Department of Agriculture and Fisheries

INTEGRATED PEST AND DISEASE MANAGEMENT MANUAL FOR PERSIMMON

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Chapter 1

IPDM – an overview

1.1 AUSTRALIAN PERSIMMON

The Persimmon industry is established from the semi-tropical far north of Queensland to the cool temperate zones of Victoria, South Australia and Western Australia, with no single centre of production. Fruit from warmer regions mature four months earlier than southern States, giving the industry a harvest spread from February to July inclusive. The majority of the Australian industry is based on sweet (non-astringent) cultivars with the major varieties including 'Jiro', 'Fuyu' and 'Izu'. Yield and fruit size vary within and between regions.

There are approximately 250 growers producing 450 000 (4kg) trays. Currently the peak industry body, Persimmons Australia Inc. (PAI), has approximately 150 members and the Australian industry is estimated to be worth approximately $12 million (Persimmon Annual Investment Plan – 2010/2011). Significant new plantings are planned over the next 5 years. Improving fruit quality and increasing post-harvest storage life are critical to increasing market penetration for both domestic and export markets.

The aim of this manual is to develop and present an integrated pest and disease package for Australian persimmon growers based on the current state of knowledge. The manual will require regular updating to remain relevant.

1.2 THE TRADITIONAL APPROACH TO PEST AND DISEASE CONTROL

The traditional approach to insect and disease control was to spray crops at regular intervals whether or not pests or diseases were evident. This approach was costly and a waste of money if pests were absent. It did not take into account the fact that small numbers of pests can be tolerated without significant effect on yield and quality. In these cases, the cost of spraying is much greater than the benefit gained by controlling the pest and increased the risk of chemical damage to the fruit. The traditional approach had the following characteristics:

- relied heavily on new chemicals being developed to replace those to which insects had developed resistance
- killed beneficial insects, and sometimes resulted in outbreaks of pests that were well controlled naturally
- exposed farm families and farm employees to a range of toxic chemicals
- increased chemical residues in fruit and the wider environment.

1.3 THE MODERN APPROACH TO PEST AND DISEASE CONTROL - IPDM

Throughout the world, there is growing trend towards producing and marketing safer, cleaner fruit with little or no chemical residues. Additionally, world food safety standards demand agricultural chemicals not exceed certain limits in fruit and vegetable products.

Integrated pest and disease management (IPDM) covers many techniques of addressing pests and diseases while reducing the reliance on chemicals. It includes such techniques as introducing predatory insects to control pest insects and improvements in orchard hygiene to eliminate many of the current disease problems.

Not all direct chemical sprays can be eliminated from the fruit production process, but safe use practices of required chemicals should ensure the health and safety of workers, as well as the satisfying the food safety requirements.

The adoption of IPDM can result in production of high-quality fruit at less cost to the grower than the cost of chemical control programs. A recent economic survey in Queensland citrus showed that IPDM resulted in savings of up to 53% compared to the costs of chemical control. There are also potential marketing advantages for 'clean and green' persimmons produced with minimal pesticide use.

Other advantages of IPM are:

- the development of pest or disease resistance to chemical is delayed or avoided due to the less frequent use of chemicals
- growers develop a thorough knowledge of pests and beneficials and diseases, and can use this to improve orchard management
- long-term control of pests is improved through the increased abundance and diversity of natural enemies
- as a result of reduced chemical use, safety is improved for people working in orchards
- as a result of reduced chemical use, environmental contamination is reduced
- chemical residues in or on fruit are minimised, enhancing consumer acceptance of the produce.

1.4 COMPONENTS OF IPM

1.4.1 Biological control

Biological control is the use of natural enemies (parasites, predators or pathogens) of pests. (The natural enemies are also called 'beneficial organisms' or 'beneficials'). The aim of biological control is to establish and maintain populations of natural enemies which will keep pest populations below economically damaging levels.

There are two main groups of beneficial insects:

- Predators - attack and eat other insects. Either adult or larvae, or both may be predatory.
- Parasites - lay eggs on or in other insects. The eggs hatch and the developing larvae consume the host, usually from the inside.

Natural enemies may be mass-reared and released into orchards. Augmentative releases aim to ensure that the natural enemy is present in sufficient numbers in time to control the pest. Before mass-rearing and augmentative release programs are initiated, it is necessary to know the true value of the various beneficials in controlling the pests.

1.4.2 Cultural control

Cultural practices should help to conserve existing natural enemies of pests. In persimmon, these practices include the management of other plants growing in the orchard, tree skirting, trunk banding and good orchard hygiene (see Chapter 8).

Maintaining trees in general good health is also important for both pest and disease control. Healthy trees are usually better able to withstand attack by pests than stressed trees. The microhabitat for beneficials is also of better quality in healthy orchards than in unthrifty orchards.

1.4.3 Chemical control

Pesticides are powerful tools to use against pests, and can play a role in IPM programs. Note, however, that the use of most broad-spectrum pesticides, even only once or twice in a season, can seriously disrupt an IPM program. Spray drift between blocks may compound these problems.

Pest control programs that rely mainly on chemicals can seem attractive, simple and low-risk. They do not require detailed knowledge of the pests and their natural enemies, and appear to be an easy solution to the problems of quickly reducing pest numbers, and guaranteeing production of quality fruit.

However, continual use of broad-spectrum pesticides on a regular calendar basis leads to a number of serious problems. These include:

- resistance of the pests, first to one pesticide, then to a whole chemical group and then across groups, which ultimately leads to poor control of the pests and increasing losses in production and quality
- increased costs for developing and producing pesticides to control resistant pests
- secondary pest problems because the pesticides kill natural enemies which normally suppress a wide range of minor pests
- environmental contamination
- pesticide residues in or on the fruit
- potentially detrimental effects on the health of orchardists, their families and their staff.

