female lays eggs into an egg sac. Each female can lay up to 500 eggs.
- Complete life cycle can take up to 3 weeks (Smith *et al.* 1989).

Control

- See entry under citrus mealybug.

Spherical mealybug

Distribution & importance of spherical mealybug in WA

J	F	M	A	M	J	J	A	S	O	N	D

Monitoring

1.2.5 Moths and Butterflies (Lepidoptera)

- Three moth species were found in citrus orchards in southwest WA during the study: citrus leafminer, light brown apple moth and citrus bud moth.
- In Kununurra and Carnarvon, other moth pests include fruit piercing moths (*Othreis* species) and citrus butterflies. With the exception of citrus leafminer which can be a major problem for orchardists in all areas with trees less than 3 years old, most moths cause little economic damage to citrus in WA.
- Please refer to Smith *et al.* (1989) for information on the moth species not reported here.

Lifecycle

- Butterflies and moths undergo a complete metamorphosis and the lifecycle of all species is similar: Egg ⇨Larva (=caterpillar) ⇨ Pupa (=cocoon) ⇨ Adult (moth or butterfly).

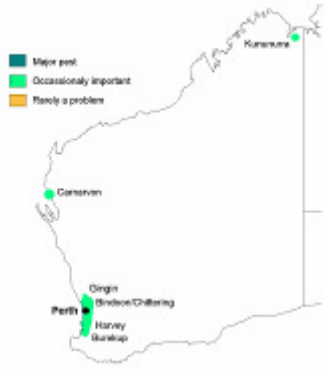
Citrus leafminer, *Phyllocnistis citrella* Stainton

- Size: 2mm long
- Origin: southeast Asia, citrus leafminer was first found in Western Australia in 1995. Citrus leafminer is present in most citrus producing areas of the world.

From top: adult CLM, damage to young tree (Photo: C. Freebairn)

Damage

- Attacks all citrus varieties.
- Larvae infest the young flushing foliage, producing a snake-like 'mine' as they feed. This damage causes the attacked leaves to twist and curl.
- Larvae can also attack fruit and stems, though this damage is rarer.
- Severe infestations can retard growth of young trees. Infestations on older trees (older than 5 years) can cause unsightly damage, but do not normally cause significant yield losses.
- In WA, CLM can be present in the orchard year round. Attacks are most severe in late autumn peaking in April or May, depending on temperature,
- In spring, damage is minor as the leafminer population is smaller. As a result, only a small proportion of the prolific spring flush is attacked.



Distribution & importance of CLM in WA

Lifecycle

- Adults are about 2 mm long, silvery white in colour with wings fringed with long hairs. Adults are rarely seen and are active in the morning and night.
- Females lay eggs singly under the leaf. Females can lay up to 50 eggs. Newly emerged leaflets (10-20mm) are the preferred egg laying site.
- After 2 - 10 days the larvae hatch; there are 3 larval stages. When they first hatch, larvae are pale-green and difficult to see. As they begin feeding on the leaf, the larvae excrete their faeces into the mine forming a visible central trail.

J	F	M	A	M	J	J	A	S	O	N	D

Monitoring

- Larvae cannot move from leaf to leaf or from lower to upper leaf surface, but remain on the same leaf throughout their life. 1-8 larval mines can be found on a single leaf.

- When larval feeding is completed (5-6 days in summer), the third instar mines near the edge of the leaf causing the leaf margin to fold over. The larva moults into the fourth instar or prepupa.
- Pupation occurs in a fold on the edge of the leaf. The pupa remains in the mine until it emerges as an adult. The pupal stage lasts 6 days.

Control

Chemical

- Insecticidal control is difficult to achieve because the larvae are shielded within their mines. The pupal stage is also protected by the rolled leaf margin.
- Systemic insecticides such as Confidor offer good control of CLM but due to the long withholding period should only be used on young trees.
- In tropical areas, Confidor has been associated with mite outbreaks (J. Beard, UQ, pers comm.).
- **Petroleum oil sprays** reduce leafminer numbers by reducing egg lay. The tiny leafminer moths avoid surfaces sprayed with oil, so sprays should be applied before too many eggs have been laid.
- Two or more sprays may be required when new leaves are produced over a prolonged period.
- New growth should be protected as soon as it has formed. Once leaves have hardened, they are resistant to leafminer attack.

The native wasp Semielacher petiolas *above, and pupa below.*

Cirrospilus quadristriatus *adult (above), pupa (below)* (Photo: C. Freebairn).

Cultural

- There are several ways to reduce infestations by limiting the production of new leaves when leafminer numbers are highest:
- Prune growth flushes;
- Fertilise in late winter to promote strong spring growth when CLM is rarer;
- Do not over water or over fertilise in late summer and autumn.

Biological

- Three of the most effective parasites in Asia (*Citrostichus phyllocnistoides*, *Cirrospilus quadristriatus* and *Ageniaspis citricola*) were introduced into Queensland in the 1990's. These species were then released into WA from Queensland.
- Only one species, *Cirrospilus quadristriatus,* appears to have established in southern WA.
- A native wasp, *Semielacher petiolatus,* was also found during this study. Both species attack the CLM larva, leaving distinct pupal cases.
- Parasitism levels are low – usually less than 5% of all larvae are attacked and for this reason, biological control appears to be ineffective in WA. In Queensland the introduced wasps can cause up to 90 per cent parasitism (Smith *et al.* 1989).
- Further parasites introductions are required, particular in areas such as Kununurra where high rainfall reduces the effectiveness of horticultural oils.
- Green and brown lacewings will also feed on CLM.

Lemon bud moth, *Prays paralis* Turner

- Yellow, to reddish-brown, up to 10mm long
- Larvae are found in the flower bud. Moths are rarely seen (40 mm wing span).
- Origin: native species

Damage

- The main crop attacked in WA is lemon.
- Bud moths were only found to be a problem at Gingin during this study.
- The larva feeds on the flower and can cause up to 50% damage.
- In WA, larval feeding can also cause fruit deformation.

Life cycle

- The female moth lays up to 20 eggs on a single bud.
- Larvae hatch and bore into the bud. Only one larva develops per bud.
- After a fortnight, the larva pupates, often at the edge of a curled leaf or on the flowers.
- There are as many as 6-7 generations per year.
- Control
- Unidentified parasites have been recorded by Smith *et al.* (1997) to attack lemon bud moth.
- In WA, parasitic larvae have been recorded feeding on lemon bud larvae though attempts to rear the parasite for identification failed.
- Selective pesticides can be applied when required (50% of buds attacked).
- However, because the larva is hidden within the bud, control with insecticides can be difficult.

From top: Lemon bud mite larva, hole made in bud by the larva.

Distribution & importance of lemon bud moth in WA

J	F	M	A	M	J	J	A	S	O	N	D

Monitoring

Unidentified larva feeding on bud moth.

1.2.6 Mites (Acarina)

- Mites can be distinguished from insects in that they have 8 rather than 6 legs. However, the nymphal stages of mite also have 6 legs.
- Of the nine species of economically important mites reported in Australian citrus (Smith *et al.* 1989), five occur in WA: brown citrus rust mite (*Tegolophus australis* Keifer), citrus bud mite (*Aceria sheldoni* (Ewing)), oriental spider mite (*Eutetranychus orientalis* (Klein)), two spotted mite (*Tetranychus urticae* Koch) and broad mite (*Polyphagotarsonemus latus* (Banks)). Oriental spider mite was only found in Carnarvon during this study.
- With the exception of citrus bud mite which can be a problem in lemons, mite damage to citrus in WA is rare.
- Species such as two spotted mite and spider mite are just visible to the naked eye. Others such as rust mite and bud mite can only be seen with the aid of a microscope or a 20X hand lens.
- Predatory mites are also often found on citrus. They can be distinguished from pest mites by their speed – they tend to be fast moving and run rapidly when disturbed.

Life cycle

- All mites have a similar life cycle: Egg ⇨Larva ⇨ Protonymph ⇨ Deutonymph ⇨Adult
- Larvae and nymphs (protonymphs and deutonymphs) resemble the adults, except that they are smaller and the larvae and nymphs have only six legs.

Citrus bud mite, *Eriphyes sheldoni* Ewing

- small, cream-coloured mite around 0.17 mm long, elongated and somewhat tapered at the posterior end.
- There are 4 legs at the front end near the mouth.

Damage

- Bud mites feed inside the buds, killing them or causing a rosette-like growth of the subsequent foliage and distortion of flowers and fruit
- Damage may reduce yield and fruit quality.
- Lemons in particular are attacked by bud mite.

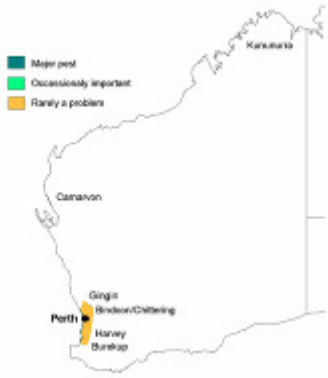
Life cycle

- Adult females lay about 50 eggs in the developing buds of flowers or leaves.
- Monitoring indicates that mites are present year- round in WA.
- Up to 20 generations can develop per year (Smith *et al.* 1989).
- Control
- Control of bud mite is difficult since they are protected with the leaf, flower or fruit bud.
- Use a selective miticide or oil spray.

Monitoring

- To detect bud mites before damage occurs, buds should be checked on green angular twigs from mid-spring to autumn.

From top: citrus bud mite (photo J. Kelly-Clark), deformed fruit.



Distribution & importance of citrus bud mite in WA

J	F	M	A	M	J	J	A	S	O	N	D

Monitoring

- Collect one bud from each of 50 randomly chosen trees throughout the orchard.
- Dissect the buds using a scalpel under a microscope. Mites, if present, will be found under the bud scale. They are usually very slow moving, or stationery.
- Determine the percent of buds infested with one or more live mites.
- As an alternative to dissecting buds, infestation levels can be estimated from infested fruit buttons (UC IPM 2006).
- Collect 1 golf-ball sized green fruit from 50 trees scattered throughout the orchard.
- Remove the button and record whether the button or the fruit beneath the button is infested with live bud mites.
- The relationship between fruit and bud infestations is not linear, but a fruit infestation of 15 to 20% indicates a bud infestation of approximately 45 to 50% (UC IPM 2006).
- Action is required if more than 10% of buds are infested.

Twospotted mite, *Tetranychus urticae* Koch

- Greenish-yellow mite around 0.5 mm long, with two dark red spots either side of the body.
- When stressed, e.g. in winter, mites turn a reddish colour.

Top: two-spotted spider mite, note the red 'spots' either side of the body. Bottom: red form.

Damage

- Two spotted mites feed on the lower leaf surface, causing the surface to become spotted (yellow).
- When populations are high, mites are found on the upperside of leaves and on fruit.
- On green fruit, damage appears as a yellow or pale-green spotting of the fruit rind.

Life cycle

- The adult female lays round, white eggs on the leaf or fruit surface within spidery webbing (produced by the mites). Females can lay up to 70 eggs over a period of a fortnight.
- Eggs hatch into larvae with 6 legs. Larvae moult three times before they become adults. After 2 moults, the larvae have 8 legs.
- One generation can be completed in 7 days and 10-20 generations can develop per year (Smith *et al.* 1989).

Distribution & importance of 2-spotted mite in WA

Control

- Control is not usually required. Use a selective miticide or oil spray.
- A number of predators provide control of two-spotted mite. These include the mite eating ladybirds, *Stethorus* spp. and predatory mites.
- In stone fruit the mite, *Phytoseiulus persimilis*, is often released to control pest mites. Similar releases may be possible in citrus.

J	F	M	A	M	J	J	A	S	O	N	D

Monitoring

Stethorus ladybird.

Brown Citrus Rust mite, *Tegolophus australis* Keifer

- Small wedge-shaped, light to dark brown mite, 0.18 mm long.
- 4 legs at the front end near the mouth.
- Hand lens or microscope required to view mite.
- Origin: native to Australia

Damage

- Mite feeding destroys rind cells, discolouring the leaves and fruit.
- Mite damage can be confused with melanose, chemical burn and weather staining. To confirm mite damage, look for white cast-off skins shed by the mite as it moults. Skins will be present on the damaged surface.
- By the time that damage is noticed, the mite population may already have disappeared. Most rust mite damage occurs from late spring to late summer.

Life cycle

- Adult females lay about 30 eggs in small depressions in the fruit rind or leaf surface.
- Eggs hatch into nymphs which are smaller and paler than the adult mites (see photo top right).
- 20-30 generations can develop per year (Smith *et al.* 1989).
- A generation may be completed in 10 to 30 days depending on temperature.

Control

- Predatory mites such as *Euseius victoriensis* and E. elinae are known to feed on brown citrus mite.
- If required, apply a selective miticide or horticultural oil. Monitoring will be required to determine if mites are present and have reached threshold numbers.

Top: rust mites (photo: C. Freebairn), bottom: damaged fruit (left), normal fruit (right)(Photo J. Villarreal, Texas A & M).