1.5 THE MODERN APPROACH TO DISEASE CONTROL

All plant diseases result from the interactions between a host (in this case persimmon), a disease causing pathogen (in this case mostly fungi) and the environment (Figure 1). Basically, disease will not occur unless all three of these factors are present and are in favour of the disease. Careful consideration of these points in relation to any crop disease interaction will usually give useful leads for defeating the fungal foe. Disease can be managed by:

i. excluding or reducing fungal infecting units (spores)
ii. increasing the hosts resistance to the disease or
iii. modifying the environment so that is unsuitable for the development of disease.

The aim of the exercise is to make life as difficult as possible for the fungus. It's not enough merely to spray it with a chemical. That is just a challenge to the mighty fungus to do one better, and it often does. It does mean directing our attack to any point of the triangle in an attempt to make life unbearable for the potential destroyer.

1.6 IPDM PROCESSES AND PROCEDURES

IPDM must be based on a sound knowledge of the pests and their natural enemies, diseases, action levels and management strategies. Building up to a high-level IPDM program is a gradual process, needing careful attention. This can lead ultimately to minimal or no use of pesticides, with pest control achieved mostly by natural enemies and/or cultural control. The basic processes and procedures are outlined below:

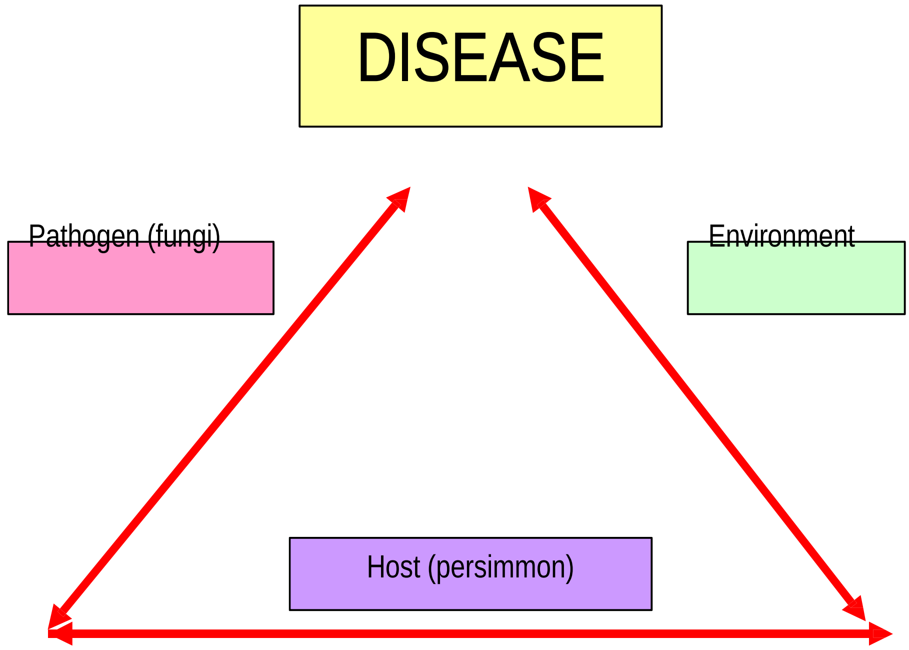


Figure 1. The interaction between fungi, host and disease necessary for the occurrence of a disease.

- *Identification of pests and natural enemies and diseases*. Specialist training in pest and disease diagnosis (e.g. by working alongside a pest scout or entomologist), and understanding of IPDM techniques are required.
- *Monitoring of pests and natural enemies and diseases*. Monitoring of pests and their natural enemies is a vital component of IPDM. Monitoring is a structured system for quantifying the likelihood of a pest or disease becoming a problem in the orchard and includes recording selected trees in the orchard and weather conditions favourable for the development of disease. Monitoring can be carried out by a commercial pest scout or by the orchard manager. In either case, it must be done regularly in a systematic manner.
- *Action levels or thresholds*. Action must be taken to control pests or diseases before the point at which they cause economic loss. Action levels are usually estimates based on research and experience. Pest and disease management plans should be closely linked with disease management decisions.
- *Appropriate action*. When action levels of a pest or disease are reached, the most appropriate control strategy must be selected, e.g. release of parasites, or use of a selective pesticide. Such decisions are critical to IPDM success. Avoid using broad-spectrum pesticides. If a pesticide has to be used, its effect on natural enemies must be considered first. Choose a 'soft' pesticide if possible, e.g. petroleum spray oil.

These processes and procedures are discussed in greater detail in later Chapters.

CHAPTER 2

Priority pests and diseases

2.1 REVIEW OF PESTS AND CONTROL METHODS IN PERSIMMON

Growers of horticultural crops frequently suffer from a lack of legal access to crop protection products (pesticides). The problem is that whilst their crops, such as persimmon are valuable, they are considered too small individually for agchem manufacturers to bear the high cost of registering pesticides for them (Dal Santo, 2008).

Growers are increasingly trapped in a situation where they face severe losses from diseases, pests and weeds if they do nothing to protect their crops, or face penalties if they use a product that is not registered or available via a permit. The persimmon industry is very aware of the possible consequences that can occur from the use of unregistered or non-permitted pesticides (Dal Santo, 2011). These can include;

- Produce with unauthorised pesticide residues
- Rejection of produce from local markets
- Temporary exclusion from market access
- Rejection of produce from export markets
- Jeopardising of export trading arrangements
- Fines and penalties

From a pesticide access perspective, the Australian Pesticides and Veterinary Medicines Authority (APVMA) include persimmon as a member of the 'assorted tropical and sub-tropical fruit (edible peel)' category and are classified as a minor crop.

As a consequence of the issues facing the persimmon industry regarding pesticide access, a Strategic Agrichemical Review Process (SARP) was conducted in September 2011 (DAL Santo, 2011) in conjunction with Persimmons Australia Incorporated (PAI).

The report prioritised the major pests and diseases affecting persimmon and identified gaps where acceptable pesticides were not legally available. In addition, it determined new and alternative pesticide control options using:

- Critical selection criteria for potential alternatives and/or new pesticides
- Domestic and overseas information and resources that provide options and assist decision making
- Manufacturers' support

The list of pesticide solutions for each identified gap will have the benefit of:

- IPDM compatibility, wherever possible
- Improved scope for resistance management
- Sound biological profile
- Residue and trade acceptance domestically and for export

The results of the review process have provided the persimmon industry with sound pesticide options for the future that the industry can pursue for registration with the manufacturer, or minor-use permits with APVMA.

In addition, a phone survey on the incidence and severity of different pest and diseases in the major production regions was also conducted in November 2011 by Dr Alan George, external consultant to the Australian persimmon industry. The integrated findings of the SARP review and the phone survey are presented below.

2.2 PESTS

2.2.1 Range of pests

A list of pests attacking persimmon in Australia is presented in Table 1. Based on grower observations, these pests have been classified by the authors into categories of high, moderate and low severity. We believe that this is a fairly comprehensive list of pests of persimmon in Australia but further studies may identify new pests and reclassify some of the existing ones. Many growers surveyed were unable to identify the exact species of a particular insect type e.g.scale on their persimmon trees. More thorough examinations by an entomologist will be needed to classify these species more correctly.

TABLE 1.
Insect pests of persimmon in Australia.

Common name	Scientific name	Comments
High severity		
Queensland fruit fly	*Bactrocera tryoni*	All states - major pest.
Mediterranean fruit fly	*Ceratitis capitata*	Major pest - WA only.
Fruit spotting bug	*Amblypelta nitida*	Qld - major pest in some areas, seasonal, depends on native bush in area. Other states - nil.
Banana spotting bug	*Amblypelta lutescens*	Qld - major pest in some areas, seasonal, depends on native bush in area. Other states - nil.
Citrus Mealybugs	*Planococcus citri*	Eastern sates - major pest.
Longtail Mealybugs	*Pseudococcus longispinus*	All states especially SA and Vic - major pest.
Citrophilus Mealybugs	*Pseudococcus calceolariae*	Eastern sates - major pest.
Nigra scale	*Parasaissetia nigra*.	Scales – major pest in all states.
White wax scale	*Ceroplastes destructor.*	Scales – major pest in Qld.
Pink wax scale	*Ceroplastes rubens*	Scales – major pest in Qld.
Black scale	*Saissetia oleae*.	All states - major pest.
Clearwing moth/girdler (Carmenta)	*Ichneumenoptera chrysophanes*	Qld & NSW - major pest. Other states - nil.
Borer moth	*Unknown*	SA and Vic
Ants	*Formicidae spp.*	Major problem – all states.
Plague thrips	*Thrips imaginis*	Qld (inland) & SA - major pest.
Moderate severity		
Light brown apple moth	*Epiphyas postvittana*	More of a pest in southern states, can become a major pest.

TABLE 1. Cont.

Common name	Scientific name	Comments
Thrips (green, black, red banded)	*Various spp. Heliothrips haemorrhoidalis, Selenothrips rubrocinctus*	Red-banded thrips in Qld - major pest in some seasons, minor previously. Other species are minor pests in all states.
Fruit piercing moth	*Eudocima salaminia*	Moderate pest in Qld only.
Cluster caterpillar	*Spodoptera litura*	Qld - major pest in some small areas, fast moving and sporadic. Other states - nil.
Yellow peach moth	*Conogethes punctiferalis*	Qld - moderate pest. Other states - nil.
Earwigs	*Various spp. Forficula auricularia, Gonolabis michaelseni*	SA - moderate problem.
Low severity		
Mussell Scale	*Lepidosaphes beckii*	Minor pest in Qld.
Green Coffee Scale	*Coccus viridis*	Minor pest in Qld.
Long soft scale	*Coccus longulus*	Minor pest in Qld.
Two-spotted (Red spider) mite	*Tetranychus urticae*	Two spotted mite – minor pest Qld.
Mites (Bud, eriophyid)	*Various spp. Eriophyidae, possibly spp. Aceria diospyri*	Bud mite - overseas is a major pest, Aust unknown, suggests minor pest in Australia.
Weevils	*Various spp. e.g. Orthorhinus cylindrirostris*	Minor problem – all states.
Aphids	*Myzus persicae.*	Minor problem – all states.
Orange fruit borer	*Isotenes miserana*	Qld - minor pest.
Leaf rollers	*Various spp. Epiphyas postvittana, Homona spargotis*	Minor problem in most states.
Leaf hoppers	*Various spp. e.g. Siphanta acuta*	Minor problem – all states.
Loopers	*Various spp. e.g. Trichoplusia ni*	Qld - moderate pest is some areas. Other states - nil.
Red Shouldered Leaf beetle	*Monolepta australis*	Minor problem in most states.