Distribution & importance of rust mite in WA

J	F	M	A	M	J	J	A	S	O	N	D

Monitoring

1.2.7 Thrips (Thysanoptera)

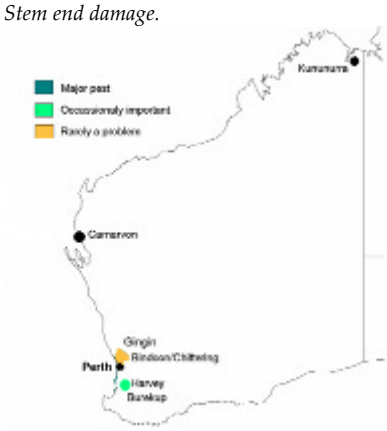
- Thrips are small, slender, soft-bodied insects, just visible to the naked eye: adults are 1-2 mm in size.
- In Western Australia, only two species of thrips are economically important: Kelly's citrus thrips (*Pezothrips (Megalurothrips) kellyanus* (Bagnall)) and greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché). Kelly's citrus thrips are often found on fruit at flowering, whilst greenhouse thrips are present on mature fruit.
- Other species of thrips such as plague thrips (*Thrips imaginis*) may be present at flowering to feed on pollen, but do not damage the fruit.
- Thrips known to be a problem in Queensland such as citrus rust thrips (*Chaetanaphothrips orchidii* (Moulton) and scirtothrips (*Scirtothrips albomaculatus* Bianci, *S. dorsalis* Hood, South African citrus thrips, *Scirtothrips aurantii* (Faure)) have not been found in WA to date.
- Lifecycle
- All thrips species have a similar lifecycle, undergoing what is termed an incomplete metamorphosis.
- Egg ⇨ 1st Instar Larva ⇨ 2nd Instar Larva ⇨ Propupa ⇨Pupa ⇨ Adult

Kelly's citrus thrips, *Pezothrips kellyanus* (Bagnall)

- Adult *P. kellyanus* are black, 2-3 mm long, with black legs. The wings are dark with a small clear band at the top. Nymphs are pale yellow.
- Similar to greenhouse thrips. However, *P. kellyanus* have black wings and black legs.
- In WA, *P. kellyanus* has only been a problem on navel oranges in a few orchards in the Harvey area, though has been detected as far north as Bindoon.
- Origin: originally thought to be native to Australia. Now considered to be an introduced species.

Kelly's citrus thrips (KCT) – adult on citrus flower.

Stem end damage.



Distribution & importance of KCT in WA

Damage

- Thrips feed under the calyx of the young fruit, causing ring scarring (halo damage) and scurfing. Affected fruit are downgraded.
- By the time that damage is noticed the thrips population may already have disappeared.

Life cycle

- Adult females lay eggs in the fruit rind or leaf tissue.
- Eggs hatch into nymphs which are small and pale. The nymphs feed under protected areas such as the calyx and between touching fruit.
- The larva undergoes a propupal and pupal stage before becoming an adult. Adults can be recognised by the presence of wings which are often folded back along the body.
- In WA, KCT are present year round but can become a particular problem for growers from October-March.

J	F	M	A	M	J	J	A	S	O	N	D

Monitoring

- At least 6 generations can develop per year (Smith *et al.* 1989).

Control

- Predatory thrips such as the native *Haplothrips* spp. are known to feed on *P. kellyanus* (Smith *et al.* 1989). *Haplothrips victoriensis* was recorded from citrus in this study, but did not appear to be in sufficiently large numbers to control the *P. kellyanus* population.
- Chemical control of *P. kellyanus* is not recommended unless absolutely necessary. Horticultural oils should be used first if possible.
- Studies in South Australia indicate that spraying may increase the problem, due to the death of beneficials such as predatory soil mites that appear to be predating on thrips pupae that are present in the soil (G. Baker, SARDI, pers. comm.).

Greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché)

- Adult greenhouse thrips are black, 1.5 mm long, with yellowish legs. The wings are also black. Nymphs are pale yellow or white. Newly emerged adults are black and brown.
- Similar to Kelly's citrus thrips. However, *P. kellyanus* have black wings and black legs.
- In WA, greenhouse thrips are only a problem on oranges and grapefruit that are harvested late (January-March).
- Origin: unknown. World wide distribution.

Greenhouse thrips – adults and nymphs (photo M. Steiner). Note the black excreta being produced at the tail end of the nymphs.

Damage

- Adults and nymphs feed on leaves, between touching fruit or under a leaf or stem touching the fruit.
- Damage results in grey scars or 'bleaching' between touching fruit. The area is often covered with black spots which are excreta produced by the nymphs as they feed.

Bleaching caused by greenhouse thrips feeding.

Life cycle

- Adult females lay eggs in the fruit rind or leaf tissue.
- Eggs hatch into nymphs which are small and pale.
- The larva undergoes a propupal and pupal stage before becoming an adult. Adults can be recognised by the presence of wings which are folded back along the body. One generation can be completed in 33-38 days (Waterhouse & Sands 2001).
- In WA, greenhouse thrips are present year round but are usually only a problem for growers from December-March.
- At least 6 generations can develop per year (Smith *et al.* 1989).

Distribution & importance of Greenhouse thrips in WA

J	F	M	A	M	J	J	A	S	O	N	D

Monitoring

Control

Biological Control

- the minute wasp, *Thripobius semiluteus Boucek* (0.6mm long), is established on greenhouse thrips in Burekup and may be present in other citrus growing areas as well.
- The wasp attacks first instar and to a lesser extent, second instars.

- The immobile parasite pupae appear black and may be found amongst colonies of translucent, unparasitised thrips or by themselves.
- *Thripobius* is not available commercially. Parasites either move into the orchard on their own or must be located in nearby avocado or citrus orchards and relocated.

From top: Thripobius pupae. Thripobius adult (Photo: Doug Allan, Horticulture and Food Research Institute of New Zealand)

Cultural Control

- Early harvest in affected areas can minimize the amount of damage.
- In addition, because much of the greenhouse thrips population resides on the fruit, it is removed from the orchard at harvest.
- An early harvest strategy can thus reduce the crop-to-crop overlap time and minimize the greenhouse thrips movement to (and resultant damage of) the following year's crop.

1.2.8 Beneficial Insects

- Three types of beneficials occur naturally: parasites (adults lay eggs and develop in or on the host), predators (larvae and adults eat the host, thereby killing it) and pathogens (nematodes, viruses and bacteria infect the host, thereby killing it).
- Parasites have been reported under the relevant citrus pest. Information on predators only is provided here.

Lacewings

- All species have four transparent, lacy wings, hence their name.
- *Prey*: aphids, moth eggs and small larvae, scales and whiteflies. Larvae are the main predatory stage.
- *Commercially available*: yes (Queensland, green lacewings)

Seasonal abundance:

J	F	M	A	M	J	J	A	S	O	N	D

Green lacewings, *Mallada signata* (Schneider), *Chrysopa* spp.

- Adults are bright green, 10-30mm long, with golden eyes and long antennae. Adults can often be seen resting on leaves and are often attracted to lights at night.
- Larvae are yellow to brown with darker markings, 3-20mm long, with large, powerful mandibles. The larvae are called trash bugs because of their habit of putting prey remains on their back.
- The larvae are the main predatory stage.

Life cycle

- Females lay tiny, oblong eggs on stalks onto the citrus leaf. Eggs may be laid singly or in clusters.
- When first laid, green lacewing eggs are green but darken before hatching. Hatched eggs are white.
- Eggs hatch after 4 days and larvae develop through three instars before pupating.
- Pupation occurs in loosely woven, spherical, silken cocoons.

Commercial availability

- *Mallada signata* are produced commercially for release.
- Lacewings are shipped as pupae and hatch shortly before or after arrival.
- They should be released as soon as possible as larvae will eat each other.

From top: green lacewing egg, green lacewing larva eating an aphid, pupa, adult.

Brown lacewings, *Micromus tasmaniae* (Walker) (Tasman's Lacewing).

- Brown lacewings are less common than green lacewings and are about half the size (10-15 mm long).
- Eggs are creamy white and laid flat onto the leaf rather than on stalks.
- Larvae are light brown to yellow, 3-20 mm long with two stripes running the length of the body. Unlike green lacewing larvae, they do not carry prey remains around with them on their back.
- Pupation occurs in loosely woven silk cocoons.
- *Origin*: native species
- *Commercially availability*: being developed (Victoria)

From top: brown lacewing egg (Photo HortNet New Zealand), larva with aphid, pupa and Micromus tasmaniae *adult.*

Ladybird beetles

Prey: scale, aphids, mealybugs and whitefly.
Seasonal activity:

J	F	M	A	M	J	J	A	S	O	N	D

Transverse ladybird, Coccinella transversalis lifecycle. From top: eggs, newly hatched larvae, larva eating aphids, pupa. Adult.

Description

- Larvae vary in colour, size and shape depending on species. Larvae are elongate with long legs and resemble tiny alligators, ranging in size from 1mm to 13mm long. Some species are blackish with orange spots, others are completely black.
- Adults have a shiny half-dome shape and short, clubbed antennae. They range in colour from orange to red to black and can be spotted or without spots. Size varies from 1mm for mite eating ladybirds, up to 6mm.
- Origin: native and introduced species

Life cycle

- The lifecycle of all ladybirds is similar, although the duration of each stage, total length of the life cycle and the number of generations per year will differ from species to species.
- After mating the adult female lays 200-1,000 spindle-shaped, yellow eggs, 1mm in size, often near a pest infestation. Eggs may be laid singly or in clumps. The eggs hatch in a few days and the larvae begin to feed on their prey.
- The larvae are smaller than their prey at first, but quickly grow, moulting a total of 4 times (i.e. there are 4 larval stages).
- The prepupal and pupal stages are often found on leaves and branches near an infestation.
- Adults emerge 7-9 days later, depending on temperature and species. The pupal skin splits along the back and the adult emerges. At first the adult is pale but soon darkens a few hours or days.
- An entire lifecycle can be completed in 4-8 weeks and there is at least one generation per year.

Transverse ladybird, *Coccinella transversalis* Fabricius

- Origin: native
- Commercially available: no
- Most common ladybird. Adult bright orange to orange-red in colour with spots merging on their back.
- Larvae are brown-black with lighter bands across the body, 1mm when newly hatched up to 12mm.

Common spotted ladybird, *Harmonia conformis* (Boisduval)

- Origin: native to Western Australia
- Commercially available: no
- Adult bright orange in colour with 23 black dots on its back.

- Larva dull black in colour, with two yellow-orange bands on the abdomen, up to 12mm in length.
- Spotted amber ladybird, *Hippodamia variegata* (Goeze)
- Origin: accidental introduction to Australia, first found in Brisbane in November 2000, in WA citrus in 2005
- Commercially availability: being developed (Victoria)
- adult black, 5 mm long, with 6 orange spots – 3 spots either side of the body.
- The larvae are easily recognisable by its prominent spines.

Common spotted ladybird, Harmonia conformis

Mealybug destroyer, *Cryptolaemus montrouzieri*

- Origin: native (to NSW), first introduced to WA in 1902 (Waterhouse & Sands 2001); one of the most widely distributed ladybird species worldwide.
- Commercially available: yes (Queensland)
- Adult 4 mm long, dark brown to black with an orange-brown head and tail. Females can lay up to 100 eggs in 1 month.
- Eggs hatch in 4-8 days, and wax covered larvae develop in 12-20 days. Larvae can grow up to 13 mm long and are often confused with mealybugs but move much faster, and have distinct jaws and legs.
- If the waxy cover is scraped away an alligator shaped larvae will be seen underneath.
- An entire lifecycle can be completed in less than a month (Sands & Waterhouse 2001).

Mealybug destroyer, Cryptolaemus montrouzieri, *from top: larva feeding on mealybug, larva feeding on cottony cushion scale and adult bottom.*

Parapriasus australasiae (Boisduval)

- Origin: native; little information available on its biology
- Commercially available: no
- Adult black, 5 mm long, with 6 orange spot and blotches – 3 either side of the body.
- The larvae are orange-black with prominent spines.

Vedalia beetle, *Rodolia cardinalis* (Mulsant)

- Origin: native species
- Commercially available: no
- Prey: Cottony cushion scale
- Adult 2-4 mm long, red and black with a covering of fine hairs which often gives them a grayish appearance (photo next page).
- Larvae reddish in color.
- Red and black pupae develop within the grayish skin of the last larval instar and are found among or near scale colonies.
- Oblong, red eggs are laid singly or in groups on or near cottony cushion scales.
- In California, *R. cardinalis* has 8 or more generations per year (UC IPM 2006).

Parapriasus australasiae, *larva (top) and adult (bottom)*

Red chilocorus, *Chilocorus circumdatus* Gyllenhal

- Origin: introduced (Israel)
- Commercially available: yes
- Prey: scale insects including red scale
- Adult helmet shaped, 5mm long, orange in colour fine black margin around the base of the wing covers.
- Larvae orange with black spines.
- This species was released in Burekup in 2004 and 2005, but failed to establish soon after release.

Red chilocorus, Chilocorus circumdatus

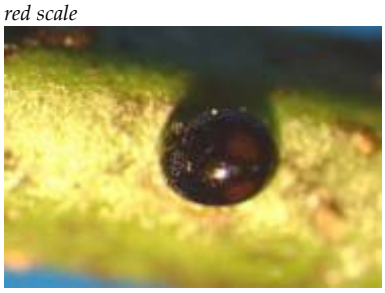
Scale-eating ladybird, *Rhyzobius lophanthae* (Blaisdell)

- Origin: native
- Commercially available: no
- Prey: hard & soft scale
- Adults black with two red spots
- Larva has light-coloured bands running lengthwise along abdomen, up to 10mm long.

Rhyzobius lophanthae *larva feeding on red scale*

Minute two-spotted ladybird, *Diomus notescens* (Blackburn)

- Origin: native
- Commercially available: no
- Prey: mealybug, aphids, citricola scale.
- Adults 2.5mm long, black with two red spots either side of the body.



Diomus notescens *adult*

Pest species

28 spot ladybird, *Henosepilachna vigintisexpunctata* (Boisduval)

- Origin: exotic
- Larvae are yellow with sparse stiff dark hairs. They feed on various members of the plant family Solanaceae (potatoes, tomatoes etc) and are often found on solanaceous weeds growing under citrus.
- Adult orange-yellow, with 13 black spots on each wing cover, two spots on thorax, i.e. 28-spots in total. Dense short hairs present on body.

Rodolia cardinalis *adult (Photo: C. Freebairn)*

Spotted amber ladybird, Hippodamia

28 spot ladybird adult (Photo: D. Cousins)

Hoverflies

- Prey**:** small scale, aphids, and other small larvae.
- Commercially available: no
- Origin: native
- Adult hoverflies are black and yellow, 10mm long. They are often seen hovering in the orchard, able to remain stationary in mid-air, hence their name. They are sometimes confused with bees.
- The larvae are 1-13 mm long, yellow and are seldom seen unless there is a large outbreak of aphids.

Lifecycle

- Females lay whitish to grey oblong eggs, 1 mm in size, singly on their sides usually near aphids or within aphid colonies.
- Larvae are legless and maggot shaped. They have a tapered head, lack legs and have an opaque skin through which their internal organs can be seen.
- Larvae vary in length from 1 to 13 mm depending on their developmental stage and species.
- Pupae are oblong and dark brown in colour and are found on the plant or on the soil surface.

From top: syrphid egg near aphid (photo J. Kelly-Clark), larva feeding on aphid, pupa, adult (photo P. Chew).

PART 2: Insecticide trial

2.1 Introduction

In December 2004, a demonstration trial was set up at two locations: Gingin and Wokalup, to demonstrate the effectiveness of an 'IPM compatible' product (Confidor) against a range of citrus insect pests.

2.2 Materials and methods

2.2.1. Trial site

Demonstrations were conducted at two sites: Wokalup Agricultural College and Gingin.

2.2.2 Trial design

Trial design varied with location. At Gingin, a paired plot design was used with each treated plant paired with an untreated control in the same row (total thirty pairs). At Wokalup site 1 (oranges), 21 trees infested with black scale were treated (21). Control plants were selected from within the same rows as the treated plants and included trees heavily and lightly infested with black scale. At site 2 (mandarins), two rows were selected. 31 trees in one row were treated with Confidor, 31 trees in the other row were left untreated (control). All trees (treated and control) at all sites were labelled with flagging tape (treatment, tree number) for monitoring purposes.

2.2.3. Application details

Confidor 200 SC (200 g/L imidacloprid) or Confidor Guard (350 g/L imidacloprid) was applied to the soil around trees at the recommended concentration (1.5L Confidor to 50L water). Confidor acts as a systemic as well as a contact insecticide. At Wokalup site 1, approx. 24 mL were applied immediately around the base of the tree including the bottom 20 cm of the tree trunk; 42 mL/tree were applied to trees at site 2. At Gingin, 42 mL were applied around the base of the tree including the bottom 20 cm of the tree trunk.

2.2.4. Efficacy assessment

Treatments were evaluated prior to treatment and 1, 2 and 3 months after treatment, giving a total of 5 assessment times. The final assessment was made 12 months after the initial pesticide application.

Five branches, including the leaves, were randomly selected and examined for pests (mealybug, scale, thrips, citrus leaf miner etc) and beneficials (lacewings, ladybird adults and larvae, syrphid larvae, lacewing adults and larvae). All fruit (immature and mature) were examined for pests. A rating scale of 1-6 was to rate scale insect abundance on branches, leaves and fruit (Table 1). For grasshopper and citrus leaf miner, presence/absence of damage was recorded for each branch examined.

2.2.5 Statistical Analysis

Data from treated and control plants were compared using a paired student's t-test at Wokalup site 2 and Gingin. The data at Wokalup site 1 could not be analysed because trees had not been randomly selected (trees were selected by Bayer).

Table 2.1. Rating system for scale insects on leaves, branches and fruit.

Scale	Rating
1	0 (no scale present)
2	1-5 scale
3	6-10 scale
4	11-20 scale
5	>20 scale
6	100 or more

2.3. Results and discussion

2.3.1 Scale insects

Black (*Saissetia oleae*), soft brown (*Coccus hesperidum)*, red (*Aonidiella aurantii*) and cottony cushion scales (*Icerya purchasi*) were found during the study. Cottony cushion and soft brown scale were present in very small numbers on a few trees; black scale was more common and abundant than red scale at all sites. Confidor significantly reduced black scale populations on the leaves and branches of treated trees compared to the control, with action against scale for a period of at least 12 months.

Black scale

Prior to treatment with Confidor, no significant differences in black scale abundance on leaves on control or treatment groups was detected (Gingin: t=0.14, P=ns, df=29; Wokalup: t=2.32, P=0.33, df=30). However black scale were more abundant on the branches of the treatment group at Gingin (t=2.41, P=0.02, df=29), but not Wokalup. One month later (assessment 1) black scale populations had increased significantly on the leaves and branches of control trees (Gingin leaves: t=7.91, P<0.0001, df=29; branches: t=4.25, Wokalup leaves: t=23.08, P<0.0001, df=30; branches: t=3.4, P<0.0001, df=29). The last assessment (5) shows that black scale had disappeared on all trees, both treated and control at Wokalup. At Gingin however, control trees had significantly more black scale populations on branches and leaves compared to treated trees (leaves: t=8.01, P<0.0001, df=29; branches: t=19.01, P<0.0001, df=29).

Fruit

Very few fruit were present at any of the trial sites. Of the 18 fruit on control trees at Gingin, 7 were infested with red scale. Of the 9 fruit present on treatment trees, none were infested with red scale. At Wokalup site 1, 81 of the 199 fruit on control trees were infested with red scale whilst 49 of the 195 fruit on treatment trees were infested with red scale. No fruit were present on trees at Wokalup site 2 which were too young to bear fruit.

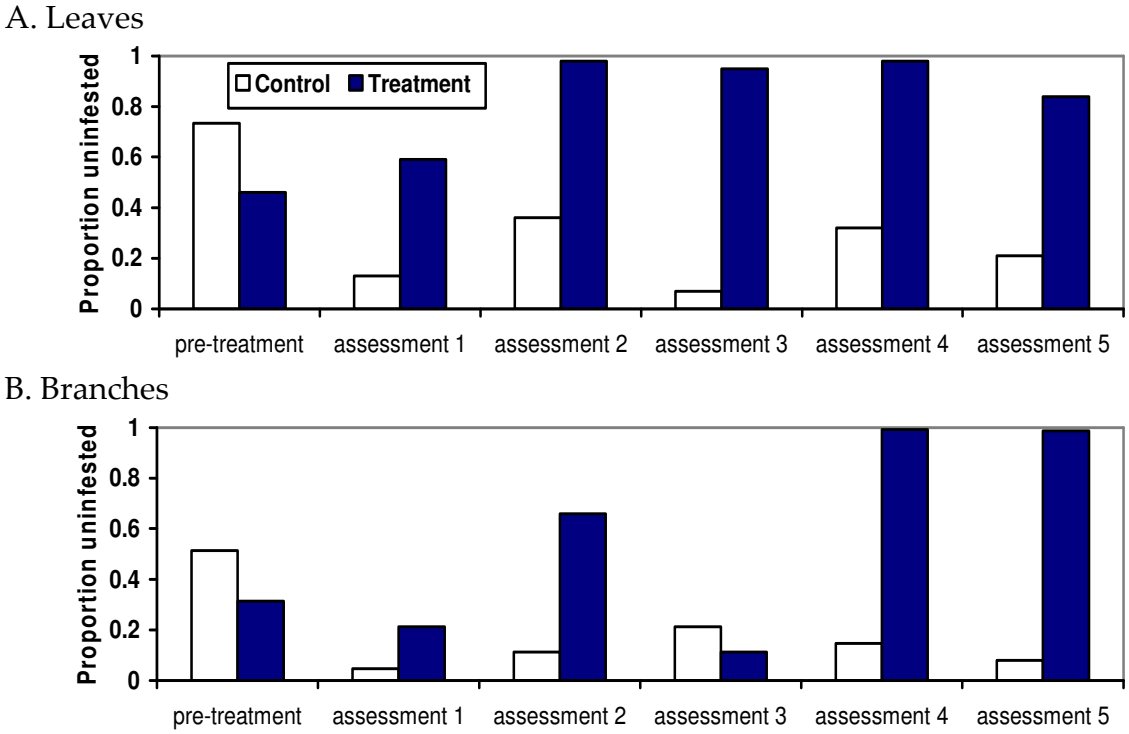


Figure 3.1 Proportion of leaves and branches free of black scale on treated (Confidor) and control trees at Gingin. The higher the proportion (i.e. approaching 1 or =1) the smaller the infestation. A value = 1 indicates that no scale was present.

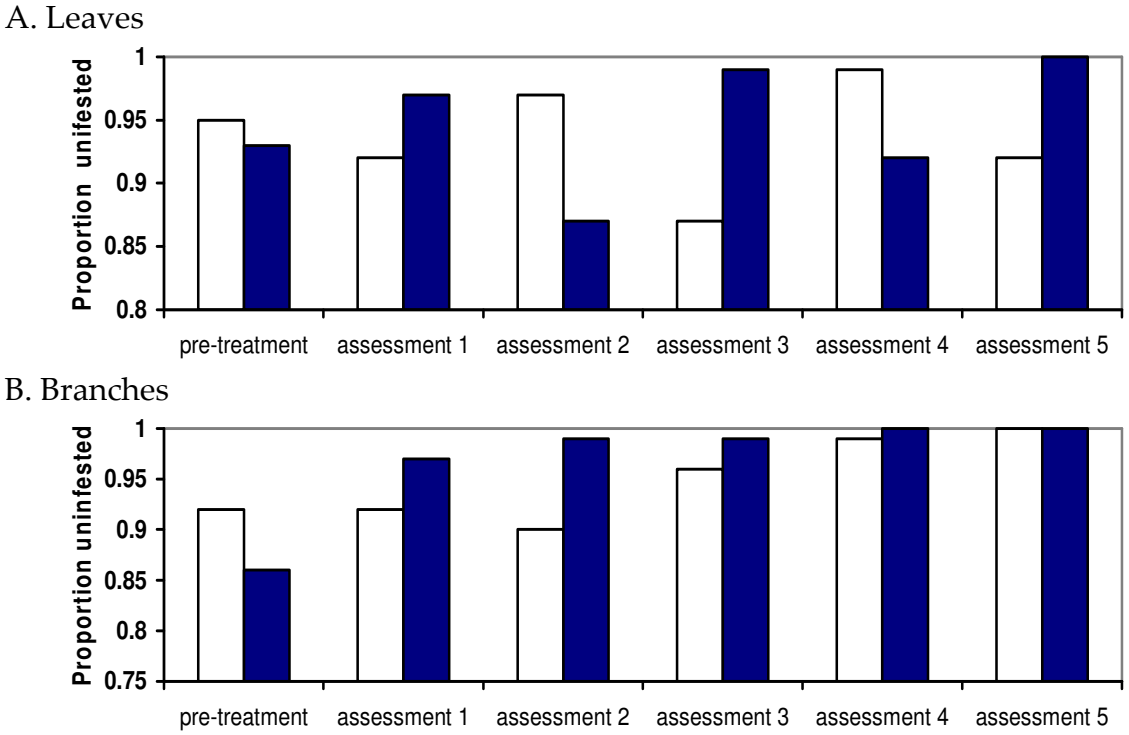


Figure 3.2 Proportion of branches free of black scale on treated (Confidor) and control trees at Wokalup site 2. The higher the proportion of branches (i.e. approaching 1 or =1, the smaller the infestation). A value = 1 indicates that no scale was present.

2.3.2 Grasshoppers and citrus leaf-miner

Grasshoppers were a problem at Wokalup, feeding on the foliage and young branch tips. Citrus leafminer, *Phyllocnistis citrella,* was found at Gingin from February to May, but was most damaging and abundant at Wokalup site 2. The proportion of trees that were attacked by citrus leafminer and grasshopper at Wokalup site 2 for each treatment group is shown in Figure 3.3. A total of 1 indicates that all trees had been attacked by leafminer on at least one of the five branches examined. Confidor protected trees against attack by grasshoppers and had some affect on citrus leafminer for at least 12 months after treatment at Wokalup, but not at Gingin (data not shown).

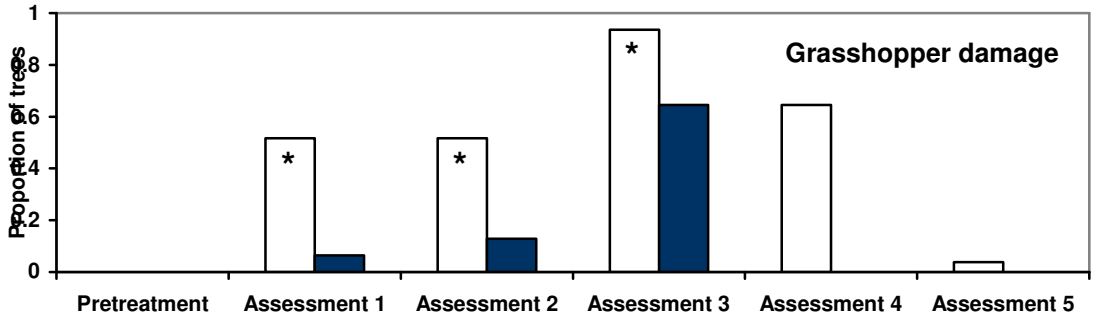


*Figure 3.3. Grasshopper damage to treated (solid bar) and control trees at Wokalup site 2. * denotes statistically significant result (assessment 1, t=10.77, P=0.0001, df=30; assessment 2, t=10.36, P<0.0001, df=30; assessment 3, t=5.05, P<0.0001, df=30).*

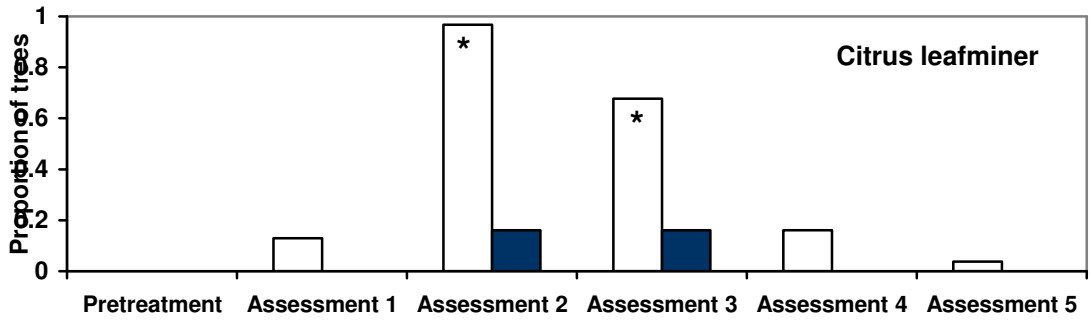


*Figure 3.4. Citrus leafminer damage to treated (solid bar) and control trees at Wokalup site 2. * denotes statistically significant result (assessment 2, t=3.28, P=0.002, df=30; assessment 3, t=2.26, P=0.03, df=30).*

2.3.3 Beneficials

Beneficial insects including ladybirds (*Cryptolaemus montrouzieri*, transverse ladybird (*Coccinella transversalis), Hippodamia variegata*) and green lacewings were found at Gingin and Wokalup. These insects are generalist predators, feeding on a wide range of prey including scale, aphids and mealybugs. Highest numbers of beneficials were found at Gingin (Figure 3.5). Prior to treatment, the highest numbers of beneficials were present on treated trees (t=5.08, P<0.001, df=29). One month after the Confidor application, beneficial numbers fell on control and treated trees. From a total of 104 *Coccinella* adults on treated trees, numbers fell to 15 adults one month after treatment with no significant differences between beneficial populations on either treated or control trees. For *Cryptolaemus*, numbers fell from 19 to 4, for *Mallada*, numbers fell from 19 to 4. 12 months after application, control trees had significantly more beneficials than treated trees (t=2.41, P=0.02, df=29), but overall, fewer beneficials

were present in year 2. Too few beneficials were present at Wokalup for statistical analysis.