The list of insecticides and fungicides registered for use on persimmon is presented in Chapter 7. Following the Strategic Agrichemical Review of 2011, PAI has requested that APVMA issue minor use permits for a range of new insecticides and fungicides for trial on persimmon. A list of these pesticides where minor use permits are being applied for is presented in Chapter 7.

2.2.2 Regional incidence of pests

Incidence of pests in different regions of Australia is presented in Figure 1. Pest pressures were two to three times higher in sout-east Queensland and northern NSW compared with Victoria and South Australia. This is probably due to the warmer and wetter climates of the northern States favouring insect growth (see Chapter 8) but it also may be a function of natural physical barriers and quarantine restrictions restricting insect movement. There were insufficient growers surveyed in Western Australia to develop an accurate picture on the status of pests in that State.

2.2.3 Grower ratings on importance of specific pests

Growers were surveyed to identify the three most significant pests in their orchards. These were rated in order of importance (Figure 2). The three most important pests identified in Queensland and northern NSW, in order of importance, were:

1. Queensland Fruit fly (*Bactrocera tryoni)*
2. Clearwing moth (*Ichneumenoptera chrysophanes*)
3. Mealybugs (*Pseudococcus spp.)*

In South Australia and Victoria, the three most important pests identified were:

1. Mealybugs (*Pseudococcus spp.)*
2. Scale *(various e.g.Chrysomphalus aonidum*)
3. Borer moth (*unidentified species),* Thrips (*various* e.g. *Heliothrips haemorrhoidalis)*

In South Australia and Victoria, thrips and borer moth (unknown species) were tied in 3rd place in grower ratings. The order of importance of pests for the two different regions was reasonably similar except for fruit fly which is not present in most regions of Victoria or South Australia.

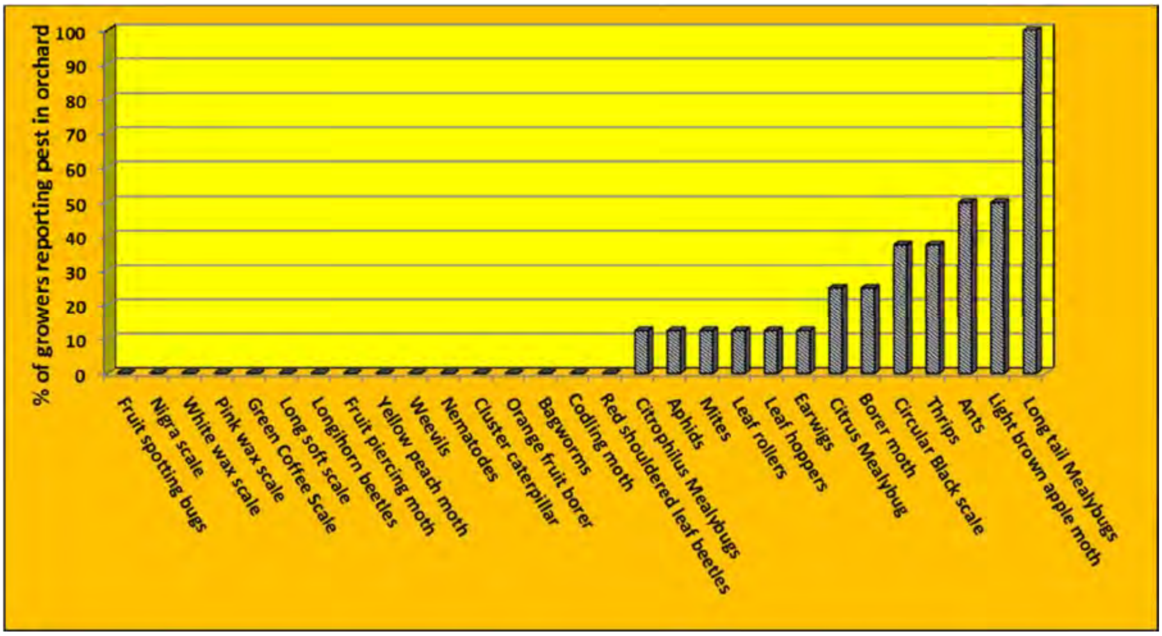


Figure 1 a. Percentage of growers who reported a specific pest in their orchard in south-east Queensland and northern NSW. Data are means of 10 growers in each region.