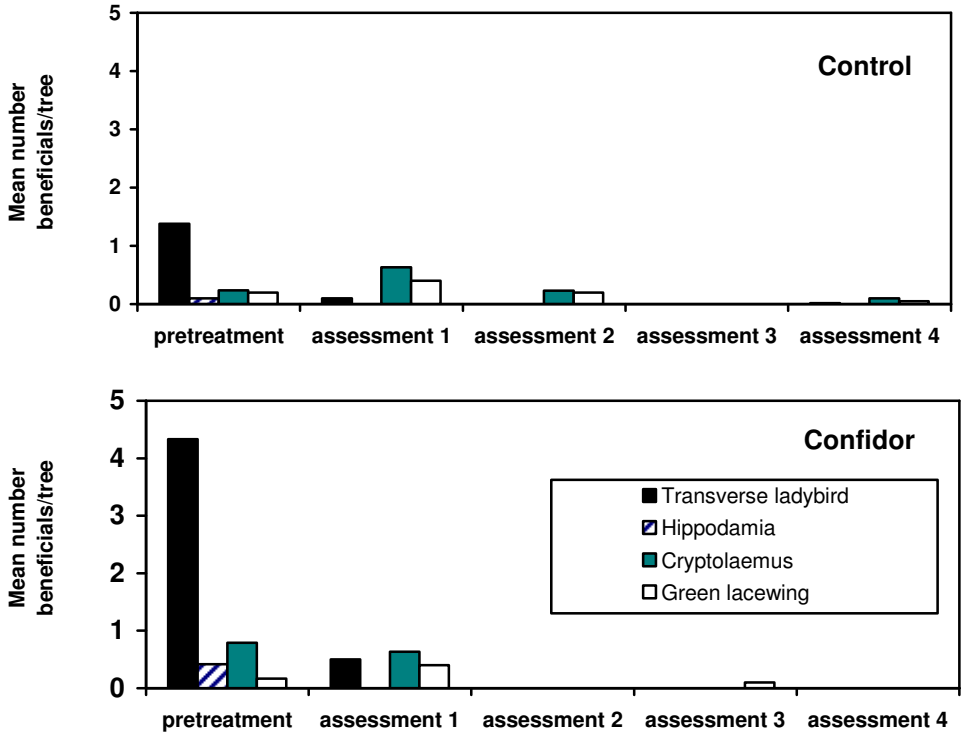


Figure 3.5. Mean number of beneficials found on control (unsprayed) and Confidor-treated trees at Gingin. Transverse ladybird, Hippodamia and Cryptolaemus are all different species of ladybirds.

2.4 Conclusions

Confidor is recommended for the control of Citrus Black citrus aphid, citrus leafminer, pink wax scale, and red scale in citrus at an application rate of 9mL/tree (Hall 2006). Whilst the application rate used in this study was considerably higher (24-42mL/tree), the results show that Confidor significantly reduced black scale populations as well for a period of at least 12 months. Black scale is a problem in young citrus in WA, feeding on the phloem of the tree and producing honeydew and sooty mould. This in turn reduces photosynthesis, thereby reducing plant growth. Pink wax scale was not present at any of the study sites and red scale was not abundant enough for Confidor to be evaluated against it. Confidor had some effect on citrus leaf miner which feeds on the leaf and mines the leaves and can be a serious pest of young trees in WA. However the results varied from site to site, with Confidor more effective on younger, smaller trees. Confidor also appeared to have some effect against grasshoppers at one site.

Whilst Confidor can be recommended for use in young trees, its use in older, established orchards in Western Australia is not recommended. Confidor has a long withholding period (20 weeks) which would not be practical for use in continuous crops such as lemons. Our results also suggest that at least in young trees, there is some residual effect for 12 months which may be present in the fruit at harvest over 12

months later. Scale and leafminer are rarely a problem in older orchards and if required, parasite releases for red scale or horticultural oil sprays are effective.

The use of Confidor in an IPM program also needs to be further evaluated. This study suggests that Confidor reduced the populations of ladybird beetles and lacewings in treated and untreated trees. Whilst ladybird populations were expected to decline on Confidor treated trees as their food source died off, a drop in beneficial populations on control trees was also recorded. This was unlikely to be due to changes in food availability or temperature, since scale abundance did not decline on control trees and no significant changes in temperature were recorded. A possible explanation is that adult ladybirds were moving between control and treated trees and had consumed a lethal dose of treated scale. For this reason, further research is required to determine the effect of Confidor on beneficials commonly used in citrus such as the ladybird beetle *Cryptolaemus montrouzieri* and the parasitic wasp *Aphytis lignanensis*.

Part 3: Technology Transfer

3.1 Grower attitudes to integrated pest management (IPM)

Contribution by Gavin Foord (Citrus IDO WA)

In October 2003, a grower survey was conducted to identify production practice change resulting from the various activities (Appendix 2). The survey asked growers:

- If a change was made in the past few years
- Why they made that change
- Where they got the information to make that change

The questions were designed to identify what motivated change, determine the effectiveness of the current activities and help plan future activities to be more effective. The survey also provided an opportunity to ask questions on environmental management to benchmark understanding of environmental issues and attitudes and aspirations in regard to environmental management.

3.1.2 Results

There was a high level of practice change in the production issues assessed:

irrigation management	73%
nutrition management	70%
pest management	73%
watermark on imperials	78%

Most growers indicated that they had made changes in the past few years, they also indicated that they wanted more information on those same issues. It was particularly interesting that the two practices our growers believed pose the highest risk to the environment [chemical sprays (86%) and fertilisers (50%)], involved practices they had recently changed ie pest management (73%) and nutrition management (70%).

When asked '...why did you make a change?' the most common responses were 'to improve quality' and 'to improve yields'. What was surprising was that growers ranked 'to reduce environmental impact' as more important than 'to save money'. Another notable result was that while 76% of those surveyed believed that "…current best management practices minimise environmental impact…", 80% wanted more information on environmental management.

3.2 IPM workshops

There are approximately 230 commercial citrus growers in WA, with >90% of properties owned, managed and operated by individual families with help from their spouse and/or children. Since WA has no citrus scouts or IPM services operating in citrus at present, growers need to carry out their own monitoring. To demonstrate to growers what is involved in an IPM program, workshops on insect identification, use of action thresholds, and when and how to release beneficials were required.

The aims of the IPM workshops were to: (1) introduce growers to monitoring and identification techniques so that they become proficient in the identification of pests

and beneficials in their local area; (2) familiarise growers with IPM techniques used in citrus. Particular emphasis was placed on biological control, since the use of beneficial insects encourages growers to use less pesticides.

3.2.1 Advertising

IPM workshops were promoted by advertising in the monthly newsletter, "WA Fruit Grower", in October 2004. The WA Fruit Growers' Association produces "WA Fruit Grower", featuring management and marketing articles on pomefruit, stonefruit and citrus. Half and quarter page advertisements from chemical companies, nurseries and packaging companies feature regularly. Advertising in the newsletter was free for the WA Department of Agriculture and Food. The advertisement in the form of a written column attracted only 10 citrus growers. Subsequent to this rather than advertising in grower newsletters or local rural newspapers, advertising was made directly through CITTgroups.

3.2.2 Getting the message across

The failure of farmers to adopt new technologies using old approaches to extension has resulted in a shift to group empowerment, or the 'bottom up' approach. The bottom up approach recognises that farmers have specific knowledge and skills, and that by involving farmers in research and extension, changes are more likely to occur since farmers 'own the project' (Black 2000; Murray 2000). CITTGroups for example, are based on the bottom up approach. In developing an IPM workshop, it was thus important to use and develop preexisting knowledge. Attention was also paid to the way that adults learn. A review by Black (2000) of agricultural extension programs in Australia indicates that most farmers prefer project based/hands on learning, and watching, listening and asking questions to reading. This suggests that most farmers use concrete experience and reflective observation in their approach to learning (Kolb & Fry 1975). A range of different activities were thus included in the workshops to accommodate different learning methods and thus engage all growers (Appendix 5).

Two workshops lasting 2-3 hours, one month apart with small groups (6-8 people) were selected as the most appropriate delivery method. Resources such as microscopes and books limit group size; funding limited workshops to areas near Perth (north and south CITTGroups only).

Growers who successfully complete the two workshops should be able to:

- State the aim of IPM programs without referring to a resource e.g. book;
- Draw a plan of their orchard and determine how many different areas need to be sampled (using reference materials);
- Demonstrate the use of a hand lens correctly;
- Identify the main insect pests and beneficials present in the local area using information guides;
- Determine the species of beneficial insect required for release against a particular pest using information sources (handout, book, internet);
- Demonstrate how to release beneficials in the orchard;
- Determine if any action needs to be taken using information sources (handout, book, internet);

- Demonstrate their awareness of the limitations of using biological control and pesticides.

IPM Manual

An IPM manual was developed for the workshop, consisting of articles on how to monitor, why growers need to monitor, what pests to look for and where and when to look, as well as more detailed information on important pests of citrus in the form of farmnotes (Appendix 6). All material was contained within an A4 file so that information could be added to the manual as new or updated information became available. Growers were also given a 10X hand lens for insect identification.

3.2.3 Workshop Evaluation

The aims of these workshops were to encourage growers to use IPM in their orchards. Since a change in grower skills and management practice is the ultimate goal, a pre and post evaluation had been planned. However, owing to time constraints on the project, only pre-evaluation was carried out. Growers were evaluated using a one-page questionnaire at the end of the first workshop (Appendix 4).

Of the ten questionnaires returned by growers attending the workshop, three had some knowledge of what was meant by an IPM program. Further workshops and informal testing of growers (e.g. by asking them to identify pests) is clearly required.

4. Acknowledgements

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The following people kindly allowed permission to use photographs from their collections: Chris Freebairn (QDPI), Marilyn Steiner (NSW Agriculture); Jack Kelly Clark and Larry Strand (California Statewide IPM Project; University of California), and David Cousins (WA Dept. Agriculture & Food).

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6. Appendices

Appendix 1: Assessing parasitism rates for red scale

- Collect 20 infested fruit at random from a block for assessment.
- Examine **100** female scale. Record the following data for each scale examined.

Unparasitised scale		Parasitised scale	
Live	Dead	Active	Emerged
Unmated		*Aphytis*	
		Emerged	
		Live	
		Parasitised	
Σ= (u)		Σ= (a)	
Mated		*Comperiella*	
		Live	
		Parasitised	
Σ= (m)		Σ= (c)	
Σ(u+m)= (l)	Σ = (d)	Σ(a+c)= (l)	Σ = (e)

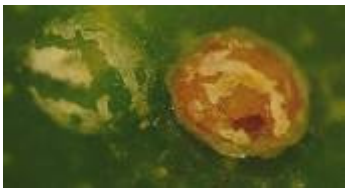
Totals		
Total scales sampled = (l+d+p+e)=		(t)
Live scale = (l/t) x 100 =		%
Aphytis parasitism = a/(a+u) x 100 =		%
Comperiella parasitisim = c/(c+m) x 100 =		%
Total parasitism = p/(p+1) x 100 =		%

Step 1: **Male or female?** determine if the scale is male or female. Male scales have an elongated scale cover, females are round. Disregard any male scales.

Step 2: **Mated or unmated?** determine if the females are mated or unmated. Unmated female red scale can be distinguished from unmated scale by the attachment of the scale cover. Using a pin, insert it carefully under the scale cover and try to lift it off. If it lifts off it is an unmated female, if it does not then it is a mated female.

Male red scale

Step 3: is the scale live or has it been parasitised? Can you see any emergence holes? Are there any larvae attached to the body of the scale? Are there any pupae present under the scale cover? (see figure right)


Mated female – cover & body are joined

Step 4: if larvae are present are they *Aphytis* or *Comperiella*? You can determine this from the colouration of the pupae. *Aphytis melinus* pupae are pigmented only in the thoracic area; *Comperiella* have black pupae.

Step 5: Sum all the data.

Step 6: parasitism levels should be 20% or more early in the season and 50% by autumn.