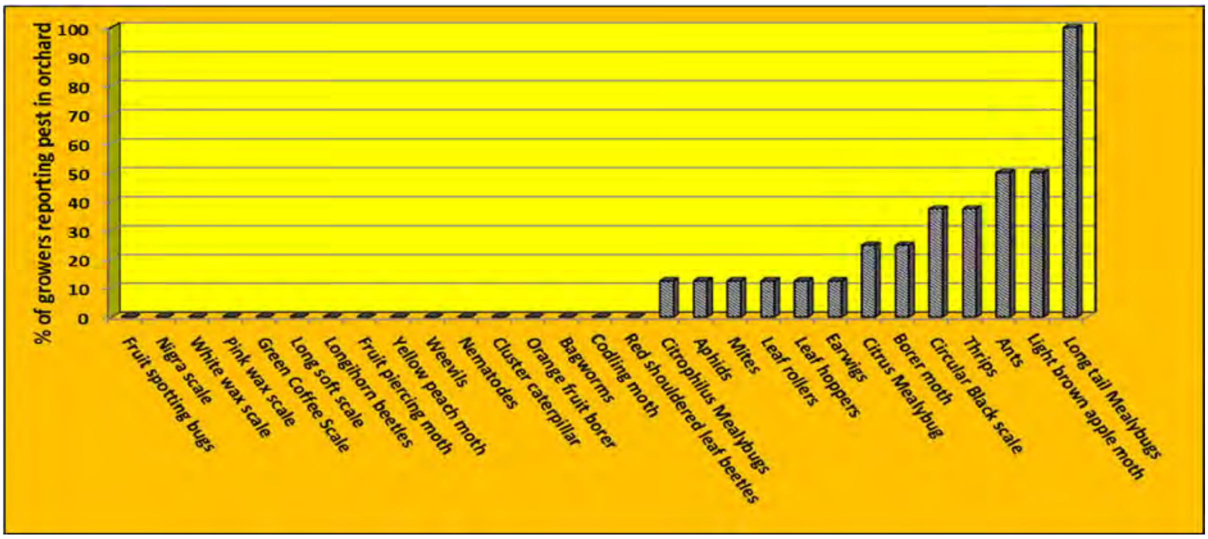
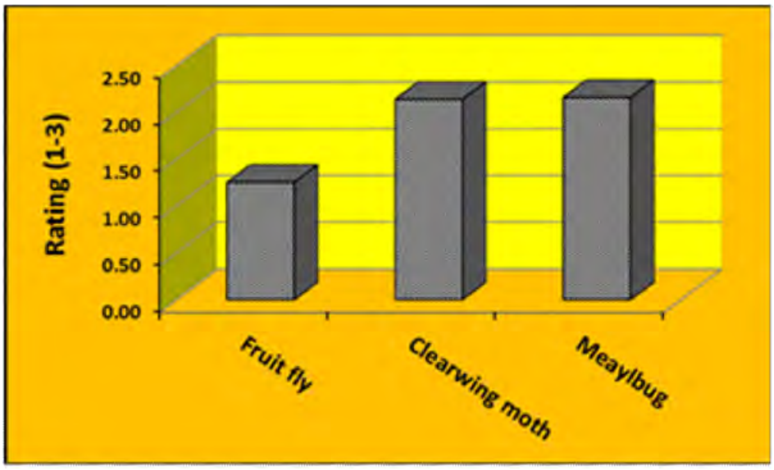


Figure 1 b. Percentage of growers who reported a specific pest in their orchard in Victoria and South Australia. Data are means of 10 growers in each region.



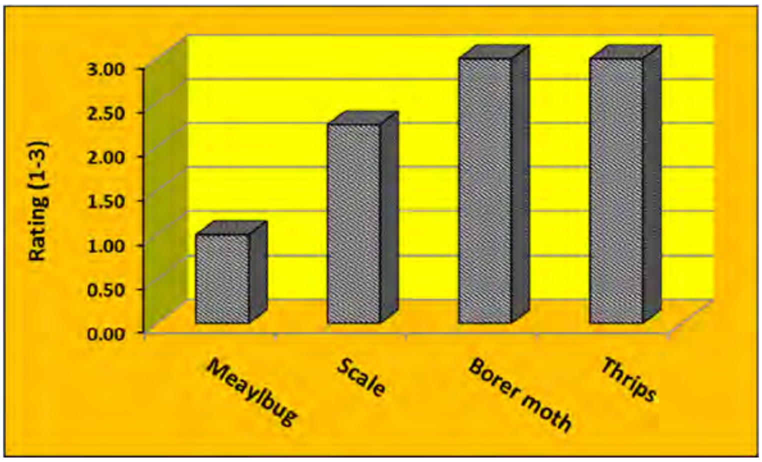


Figure 2. Ratings for the three most serious pests in different regions. Top: South-east Queensland and northern NSW. Bottom: Victoria and SA. Data are averages of 10 growers who rated the pests on a scale of 1-3, 1=most serious, 3=least serious. The lower the score the more serious the pest severity. In South Australia and Victoria, Borer moth and thrips were tied for 3rd place as the most important pest.

2.3 DISEASES

2.3.1 Range of diseases

The major diseases found on persimmon in Australia are presented in Table 2. We believe that this is a fairly complete list of diseases but in recent years we have identified several new organisms associated with persimmon disease symptoms but pathogenicity of these organisms are yet to be verified.

TABLE 2.
Diseases of persimmon in Australia.

Common name	Scientific name	Organ affected	Comments
High priority			
Angular leaf spot	*Pseudocercospora spp.*	Leaf	Qld - high; WA & NSW - medium - high. Problem in areas with summer rainfall.
Circular leaf spot	*Mycosphaerella* spp.	Leaf	Qld - high. WA & NSW - medium - high. Problem in areas with summer rainfall.
Anthracnose	*Colletotrichum spp. (gloeosporioides or kaki)*	Fruit, calyx, leaf	Qld - medium & increasing, low-nil elsewhere.
Twig blight Sooty mould	*Phomopsis spp?.* *Various genera - Capnodium, Fumago, Scorias, Capnodium,*	Twigs, laterals Leaf, calyx, fruit	Qld & WA - medium, SA - low. Problem – all states.
	Fumago, and Scorias.		
Moderate priority			
Botrytis Pestalotiopsis spot	*Botrytis cinera* *Pestalotiopsis spp.* *Pestalotiopsis diospyri*	Leaf, fruit, calyx Leaf, calyx, shoots	Moderate problem in SA and Vic. Disease has been mis-identified as other leaf spots.
			Problem in Qld and northern
			NSW.
Low priority Rhizopus/Penicillium	 *Rhizopus spp.*	 Fruit (post-	 Minor problem - all states.
	Penicillium spp.	harvest rots)	
Bacterial wilt	*Psuedomonas*	Roots, trunk,	Minor problem - all states.
	solanacearum	tree	
Armillaria root rot Phytophthora root	*Armillaria luteobubalina* rots	Roots, trunk	Minor problem - all states.

Phytophthora cinamomi

Roots

Minor problem - all states.

TABLE 2. Cont.

Common name	Scientific name	Organ affected	Comments
Fusarium root rot	*Fusarium solani*	Seedling roots	Minor problem - all states.
Crown gall	*Agrobacterium tumefaciens*	Roots, trunk	Minor problem - all states.

2.3.2 Regional incidence of diseases

Similar to pests, disease pressures were two to three times higher in south-east Queensland and northern NSW compared with Victoria and South Australia (Figure 3). This is probably due to the warmer and wetter climates of the northern States which are more condusive to disease development (see Chapter 8). There were insufficient growers surveyed in Western Australia to develop an accurate picture on the status of diseases in that State.

2.3.3 Grower ratings on importance of specific diseases

The three most significant diseases identified by growers in Queensland and northern NSW (Figure 4), in order of importance, were:

1. Leaf spots *(Pseudocercospora spp., Mycosphaerella* spp.)
2. Anthracnose (*Colletotrichum spp.)*
3. Twig blight (*Phomopsis* spp.?)

Victorian and South Australian growers identified no serious diseases in their regions. Consequently, these were not rated.

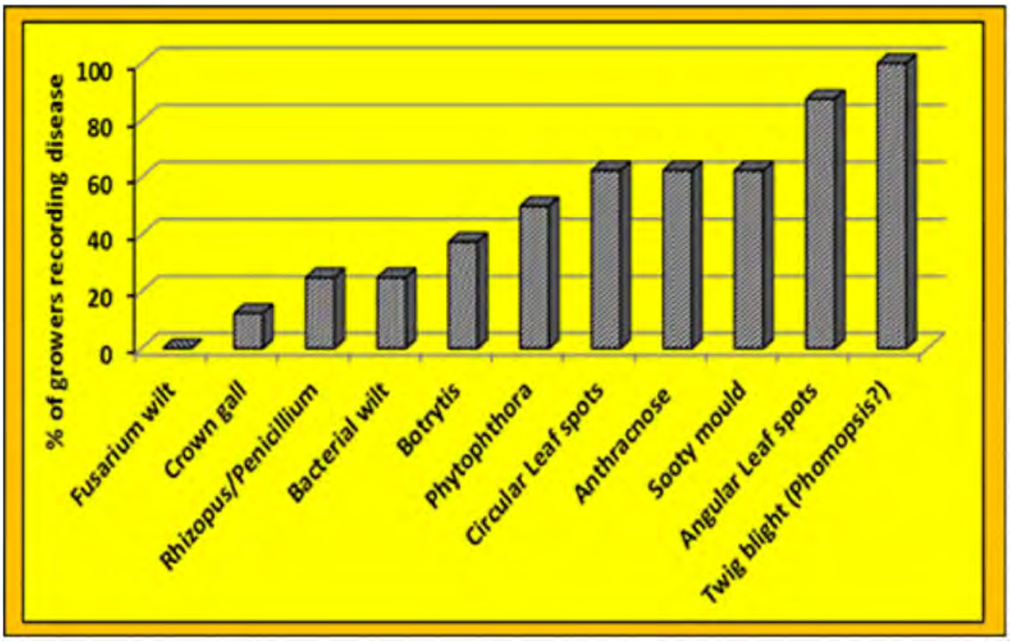


Figure 3 a. Percentage of growers who reported a specific disease in their orchard in south-east Queensland and northern. Data are means of 10 growers in each region.

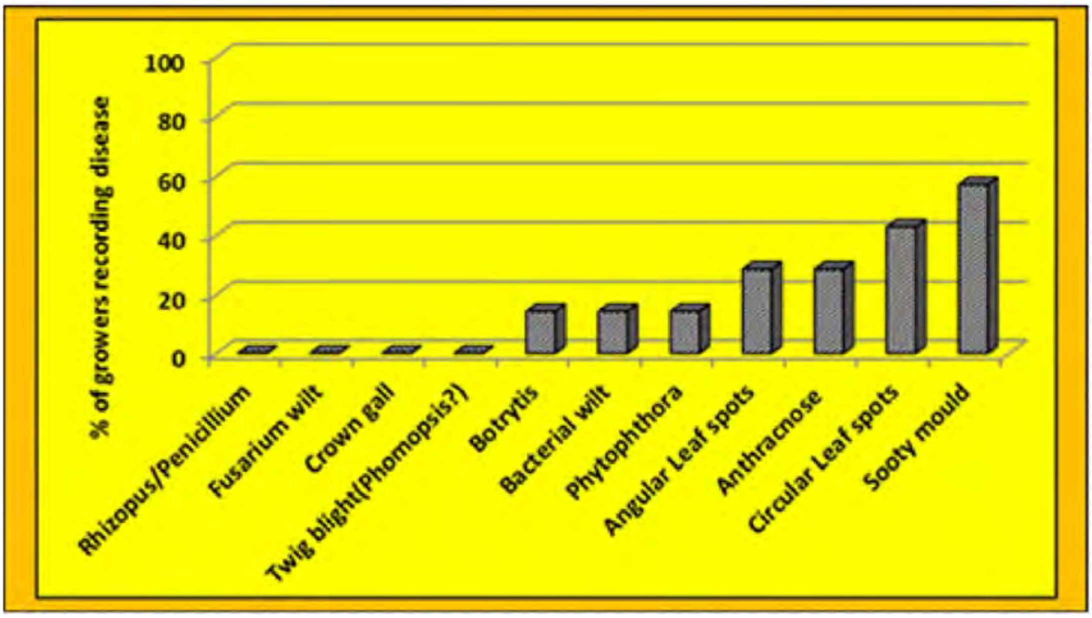


Figure 3 b. Percentage of growers who reported a specific disease in their orchard in Victoria and South Australia. Data are means of 10 growers in each region.