Mated female scale – the cover is attached to the body

Appendix 2: WA Citrus Orchard Management Practice Survey

1. Irrigation management

1.1 How do you decide when to water and how much to apply?

1. Set program	2. Depends on the weather	3. Evaporation	4. Soil moisture monitoring	5. Other _____

1.2 Does this change during the season? Please answer yes or no.

Yes No

1.3 Has your practice changed over the past few years?

Yes No

1.4 If yes, why did you make a change?

1. to save money	2. to improve quality	3. to improve yields	4. to reduce impact on the environment	5. Any other reason? _____

1.5 If you have made a change, where did you get the information to make that change?

1. Irrigation supplier	2. Neighbours or other growers	3. Department of Agriculture	4. Cittgroups (Improvement Groups)	5. Any other source? _____

1.6 Would you like more information on irrigation management?

Yes No

2, Nutrition management

2.1 How do you decide when to fertilise and how much to apply?

1. By a set program	2. Based on past experience	3. Based on soil or leaf analysis report	4. Based on a program from consultant	5. Other _____

2.2 Has your practice changed over the past few years?

Yes No

2.3 If yes, why did you make a change?

1. to save money	2. to improve quality	3. to improve yields	4. to reduce impact on the environment	5. Other _____

2.4 If yes, where did you get the information to make a change?

1. fertiliser supplier	2. Neighbours or other growers	3. Department of Agriculture	4. Cittgroups	5. Other _____

2.5 Would you like more information on Nutrition Management?

2.6

Yes No

3. Pest management

3.1 From the list below, what pests are problems in your orchard?

1. Mediterranean Fruit Fly	2. Scale Insects	3. Leaf miner	4. Snails	5. Thrips
6. Mites	7. Moths, grubs etc	8. Ants	9. Other _____	

3.2 In general terms, how do you manage these pests and diseases?

1. No real management strategy	2. Set Spray Program based on experience, calendar or crop stage	3. Monitor in orchard and spray as required	4. Use an Integrated Pest Management approach	5. Other _____

3.3 Have you released beneficial insects into your orchard?

Yes No

3.4 Has your pest management changed over the past few years?

Yes No

3.5 If yes, why did you make a change?

1. to save money	2. to improve quality	3. to improve yields	4. to reduce impact on the environment	5. Other _____

3.6 If you have made a change, where did you get the information?

1. Chemical supplier	2. Neighbours or other growers	3. Department of Agriculture	4. Cittgroups (Improvement Groups)	5. Other _____

3.7 Would you like more information on Pest and Disease Management?

4. Watermark on imperial mandarin

4.1 Do you grow Imperial Mandarins? If no, go to Q5

Yes No

4.2 Have you ever experienced problems with the disorder locally known as Watermark?

Yes No

4.3 What steps (if any) do you take to reduce the disorder?

_____

4.3 Has your practice changed over the past few years?

Yes No

4.5 If yes, what change have you made?

_____

4.6 If you have made a change, where did you get the information?

1. Local Stockist	2. Neighbours and other growers	3. Department of Agriculture	4. Cittgroups (Improvement Groups)	5. Other _____

4.7 Would you like more information on reducing Watermark on Imperial Mandarin?

Yes No

5. Environmental management

5.1 On a scale of 1 to 5, how do you rate your orchard in terms of environmental impact?

1. No impact on the environment	2. Minimal impact	3. Some impact	4. Serious impact	5. Environmental disaster

5.2 On a scale of 1 to 5, how do you rate your knowledge of Environmental Management Systems (EMS) or EurepGap?

1. Never heard of it	2. Very Limited Understanding	3. Basic Understanding	4. Good Understanding	5. Total Understanding

5.3 In your opinion, which (if any) of the following orchard practices pose a risk to the environment?

1. Irrigation 2. Fertilisers 3. Chemical sprays 4. Waste management 5. Other _____

5.4 Do you believe that current best management practices minimise environmental impact?

Yes No

5.5 Would you like more information on Environmental Management?

Yes No

6. OTHER ISSUES: Would you like to highlight any other issues important to the WA Citrus Industry?

_____
_____
_____
_____

Name (optional): _____

Appendix 3: Different instructional methods used in the workshop, including relative effectiveness of each method.

	Source	Doing	Observing	Relative effectiveness*/notes
DIRECT	Original data & sources	Draw property map; list pests & beneficials in orchard. Resource: sampling sheet.		6. Student centred. Project carried out at home and brought to workshop.
		Scout property for pests. Resource: magnifying lens, data sheets	Demonstration on how to scout	6. Initially teacher centred for instructional purposes, shifting to student centred. Can be done individually or in pairs.
		Collecting insects for ID. Resource: ute guide	Demonstration on how to use book to identify insects Resource: book, microscopes, lens	6. Initially teacher centred for instructional purposes, shifting to student centred. Can be done individually or in pairs.
INDIRECT	Secondary data & sources Lectures, books		Lecture - kept to a minimum (what is IPM)/workbook Resource: workbook	2. Teacher centred but required to deliver information. Can be more active if students state experience with using IPM, write things down in workbook.
		Case studies - S. Kay's use of *Aphytis* to control red scale		4. Can be more active if students relate story to their own experience.
			Story (DVD on IPM)	4. Can make more active by students/teacher asking questions.
ONLINE	Internet	Use internet to aid in ID of insects		4. Teacher centred since access to internet unlikely. More active by students trying out task at home (if they have internet access!).

* relative effectiveness rating derived from Rogers 1998, p. 182; 6 being high, 2 being low).

Appendix 4: Workshop Questionnaire

Questionnaire

Name: _____

Orchard: _____

1. What IPM techniques do you currently use? Please circle one or more.

Monitoring for pests Pick fruit before pest becomes a problem	Release beneficials Use action thresholds in citrus guide to determine whether control is needed	Use IPM-friendly pesticides	Use horticultural oils

2. What are your main insect pests? Please select from list below. If pest is not on list, please add under 'other'

	Level of occurrence				Level of importance				Difficulty to control			
Pest	never	some	often	always	none	low	med	high	none	low	med	high
Red scale												
Brown scale												
Black scale												
Medfly												
Citrus leaf miner												
Mealybug												
Thrips												
Snails												
Other												

3. What do you think the main aim of IPM is?

_____

_____

Appendix 5: IPM Workshop Outline

Day 1

tea and coffee Start (on time!)

Introduction

- explanation of what will happen - a quick look at the workbook.
- why the workshop is being held, what the format of the workshop is statement of flexibility to accommodate needs expressed by group.

IPM - what is it?

- Topic key points (essential elements of IPM) and management options are presented
- Key Points are presented visually using multimedia
- Slides/specimens to illustrate and reinforce key points
- Use of anecdotes
- Question Time (limited)

Monitoring

- Topic key points (why monitor)
- Key Points are presented visually using multimedia
- Slides/specimens to illustrate and reinforce key points
- Workbook - how to use datasheets

Fieldwork

- go out and sample orchard for pests, learn how to use hand lens for ID, collect insects

Identification

- Use of Citrus guide (Smith *et al.* 1979), ute book and other materials (world-wide web) to identify specimens.
- Compile list of pests and beneficials for the area

Group Discussion

- Are these pests a problem (use action thresholds in Citrus Guide)
- How would you control them?
- Use book to determine what IPM methods can be used to control pests.

Biological Control

- Topic key points (what is it?)
- Key Points are presented visually using multimedia
- Slides/specimens to illustrate and reinforce key points

- Workbook - what beneficials are available commercially? When should they be released?
- DVD (Natural enemies)

Case study

- Shane Kay at Bindoon - using Aphytis for control of red scale

Evaluation

Wrap up

What do they do now (in terms of managing pests)?

What might they consider changing (after hearing about IPM options presented during the session)?

What do they actually need to do (in order to implement this change)?

Presenters and other participants are encouraged to discuss and question findings so that the group becomes comfortable in using these options for adoption in their orchard.

Day 2

tea and coffee Start (on time!)

Further discussions take place to identify, clarify, and propose management practices to deal with regional issues. Growers are given the opportunity to bring along insects to identify.

Fieldwork

Growers go out and sample orchard for pests, demonstrate how to use hand lens for ID, collect insects

Identification

- Use of Citrus guide, utebook and other materials (world-wide web) to identify specimens.
- Compile list of pests and beneficials for the area.
- Are these pests a problem (use action thresholds in Citrus Guide)

Group Discussion

- How would you control these pests?
- What IPM strategies can be used?

Biological control

Field work - release beneficials into the orchard.

Demonstration on techniques used to determine parasitism in field and lab.

Chemical control

- Topic key points (what is it?) How are insects killed? Insecticide groups.
- Key Points are presented visually using multimedia
- Slides/specimens to illustrate and reinforce key points

- Changes in pesticide use (increasing rather than decreasing)
- New pesticides being used that are IPM compatible

Group discussion

- Have they made any changes to their practice since the last workshop (in terms of managing pests)?
- What might they consider changing (after hearing about other grower's experience with using IPM)?
- What do they actually need to do (in order to implement this change)?

Evaluation

Appendix 6: Sample pages from the IPM book.

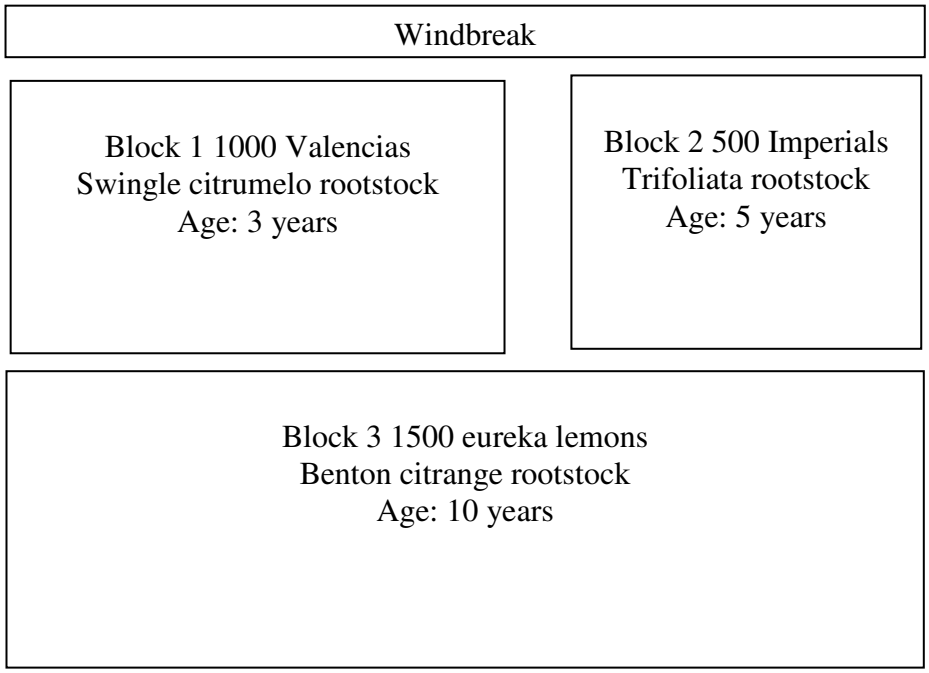
6.1 IPM Guide: Why should I monitor?

- Most of the insect pests found in WA citrus orchards can be controlled using either natural enemies (releasing parasites or predators) or spraying with petroleum oils.
- By monitoring your orchard, you can determine when, and if you need to take any action.

Starting a monitoring program

- Make a map of your orchard.
- Include details such as the number of trees, rootstock and planting date of each block.
- A block is usually composed of trees of the same variety, rootstock and age, on the same soil type, and is treated and sprayed as a unit.

Example of an orchard map



- Decide how many trees you need to sample per block. This will vary with the size of the block and the amount of time that you have to sample.

Table 1: The number of trees to sample depends on block size

# trees per block	Area (Hectares)	# trees sampled
0-500	<2	10
501-705	2-3	12
751-1000	3-4	15
1001-2000	4-8	20

When do I monitor?

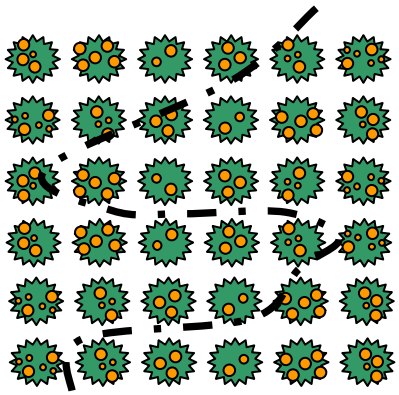
- Morning is the best time to **monitor** for insects since this is when they are least active and most likely to be seen.
- Some insects such as scale don't move about and can be found in the same spot throughout the day.

How often do I monitor?

- How often you monitor will depend on the time of year and the level of pest activity. Pest activity is seasonal; insects are more active from spring to autumn.
- The stage of development of the crop will also influence insect activity. For example, citrus leaf-miner attack young leaves.
- During high-risk periods e.g. flowering, fruit set, and as fruit is ripening, monitor every 3-7 days.
- As a minimum, sample at least once every 14 days until you know what pests are present and when.

How do I sample?

- Sampling must be random. Do not choose the same trees to sample every time, unless there is a good reason to do so. For example, if a particular area in the block has a history of being attacked by thrips. Even then, choose other trees to sample as well.
- The easiest way to randomly sample is to walk through the block on a diagonal, or on a zig-zag (see diagram right).
- Start at a new point each time that you monitor.
- Avoid sampling small or unhealthy trees as these will give you a biased sample.
- Avoid sampling border rows as these will also give you a biased sample.



Which parts of the tree need to be sampled?

- The parts of the tree that are sampled are called 'units'. Units can consist of a fruit, a branch etc.
- Which unit or units you sample depends on what pests are likely to be found at that time of year. For example, red scales are found on fruit as it matures, but at other times of the year, are found on the leaves or branches.
- Sample from four quadrants of the tree – north, south, east and west. Take the fifth sample from the middle of the tree where pests often shelter.

What do I sample for?