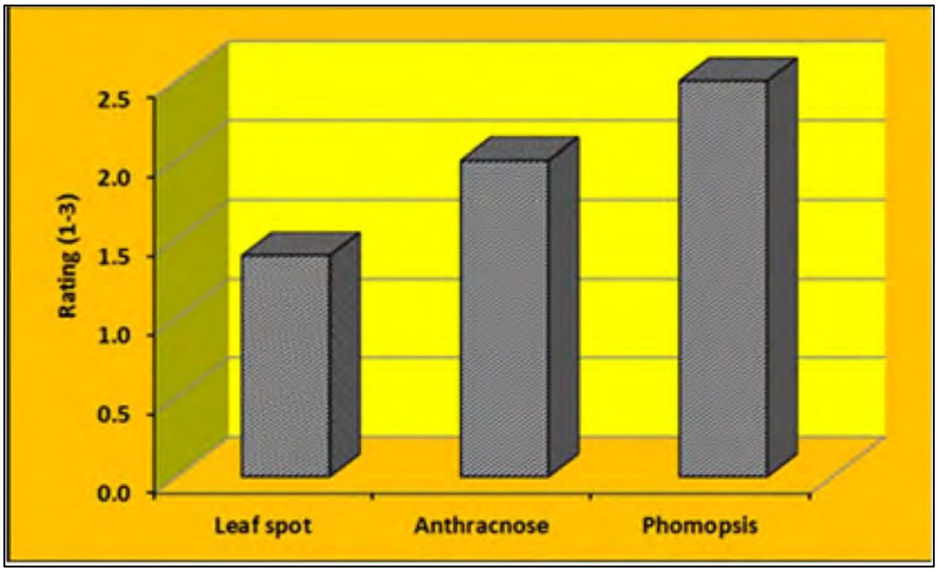


Figure 4. Ratings for the three most serious diseases in South-east Queensland and northern NSW. Data are average of 10 growers who rated the disease on a scale of 1-3, 1=most serious, 3=least serious. The lower the score the more serious the disease.

Chapter 3

Diseases

3.1 ANGULAR (PSEUDOCERCOSPORA) LEAF SPOT

3.1.1 Symptoms

Symptoms consist of an angular leaf spot with distict margins (Plate 1). The disease affects the leaf only (Plate 1). Spots are small (ranging in size up to 7mm) and brown to grey. Spots often coalesce to form large disfigured areas. Large necrotic spots are commonly seen as the disease progresses. Severe Cercospora infections can cause major fruit drop.

Plate 1. Angular leaf spot showing distinct angular margins.

3.1.2 Causal organism

Pseudocercospora spp. possibly *Pseudocercospora kaki.* This disease organism commonly infects persimmon leaves. It is a different *Pseudocercospora* species that causes husk spot in macadamia.

3.1.3 History

Pseudocercospora leaf spot has been present in Australia for at least fifty years. The disease was probably introduced by immigrants from Italy with the introduction of the older astringent varieties.

3.1.4 Occurrence and distribution

Pseudocercospora is major problem especially in wet seasons in Queensland and NSW production regions. It does not appear to be a major problem in Victoria, South Australia or Western Australia except in seasons with above average summer rainfall.

There appears to be a varietal difference in the susceptibility to the disease with cv. Izu showing greater susceptibility than other cultivars.

The disease can lead to severe loss of photosynthetic capacity and can lead to premature leaf drop in the autumn. Premature leaf drop reduces fruit size in the current season and the build up of carbohydrate for next seasons flowering and fruit development. Keeping healthy leaf on the tree in the autumn is therefore very important.

The disease overwinters as hyphae in the leaves and leaf bases. Spores of the fungus which cause this disease can survive for 5-6 months in diseased leaves and serve as an inoculum source for next year. The fungus is disseminated chiefly by water. Some growers have reported that the disease is worse under bird netting presumably due to higher humidities and slower leaf drying under netting.

3.1.5 Chemical control

Mancozeb

Mancozeb has been shown to be effective against angular leaf spot. We recommend maintaining a regular protectant spray program using mancozeb. Mancozeb is sprayed every 3-4 weeks from flowering until 4 weeks before harvest (PER12488). Up to 6 sprays per season may be needed in Queensland. Mancozeb can be washed off in high rainfall areas.

Make sure the spray rig is working correctly. Calibrate air blast and other sprayers to ensure that you get good coverage (70-100 or more droplets per square centimetre) to get good leaf and fruit protection. Check to see if the fruit are covered with fungicide. Check that the sprayer is operating at the correct pressure.

Chlorothalonil (Bravo®)

Although chlorothalonil has a minor use permit (PER13445) for application to persimmon there are some limitations to its use for persimmon. This fungicide should only be used either early (pre- flowering) or after harvesting as it can cause leaf burn and fruit burn. Some growers spray chlorothalonil *Bravo®)* up to 3 times prior to flowering. It can be used again after harvesting is finished to control leaf diseases and to reduce the rate of leaf drop. The advantage of using Bravo® is that it sticks better than mancozeb after rainfall.