All trees:

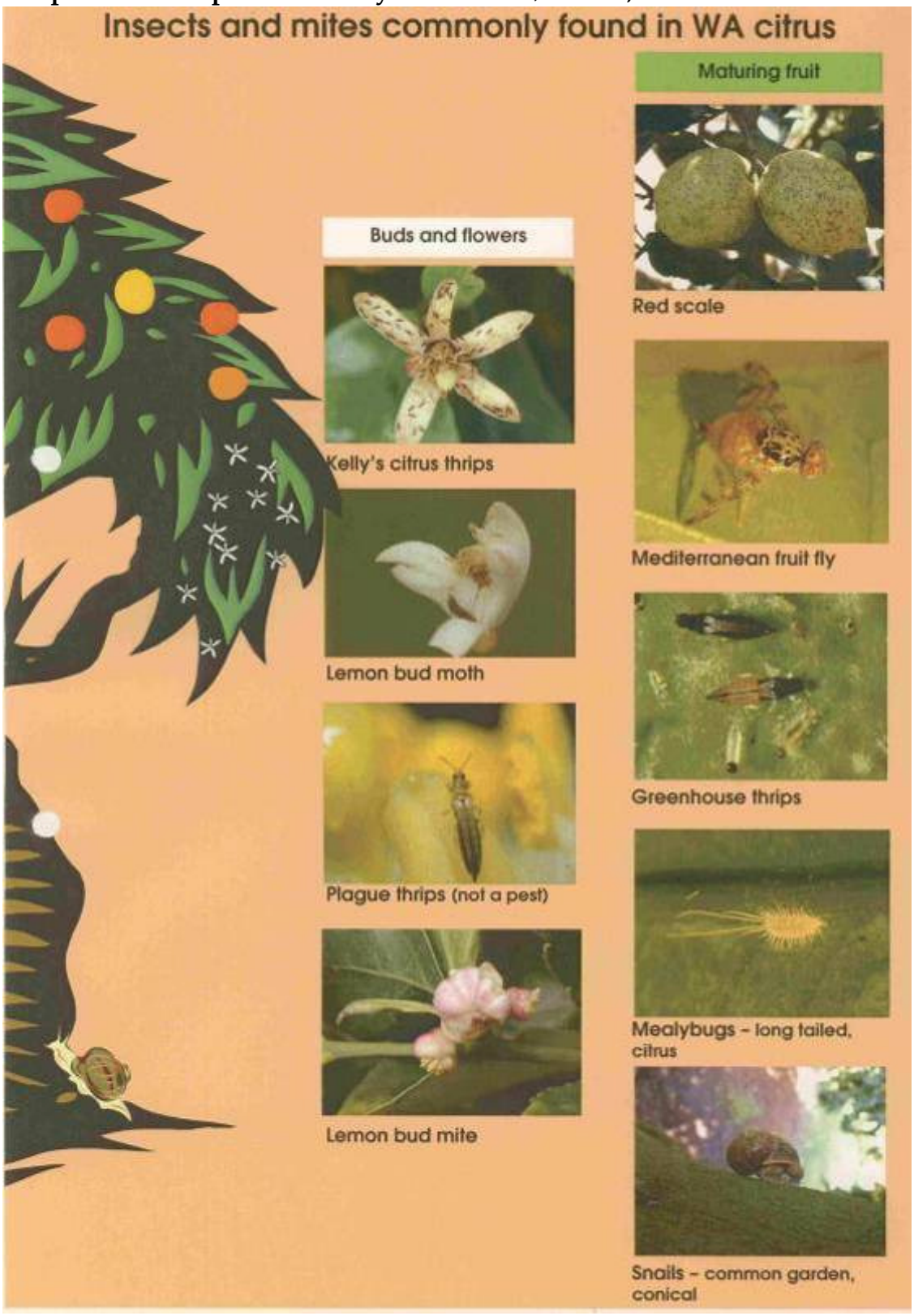
- Ants attending scales
- Beneficials (lacewings, ladybirds, mites, *Aphytis* on red scales)
- Mealybug
- Scales - Red scale, Soft brown scale, Hard Wax Scale (Chinese wax), White wax scale, black scale
- Snails
- Thrips
- Whiteflies

Young trees:
- Leafminers
- scales (soft brown, black)
- aphids.

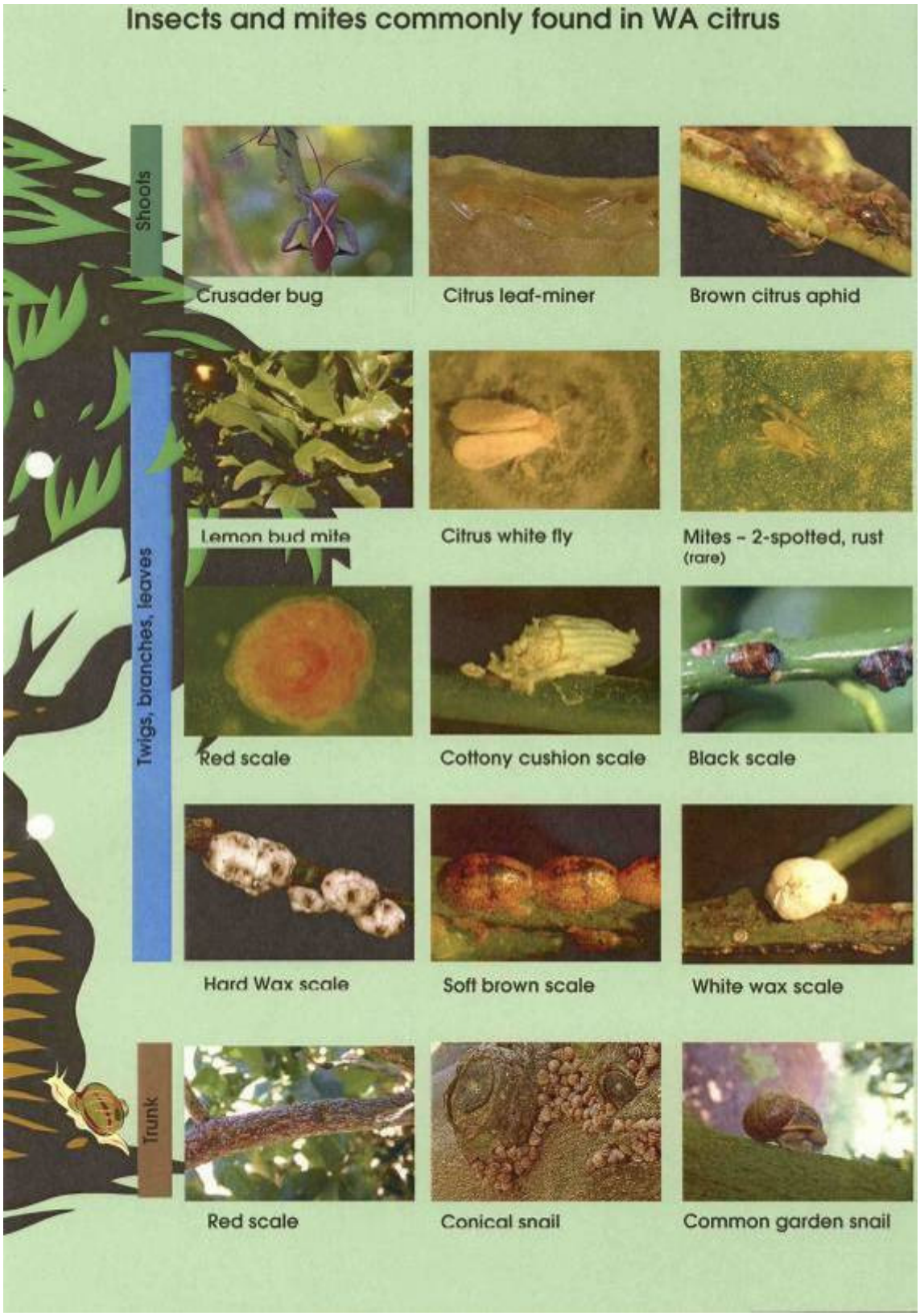
Recording data
- Data should be recorded each time you monitor. This can be done on either a sheet of paper or on a notebook. An example of a monitoring sheet is included in this kit.

Making a decision
- The level of infestation or damage at which some action must be taken to prevent an economic loss is referred to as the action level.
- Action levels for various pests are provided in "Citrus Pests and their natural enemies", by Smith *et al.* (1989) produced by QDPI. They are a guide only.
- If the action threshold has been exceeded, then there are several options available. These include releasing beneficials, application of oils or chemicals.
- If you decide to use a chemical, choose one that is least likely to harm natural enemies.

6.2 Insects and mites commonly found in WA citrus (used to show what to sample and what pests are likely to be found) – buds, flowers & fruit



6.3 Insects and mites commonly found in WA citrus (used to show what to sample and what pests are likely to be found) – trunk, leaves and branches etc.



6.4 Sampling sheets for growers (part of the IPM workbook)

SAMPLING SHEET

Brief description (e.g. flowering, fruit set size) **Date**

Block **Sampler**

tree #	red scale on fruit*					black scale	bud moth	bud mite	leaf miner		beneficials	Notes
	0	1-5	6-10	10-20	>20				old	l	p	
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
TOTALS												

e.g. 0 - No red scale on fruit
1-5 : 1-5 scale per fruit

Appendix 7: Extension Activities

Meetings/Conferences:

- November 19 2003, WACIG meeting/orchard walk – Wokalup Agricultural School. Survey results from 2003.
- December 2 2004, WAFGA, Perth Market Authority, Canningvale. IPM Project Update
- April 22 2004, National Research & Extension Meeting, Annual Citrus Conference, Mildura.
- December 16 2005, IPM project update. WAFGA, Perth Market Authority, Canningvale.
- March 27 2006, Presentation on IPM, 58th Annual Citrus Growers Conference, Field Day, Harvey.

Cittgroup workshops:

- September 10 2003, Carnarvon, Gascoyne Research Station. Presentation with Carl Childers (University of Florida).
- September 15 2003, Gingin, Bookine Orchard. Presentation and orchard walk with Carl Childers (University of Florida).
- October 21 2003, Bindoon, Shane Kay's Orchard. Presentation by James Altmann (Biological Services, Loxton, South Australia).
- October 22 2003, Burekup, Greycliffe Orchard. Presentation by James Altmann (Biological Services, Loxton, South Australia).
- May 12 2004, Harvey. Presentation by Angela Lush (SARDI) on snail monitoring and control.
- May 13 2004, Bindoon. Presentation by Angela Lush (SARDI) on snail monitoring and control.
- July 31 2004, Katherine NT. Citrus IPM. Joint presentation with Megan Connelly and Megan Hoskins (DBIRD).
- August 1 2004, Kununurra. Citrus IPM. Joint presentation with Megan Connelly (DBIRD).
- November 4 2004, Gingin, Sandgroper. Monitoring and identification of pests in the orchard.
- November 2005, IPM workshop. Niela Citrus, Bindoon.
- December 2005, IPM workshop. WA College of Agriculture, Wokalup.
- May 23 2006, Mediterranean fruit fly control, Apricot Acres, Bindoon.
- May 24 2006, Mediterranean fruit fly control, Wokalup Research Station.

Articles:

- February 2003, Unbalancing scale, WA Fruit Grower, Issue 68, pg. 6.
- May 2003, pg. 6 Insect Onside, WA Fruit Grower, February 2003, Issue 71, pgs. 6, 8.
- August 2003, Bugs experts visit, WA Fruit Grower, August 2003, Issue 74, pg. 7.
- October 2003, red alert to tip scales, WA Fruit Grower, Issue 76, pg. 4.
- November 2003, Growers swarm to IPM, WA Fruit Grower, Issue 77, pg. 8.
- December 2003, Harvey Highlights, WA Fruit Grower, Issue 78, pg. 6.
- March 2005, Pest section of WA Citrus production calendar.

- December 2005/January 2006, IPM scales down pests in WA. Citrus Insight, Vol. 81, pg. 30.
- April 2006, Citrus industry looks to the future, WA Fruit Grower, Issue 106, pgs. 1,2,7.

Appendix 7.1. Articles

Citrus Council

by Greg Beales Chairman

I was extremely sad to hear of Ray Owen's recent passing. He was the only West Australian to be Australian Citrus Growers President, while 24 years as Citrus Council Chairman speaks for itself.

On behalf of the Citrus Council, our deepest sympathy to son Ric and the Owen family.

Good Crop

With the new season and good crops likely, growers should concentrate on fruit size and quality. We've come a long way in the past seven years, but must continue our evolution if we are to continue as a viable and sustainable industry.

Large Production

The National Conference in Leeton, NSW, this April shapes as a great opportunity for growers to learn more about growing, marketing and promoting their product.

The Leeton/Griffiths area is one of Australia's largest citrus producing areas.

The conference and associated field days will be an excellent opportunity to mix with the larger growers of this region.

Interstate and overseas speakers will also be a fountain of information. For details on how to get in on the act, contact WAFGA, Tel 9455 2075, Gavin Foord, Tel 9368 3551 or myself, Tel 9571 8070.

Familiar Problem

American navel orange growers are having a familiar problem selling fruit, with prices ranging from $A22 for large counts and $A9 for the smaller counts.

Monkey Business

While local quarantine officials pour through luggage and consignments to identify sometimes microscopic threats to Australian agricultural industries, a story from the United States (US) reminds us that quarantine breaches are not always hard to spot.

When US customs officials at Los Angeles airport opened Californian, Robert Cusack's suitcase in June last year, a bird of paradise flew out. But that was nothing compared to what they found in his pants. Last December, Mr Cusack was sentenced to 57 days jail for trying to smuggle four exotic birds, 50 rare orchids and two live monkeys from Indonesia and Thailand. Most surprising was that he did not keep his tricks up his sleeve at all. Rather, he kept them up his trouser leg.

According to the Australian Quarantine and Inspection Service Bulletin, Assistant US Attorney, Joseph Johns said Mr Cusack was undergoing a routine inspection until an official opened his suitcase, freeing a bird of paradise which took off in the terminal. The agents found three more birds in his bag, tucked into nylon stockings, along with 50 orchids of a threatened species. When asked by the agents if he had anything else to tell them, Mr Cusack replied, "Yes, I've got monkeys in my pants."

Besides his prison term, Mr Cusack was ordered to pay $A26,500 in restitution.

Unbalancing Scale

Enjoying the New Year after their January introduction are new WA residents, the soft brown scale parasites, *Metaphycus luteolus*.

A very efficient parasite of soft brown scale, *M. luteolus* was imported from California. The WA release, co-ordinated by Department of Agriculture entomologist, Sonya Broughton, is part of a national project instigated by Biological Services of Loxton, SA and funded by industry and Horticulture Australia.

Releases at Bindoon, Gingin, Harvey and Burekup will be repeated monthly at each site, with Dr Broughton checking to see that the parasites have established. Where practical, releases will be advertised so local growers can attend and learn more about the project and beneficial release techniques.

Department of Agriculture entomologist, Dr Sonya Broughton, releases WA's newest parasite at Bindoon, while grower, Shane Kay, looks on.

US and Them

It was a pleasing 2002 United States (US) export season according to Australian Citrus Growers President, Peter Davidson.

More navel oranges were exported and higher prices were received for nearly all counts, despite a challenging season which included small size, blemish, a late start, a stronger Australian dollar and US wharf disputes.

Mr Davidson attributed much of the success to the orderly marketing arrangements ACG has maintained since the US market was accessed in 1992. Under Commonwealth Export Control Power legislation, a single importer/marketer, DNE World Fruit Sales, has managed the Australian citrus program into the US.

Insect onside, WA Fruit Grower, Issue 71, May 2003, pg. 6

Citrus Council Report

by Greg Beales Chairman Citrus Council

As Citrus Council Chairman and a Director of Australian Citrus Growers, I endorse the proposed increase in research and development and marketing levies and urge growers to attend a meeting to discuss associated issues (*see Finding Funding Fit for Levies, front page*).

The meeting, at the Conference Room, Market City, Canning Vale, from 10am on Tuesday, June 10, will allow local growers to register their views on the increase and examine plans for the extra funds.

At the meeting will be:

- Peter Davidson – President, Australian Citrus Growers.
- Gerard McEvilly – Senior Program Manager, Horticulture Australia Ltd.
- John Pritchard – Industry Promotions Manager, Queensland Fruit and Vegetable Growers.

Before the meeting there will be a tour of Market City, from 8.30am. For further information, contact myself, Tel 9571 8070 or WAFGA, Tel 9455 2075.

Insect Onside

Citrus growers are putting beneficial insects to good use at Carnarvon, according to Department of Agriculture citrus entomologist, Sonya Broughton.

After surveying orchards around 'the river' during a pre-Easter trip, Dr Broughton revealed the opportunities to extend integrated pest management in the region. Her presentation, at the Department's Function Centre, identified Carnarvon's pests and beneficial insects and allowed local growers to see insect pests, parasites and predators at work in the orchard and under the microscope.

Releasing Beneficials

"Many growers have been releasing 'beneficials' for some time," Dr Broughton said.

"It was good to find Lacewings (a general predator) established on most properties and Cryptolaemus (mealy bug predator) during the survey."

It was also encouraging that none of the visited properties used broad spectrum insecticides.

"Current practice at Carnarvon is to use the occasional oil spray for scale and leaf miner control and regularly release beneficials," Dr Broughton noted.

Growers have noticed the less they spray, the less they have to spray and predators and parasites are keeping the major pests under control.

Recommended Releases

While most of the pests found at Carnarvon occurred in low numbers, several measures were recommended to keep it that way, including:

- Releasing *Aphytis lignanensis* for Red Scale.

contd on back page

Insect onside (continued), WA Fruit Grower Issue 71, May 2003, pg. 8

WAFGA President's View

by Steve Dilley
President WAFGA

A recent joint media statement from Premier, Geoff Gallop and Consumer and Employment Protection Minister, John Kobelke saying there would be a *'major crackdown on dangerous work sites and dodgy bosses'* is clear evidence that the issue of work place safety will remain high on the State Government's agenda.

A further $6.6 million will be spent over the next four years to fund 20 extra WorkSafe inspectors.

While everyone would agree that *'WA workers have a fundamental right to return home safe and healthy at the end of a day's work'*, I took offence to the implication that *'the days of hazardous workplaces and dodgy bosses who put profit before the safety and health of their workers are fast drawing to a close'*.

Consuming Business

The statement may have been aimed at crane and tilt-up construction industries, but I wonder if the Premier or Minister is aware that many employers, such as primary producers, are consumed with business survival before considering what to do with any profits.

I hope the WorkSafe Commission heeds past calls for inspectors to have a practical knowledge of the industries they inspect.

Exposing Hazards

The increasing focus on occupational health and safety will continue to affect the fruit industry and growers do have a 'duty of care' to prevent exposing employees to workplace hazards.

Although no grower (employer) could viably follow duty of care requirements to the letter of the law, if a workplace accident occurred, you would need to demonstrate your duty of care to WorkSafe and your insurance company.

If you couldn't, you would probably be prosecuted by WorkSafe and abandoned by your insurance company to face legal repercussions alone.

Fitting Scenario

This scenario also fits with the new regulations for Elevating Work Platforms (EWPs), effective from August 1. Under duty of care, growers must prove they have operated, inspected and maintained their EWPs according to one of these regulations:

1. Manufacturer or designer instructions.
2. Instructions approved by the WorkSafe Commissioner.
3. Instructions as outlined in Australian Standard 2550.

If operating tractors without rollover protection structures or seatbelts, then you are legally exposed. If your forklift operators don't have the appropriate license, you are legally exposed, and the list goes on.

Alarming Perspective

While the type of legal liability may seem alarming, keep it in perspective. The reality is that nearly every WA business would be legally exposed to some degree if a workplace accident occurred.

Remember, you have nothing to fear about legal liability, unless you have a workplace accident. The key to avoiding liability is to assess the risks, make the appropriate changes and continue to minimise the chance of an accident occurring.

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Insect Onside

continued from page 6

According to Department of Agriculture entomologist, Dr Sonya Broughton, there is a good population of Lacewings in Carnarvon.

- Releasing *Leptomastix dactylopii* (mealybug parasite) and continuing with releases of *Cryptolaemus montrouzeiri* and green lacewings (predators) for Mealybug.
- Releasing southern WA parasites (if required) for Citrus leaf miner.

Further research is required to determine the pest status of other insects and to investigate appropriate ant control methods.

Northern Zone Annual General Meeting

WAFGA's Northern Zone AGM is on Wednesday, June 11 at Rocco's Golden Grove.

This is the last chance for members to present motionsfor inclusion in WAFGA's Annual Conference.

Bug experts visit, WA Fruit Grower, Issue 74, August 2003, pg. 7.

Nippy Decision

Nippy's fruit juice company has been awarded $3 million in damages after the Australian Federal Court decided salmonella bacteria found in their product was the fault of the supplying growers.

A March, 1999 salmonella outbreak left many Nippy's customers ill and 300 subsequently brought a class action against the company.

According to ABC Radio, Justice Selway found that Riverland fruit growers had supplied fruit infected with salmonella to a supply chain that led to Nippy's.

The judge found that they had breached their contract to supply fruit fit for sale.

Bug Experts Visit

WA will come under the microscope of two eminent citrus researchers during September.

Carl Childers from the Lake Alfred Citrus Research & Education Centre, University of Florida, is a world-renowned citrus thrip and mite specialist and will visit Australia in September to sample mites in Queensland, WA and SA.

By sampling mite fauna and their behaviour, Professor Childers hopes to improve integrated pest management (IPM). WA is believed to host at least two species of predacious mites that could provide beneficial biological control of eriophyid mites in Florida citrus.

Professor Childers and Department of Agriculture entomologist, Dr Sonya Broughton (pictured), will visit Carnarvon on September 11, Gingin on September 15 and Harvey on September 17.

James Altman from Biological Services, South Australia, will also visit WA during September.

He will inspect trial sites with citrus Industry Development Officer, Gavin Foord, to determine if releases of Metaphycus luteolus (a soft brown scale parasite) have established successfully. Mr Altman will also attend a series of meetings to discuss IPM.

For more information, contact Dr Broughton, Tel 9368 3271 or Mob 0429 378 392.

SQF Safely Transferred

Ownership and administration of the global food quality certification marque, 'Safe Quality Food' (SQF), has transferred to the international network of food wholesalers and retailers known as the Food Marketing Institute (FMI).

SQF, which had been managed in WA by the Department of Agriculture, has 3300 certifications in 16 countries.

Being a not-for-profit industry organisation with an international membership of 200 companies from 60 countries and representing a significant portion of global food production, FMI was selected as the most suitable owner of SQF according to the Department's Ian Longson.

Suitable Candidate

While FMI will manage SQF globally, it appointed an Australian representative after liaising with the Department to identify a suitable candidate. Graham McAlpine (pictured) and John Noonan have linked with the commercial arm of Curtin University, Curtin Consultancy Services, to fill the role.

The Department will maintain a seat on the SQF Advisory Board.

FMI President and CEO, Tim Hammonds, believes the ongoing globalisation of SQF is good for retailers and producers.

Eliminate Audits

"This system will enable suppliers to reduce costs and gain efficiencies through an internationally recognised system that eliminates audit duplication. Retailers can select suppliers who have been SQF audited and certified," he said.

Graham McAlpine

"Bagging prize W.A. fruit may not be as dangerous as shooting lions, old chap, but it's infinitely more healthy."

— 7 —

Red alert to tip scales, WA Fruit Grower, Issue 76, October 2003, pg. 4.

Apple & Pear Report

by Vick Grozotis Chairman Apple and Pear Council

Give people what they want.

Consumer research conducted through Horticulture Australia is delivering clear messages about preferred apple and pear qualities.

The survey, of more than 1200 people across Australia, identified taste, crispness and firmness as the three most important characteristics when selecting apples, while taste, juiciness and sweetness ranked highest for pears.

Flavour Paramount

The study will not be completed until early 2004, but these early results indicate that eating qualities and flavour are paramount, not colour, size or price.

The survey has found that variable quality makes it difficult for consumers to consistently select good fruit. Other concerns centered around shelf life after purchase, level of chemical inputs and perception that fruit 'doesn't taste like it used to'.

The Apple and Pear Council (APC) is reviewing promotions for the next 12 months and hopes to address these issues through the campaign.

Codling Traps

The APC has agreed to support the codling moth surveillance program for 2003/04 and is considering incorporating surveillance for other pests and/or pathogens into the program. Codling moth traps should be available in November.

Pink Lady

The Australian Fresh Fruit Company recently held its Pink Lady Australia Technical Day in Melbourne. It was disappointing that the information was presented so far from WA, which supplied 70% of Pink Lady exports this season and is home to the major growers.

We'll work to get the relevant information to growers in the next issue of *WA Fruit Grower*.

Red Alert to Tip Scales

Chemicals alone will not control red scale, which develops resistance to most synthetic pesticides.

Red scale pesticides are also often associated with secondary pest outbreaks such as two spotted mite and rust mite.

The most effective red scale control strategy combines the release of *Aphytis* (red scale parasite) with judicious use of oil sprays.

Releasing Aphytis

Releases should commence in spring (mid-October or earlier). *Aphytis* will only attack immature red scale, so first ensure immature stages are present.

Monitor red scale and parasitism levels in December to decide

cont'd on page 7

Aphytis lignanensis laying an egg into a red scale.

Red scale fruit damage.

Growers swarm to IPM, WA Fruit Grower, Issue 77, November 2003, pg. 8.

WAFGA President's View

by Steve Dilley
President WAFGA

You may recall in last month's column that I mentioned a proposed state-wide Rural Water Users' Summit scheduled for Nannup on December 11. The agenda has now been finalised and the day will proceed as planned.

In a coup, the organising committee has secured Deputy Prime Minister, John Anderson to deliver the keynote address. He is a strong advocate for the recognition of property rights and water resource security and is the driver behind the Council of Australian Governments (COAG) agreement to refresh its 1994 water reform agenda.

The fundamental importance of security of tenure over on-farm water resources is common to all landholders, regardless of which State or Territory they're from.

Water Banker

Mr Anderson's address should remind the State Government of its responsibility to the COAG agreement and the development of a national water initiative.

Stephen Carroll from the Australian Bankers' Association will outline the reluctance of lending institutions to provide long term loans to farmers who only have water license tenures for short periods.

Other presentations will include water property rights from a WA perspective and State Government regulation and consultation.

Unrealistic Estimates

A 'Future Rural Water Needs' session, which will paint a realistic picture of water use in the next 10 years, from a mining, population and irrigated agriculture perspective, should redress some of the unrealistic estimates that appear in the Government's State Water Strategy.

The final session includes presentations on local water management, irrigation co-operatives and the real cost of water from a food production perspective. Please reserve Thursday, December 11 and make the effort to be in Nannup.

This summit is the best opportunity we've had to unite with other industries and regions and send a clear message to current and future State Governments that we have rights and expect consultative and equitable decisions.

All Aboard

A bus will depart the WAFGA office at 6am on Thursday, December 11 for those wishing to attend from Perth growing regions. If you have any queries, contact WAFGA, Tel 9455 2075.

For catering purposes, growers must inform the Nannup Shire (Tel 9756 1018) that they will be attending.

Finally, a happy Christmas and New Year to all.

Christmas Zone Meetings

WAFGA's South West and Northern Zones are holding their final meetings for 2003 during December. Please see below for details and support your Zone.

South West Zone

The South West Zone will meet from 7.30pm on Tuesday, December 9 at **CWA Hall, Bentley St, Donnybrook.**

There will be apple and pear, summer fruit and citrus reports, plus general business.

For enquiries, please contact Peter Gubler, Tel 9764 1132.

Northern Zone

The Northern Zone will meet for Christmas dinner and their final meeting of 2003 from 6.30pm on Wednesday, December 10 at **Rocco's Golden Grove.**

Northern Zone growers are encouraged to attend and share a Christmas dinner with their colleagues.

For enquiries, please contact Shane Kay, Tel 9576 1093 or Helen Martin, Tel 9576 0390.

Growers Swarm to IPM

Dr Sonya Broughton and James Altman preparing samples and slides for their presentation at Bindoon.

Integrated pest management (IPM) featured again in October, with a visit from SA specialist James Altman of Biological Services and Fruit Doctors.

Mr Altman was accompanied by Sonya Broughton and David Cousins of the Department of Agriculture as he sampled scale insects from citrus orchards at Gingin, Bindoon, Harvey and Burekup. His visit included monitoring for the successful establishment of the soft brown scale parasite, Metaphycus luteolus.

Thirty-five interested growers met the team at Bindoon and Burekup during October for an informative presentation on citrus IPM. As a result, Dr Broughton is now co-ordinating group releases of Aphytis melinus for red scale control.

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Harvey Highlights, WA Fruit Grower, Issue 78, December 2003, pg. 6.

Citrus Council Report

by Greg Beales Chairman Citrus Council

Citrus growers across Australia have, unfortunately, voted against the proposed increases to the national research and development (R&D) levy, which is matched by the Federal Government, and the marketing levy.

Of 658 ballot papers counted (representing almost one third of growers), 44% voted in favour of the R&D levy increase and around 38% in favour of the marketing levy increase. The vote was determined through a postal ballot independently conducted by the Victorian Electoral Commission.

Disappointing Result

As a Board member of Australian Citrus Growers (ACG), I agree with President, Peter Davidson who said that the ACG Board was disappointed with the result, but determined to uphold the wishes of the growers.

"It will now be extremely difficult to achieve specific outcomes and growth planned for through the national levy's five year investment plan, particularly with lower to average crop production estimated over the next two years," Mr Davidson said.

"Unfortunately our Industry Advisory Committee to Horticulture Australia will have the unenviable task of cutting back on some projects."

ACG will publish and distribute Citrus Insight, the annual report of the national citrus R&D and marketing levy funded programs in January 2004.

Strategic Plan

Growers were given the opportunity to contribute to the WA industry strategic plan during a December 5 meeting. With the national citrus plantings database being compiled and new developments in the pipeline, now is probably not the time to make radical changes. However, outcomes from this meeting will update the current plan. By mid-2004, with a better understanding of current and planned plantings, we will be better placed to develop longer term strategies.

Citrus' Scintillating Secrets

Citrus fruit is beginning to reveal a potent mix of healthy qualities.

CSIRO has completed a comprehensive literature review on citrus health benefits to discover its nutritional depth.

The research found that it contains hundreds of nutrients, including high levels of Vitamin C and substantial dietary fibre, beta-carotene and folic acid. It has a low ratio of sodium to potassium, is low in fat, nutrient dense and energy-dilute, with a low glycaemic index and it is rich in antioxidants. Citrus is also brimming with non-nutrient compounds called phytochemicals, which could help prevent a range of chronic health conditions, such as cancer and heart disease.

An orange has more than 170 different phytochemicals and more than 60 flavinoids, many of which added anti-inflammatory, anti-tumour and blood clot inhibiting properties to their anti-oxidant effect.

Season Ends Light

Australia will produce its lightest Valencia orange crop since 1973 after a recent revision to the Riverland's Valencia crop estimate.

Australian Valencia production peaked in the early 1990s at around 480,000 tonnes, but this season is estimated to nudge 195,000 t.

Australian Citrus Growers (ACG) President, Peter Davidson said a combination of factors was responsible, including the move away from juicing oranges to Navel oranges and mandarins, targeted at fresh export and domestic markets. However adverse climatic conditions during fruit set and development was the main cause for the modest crop.

Harvey Highlights

WA's Citrus Improvement Group (WACIG) held a successful AGM in association with the Department of Agriculture's project update at Harvey during November, attracting 25 citrus growers from Bindoon to Burekup.

Growers north of Perth were offered transport from Canning Vale. Activity updates and a field day booklet were provided by the Department's Gavin Foord, Kevin Lacey, Jo Blunn and Dr Sonya Broughton.

The tour included:

- A drive around the new Harvey dam.
- A tour of variety assessments and new plantings at the Wokalup campus of the WA College of Agriculture with orchard manager Ellice Foster.
- An overview of the college's Harvey campus from farm manager, David Hart.
- Lunch and WACIG AGM at the Harvey campus.
- An inspection of the Pergoliti's new plantings and packing facilities.

At the WACIG AGM, all previous members were returned. The committee is: Shane Kay of Bindoon, Janet Coniglio of West Gingin, Ruth and Geoff Fawcett of Serpentine, Shane Martin of Bindoon, John Marten of Gingin, Martin Hockey of West Gingin, Sandy Pate of Chittering Valley and Jim Johns of Harvey.

Kevin Lacey showed growers top-worked trees at Wokalup.

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Last chance to get on board with Foord, WA Fruit Grower, Issue 81, March 2004, pg. 5.

Last Chance To Get On Board With Foord

by Gavin Foord, Citrus IDO

This is the last call for those interested in joining a group from Adelaide for the 2004 Australian Citrus Growers annual conference and field days to be held at Mildura, Victoria from April 18 to 22.

A bus will depart Adelaide early Sunday, April 18 and return Friday, April 23.

As in previous years, participants will be responsible for their own air travel and conference registration (see February edition of Australian Citrus News for registration details).

There are still a couple of rooms at the Mildura Grand Hotel and overnight accommodation in Adelaide can be arranged if required.

For further details and to secure your seat on the bus, please contact the WAFGA office, Tel 08 9455 2075, as soon as possible.

2004 Plan

Meetings at Harvey and Chittering in February outlined an active program for citrus growers in 2004. With a basic framework to build on, many of the issues important to citrus production and the supply chain will be touched on in the coming year.

One of the calendar highlights is in April, when a group of growers will travel to the national citrus conference in Mildura. This should be a great opportunity to network and keep up with research and marketing information (see above to 'get on board').

Coming Up

Development Officer Jo Blunn has completed the first draft of the WA citrus production calendar, which will be presented to industry for comment at improvement group meetings in May. It should be available this winter.

Jo is also planning an activity to show how the retail development project is progressing. This will be held in our season, so we can see our fruit down the supply chain, perhaps in conjunction with this year's promotion.

For those interested in more detailed insect identification and monitoring, entomologist Dr Sonya Broughton will run a series of local workshops with small groups.

Angela Lush, snail specialist from the South Australian Research and Development Institute, will visit WA in May to look at snails in orchards and relate the latest control strategies to our situation.

Late Varieties

Last year we looked at early varieties with Kevin Lacey and guest speaker Graeme Sanderson from NSW Agriculture. This year, Kevin will focus on late varieties.

We can look forward to seeing fruit on the trees at local sites and news on new varieties from around the country.

By popular demand, a series of nutrition workshops will be added to the program, providing information on a range of approaches to nutrition. New industry standards outlined in ACG's Fruit Size Management Guide and new approaches to nutrition have sparked a lot of interest.

Our aim is to provide a balance of information by people who can support local citrus growers.

September shapes as a busy month, with a plan to combine irrigation and canopy management on the one program.

Dr Andy Krajewski will be available to revisit canopy management as a follow-up to earlier workshops. We will also talk to local irrigation specialists about providing information on irrigation systems, soil and scheduling.

A group of WA Citrus growers at Mildura Fruit Company in 2001.

Dr Sonya Broughton will help growers identify 'bugs'.

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Practical Pest Workshop, WA Fruit Grower, Issue 86, December 2005, pg. 5.

Standing Room Only

by Gavin Foord, Citrus Industry Development Officer

A captive audience at the citrus nutrition seminar

About 60 people packed the new WAFGA boardroom at Canning Vale on August 6 for a citrus nutrition seminar.

The WA Citrus Improvement Group joined forces with WAFGA, Australian Citrus Growers Cittgroups Australia and the Department of Agriculture, to host what was a very informative and popular event.

A late venue change meant conditions were 'cosy' to say the least, however this failed to dampen the enthusiasm of speakers or participants.

The aim was to inform on a range of services and approaches to nutrition so growers can decide on a program, or combination, that best suits them. The program featured a variety of presentations from six professionals.

Phenology Focus

The first speaker was Andy Krajewski of International Citrus Technologies Pty Ltd.

Dr Krajewski, now based at Gingin, presented a paper titled 'Citrus Phenology and The Three Fs: Flushing Flowering and Fruiting'.

This was a brief look at citrus phenological stages, highlighting the importance of crop stages, rather than calendar dates when making decisions about nutrition and other orchard inputs.

Nutrition Links

Lawrence Kirton of Rootzone Solutions talked about the links between nutrition, irrigation and phenology, utilising the 'Rootzone Dynamics Technique'.

This approach includes considering nutrients in solution, the importance of oxygen and growth curve nutrition to optimise crop growth.

Biological Management

Paul Storer of Western Mineral Fertilisers presented a general overview, demonstrating results from using biological management programs, discussing the implications of soil microbes and how they work and the symbiotic relationship between microbes and mineral fertilisers.

Testing Services

Mark Quenby of CSBP talked about soil and tissue testing services provided by CSBP.

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Practical Pest Workshop

Do you want to learn how to monitor and sample for insect pests, discuss the joys of Integrated Pest Management and releasing insects, plus share the thrill of seeing beneficials in the wild with fellow orchardists?

The Department of Agriculture (DAWA) is holding a series of workshops through September and October.

Workshops will be held during the day, so insects can be found without a torch.

Microscopes will be provided to view live predators preying on other insects, or you can bring along your own insects to identify.

Not enough to tempt you? How about a free hand-lens?

Time and venue is yet to be decided, but workshops will take place in the northern and southern growing areas.

To express interest in the workshop, contact Sonya Broughton, David Cousins or Gavin Foord at DAWA, Tel 9368 3333.

Adult green lacewing

Ladybird pupa

— 5 —

IPM scales down pests in WA, Citrus Insight, Vol. 81, December 2005/January 2006, pg. 30.

PRODUCTION

Development of an integrated pest management program for Western Australia

Sonya Broughton, Western Australian Department of Agriculture Tel: (08) 9444 5339, Email: smbroughton@agric.wa.gov.au

Project No: CT03020
January 2004 - January 2006

Aim: Develop an integrated pest management (IPM) program for WA citrus growers.

Funding Source: R&D levy

Red scale damage on lemons

IPM scales down pests in WA

Until now, Western Australia (WA) has lacked a long-term pest management program. Little was known of the pest, parasite and predator complex present in WA citrus. In the last 18 months, surveys of the main citrus growing areas in northern WA and monitoring sites south and north of Perth have confirmed that WA has few pests. Moreover, most of these pests are easy to control using beneficial insects or horticultural oils.

A scaley problem

Whilst the pest complex differs from region to region, and from orchard to orchard, scales top the pest list. Found clinging to leaves, twigs or fruit, and appearing to lack eyes, legs, and antennae, scale insects are easy to monitor since they don't move, at least, not as adults. Growers are releasing parasitic wasps (*Aphytis* species) in spring and autumn to control red scale (*Aonidiella aurantii*). Since releases first started in 2004, red scale has become less of a problem in packout of fruit at monitored sites.

Soft brown (*Coccus hesperidum*) and black scales (*Saissetia oleae*) are problems on young trees; no commercially produced parasites are presently available for their control. Whilst naturally occurring beneficials such as ladybirds (*Cryptolaemus montrouzieri*, *Coccinella transversalis*), lacewings and syrphids begin to appear in citrus orchards in spring, their populations appear insufficient to control the scale population. It is recommended that growers spray with horticultural oil once crawlers appear. However, those lucky enough to have been part of the *Metaphycus lutteolous* and *M. helvolus* release program in 2004, report that their soft brown scale problem has disappeared. Workshops in 2005/06 aims to teach growers how to identify and monitor these and other insect pests as well as their beneficials.

Pesticide trial

A second part of this project is to compare the effectiveness of IPM-compatible pesticides. Confidor® (a product marketed by BayerCropScience as IPM compatible) was applied as a soil drench to control black scale at Gingin and Wokalup in November 2004. The black scale and beneficial populations (ladybirds, lacewings) plummeted shortly after application. In contrast, black scale populations on control trees (unsprayed) increased, whilst beneficials continued to thrive (Figure 1).

The single application seems to have had an effect on pests arriving later in the season - grasshoppers and citrus leaf miner, with treated trees less frequently attacked than the control trees (data not shown). The sites continue to be monitored every three months. Growers attending the annual citrus conference in WA next year will be able to compare the results for themselves.

Key outcomes

Produce an IPM management guide for WA citrus growers containing a list of beneficial insects and insect pests present in the citrus growing regions of south west WA.

Evaluate commercially available biocontrol agents and established biological control agents.

Publish a series of industry fact sheets.

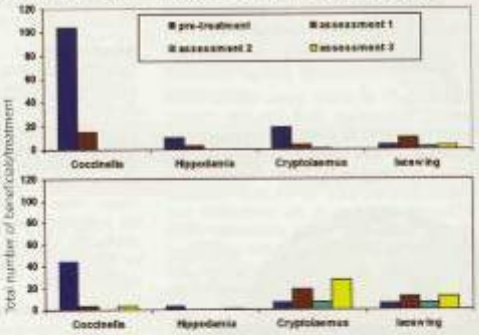

Figure 1. Total number of beneficials found on (A) treated (Confidor) and (B) control (unsprayed) and trees at Gingin. *Coccinella*, *Hippodamia* and *Cryptolaemus* are all ladybirds.

South African citrus thrips in Australia - identity pest status and control

Chris Freebairn, Queensland Department of Primary Industries and Fisheries, Maroochy Tel: (07) 5444 9324 Email: chris.freebairn@dpi.qld.gov.au

Project No: CT03022
October 2003 - September 2006

Aim: Determine the potential threat posed by South African citrus thrips to Australian citrus and ascertain Integrated Pest Management options to manage it.

Funding Source: R&D levy

South African citrus thrips – a pest of Australian citrus?

In South Africa, South African citrus thrips (SACT, *Scirtothrips aurantii* Faure) is one of the two most important pests of citrus. It also damages banana, grape, macadamia and mango and occurs on a broad range of non-crop hosts.

SACT is not as big a threat to Australian citrus as the disease citrus canker, but insecticide sprays to control it for up to 12 weeks after petal fall could significantly increase the costs of fruit production and disrupt long established citrus IPM systems.

While the thrips has not yet been detected on citrus in the field, the aim of this research project is to determine if SACT poses a real threat to Australia's citrus industry, and if it does, which control methods and strategies are most effective.