3.1.6 Orchard management strategies

- Spray dormant trees and leaf litter with oil and copper after pruning – several applications may be required. Note: copper is not currently registered for use on persimmon.
- When pruning, open up the trees more to improve spray penetration. Dense foliage reduces spray penetration. Prunings which contain carry-over spores and old fruit left on the ground should be removed from the orchard.
- Prune tree skirts to 50 cm above the ground. This will minimise humidity in canopy and ensure optimum spray coverage.
- Remove prunings from the orchard whenever possible, or mulch them quickly to assist natural breakdown. If dead leaves or prunings are left under trees, cover them with straw mulch 50 mm or more in depth to stop spore movement up into the tree. Moisten leaves and mulch to promote leaf breakdown.
- Regularly monitor fruit for infection during the season so that spraying can start before fruit diseases get too severe. Where fruit diseases are an ongoing problem, regular spraying may be required.

3.2 CIRCULAR LEAF SPOT

3.2.1 Symptoms

Large circular spots surrounded by a watermark-like halo (see Plate 1). Compared with angular leaf spot, the spots are larger and more rounded.

Plate 1. Circular leaf spot.

3.2.2 Causal organism

Mycosphaerella spp.

3.2.3 History

Circular leaf spot was first identified and described by NSW DPI in 2003. Because of similar symptoms, this leaf disease has often been confused with angular leaf spot.

3.2.4 Occurrence and distribution

Circular leaf spot is major problem especially in wet seasons particularly in northern NSW and western Sydney. There appears to be a varietal difference in the susceptibility to the disease. This disease can lead to severe loss of photosynthetic capacity and severe infestations can cause premature leaf drop in early autumn. Premature leaf drop reduces fruit size in the current season and reduces the buildup of carbohydrate for next seasons flowering and fruit development.

The disease overwinters as hyphae in the leaves and leaf bases. Spores of the fungus which causes this disease can survive for 5-6 months in diseased leaves and serve as an inoculum source for next year. The fungus is disseminated chiefly by water.

3.2.5 Chemical control

Mancozeb

Mancozeb has been shown to be effective against circular leaf spot. We recommend maintaining a regular protectant spray program using mancozeb. Mancozeb is sprayed every 3-4 weeks from flowering until 4 weeks before harvest. Up to 6 sprays per season may be needed in Queensland. Mancozeb can be washed off in high rainfall areas.

Make sure the spray rig is working correctly. Calibrate air blast and other sprayers to ensure that you get good coverage (70-100 or more droplets per square centimetre) to get good leaf and fruit protection. Check to see if the fruit are covered with fungicide. Check that the sprayer is operating at the correct pressure.

Chlorothalonil (Bravo®)

Although chlorothalonil has a minor use permit for application to persimmon there are some limitations to its use for persimmon. <u>This insecticide should only be used either early (pre-flowering) or after harvesting as it can cause leaf burn and fruit burn</u>. Some growers spray chlorothalonil *Bravo®)* up to 3 times prior to flowering. It can be used again after harvesting is finished to control leaf diseases and reduce the rate of leaf drop. The advantage of using Bravo® is that it sticks better than mancozeb after rainfall.

3.2.6 Orchard management strategies

- When pruning, open up the trees more to improve spray penetration. Dense foliage reduces spray penetration. Prunings which contain carry-over spores and old fruit left on the ground should be removed from the orchard.
- Prune tree skirts to 50 cm above the ground. This will minimise humidity in canopy and ensure optimum spray coverage.
- Remove prunings from the orchard whenever possible, or mulch them quickly to assist natural breakdown. If dead leaves or prunings are left under trees, cover them with straw mulch 50 mm or more in depth to stop spore movement up into the tree. Moisten leaves and mulch to promote leaf breakdown.
- Regularly monitor fruit for infection during the season so that spraying can start before fruit diseases get too severe. Where fruit diseases are an ongoing problem, regular spraying may be required.

3.3 PESTALOTIOPSIS LEAF SPOT

3.3.1 Symptoms

Symptoms on leaves are large grayish brown circular ringspots (Plate 1). Usually, they are solitary, but occasionally, two to three spots occur on an affected leaf. In severe cases, lesions develop on more than one-third of the leaf, resulting in defoliation. Small black acervular conidiomata are visible in the surface of spots. Symptoms may also appear on the calyces sepals as brown-to-black necrotic areas; one to four sepals per fruit could be affected (Plate 1). Severe infestations can cause early fruit maturation and premature abscission. In Spain, the disease can also cause cankers on shoots (Plate 2).

Plate 1. Pestalotiopsis leaf spot on leaves and calyces.

3.3.2 Causal organism

Pestalotiopsis spp has been isolated from samples sent to Maroochy Research Facility in 2011. The disease organism is possibly one of two species (*Pestalotiopsis theae* or *Pestalotiopsis diospyri).* These organisms have been isolated from persimmon leaves in New Zealand and Spain, respectively.

Plate 2. Canker caused by *Pestalotiopsis diospyri* on persimmon shoot in Spain (Alves *et al*., 2011).

3.3.3 History

In November 2006, *P. diospyri* was reported to be present on calyces of unhealthy persimmon fruits in different production regions in New Zealand and for the first time, pathogenicity of *Pestalotiopsis* was demonstrated on sweet persimmon fruit in Spain (Blanco *et al.*, 2008). This leaf disease was first noticed in Queensland in 2010. The disease may have introduced on imported fruit.

3.3.4 Occurrence and distribution

Pestalotiopsis is more of a problem in wet seasons in Queensland and NSW production regions. It does not appear to be present in Victoria, South Australia or Western Australia. Similar to the other leaf diseases its development is favoured by heavy rainfall.

3.3.5 Chemical control

Mancozeb has been shown to be effective against Pestalotiopsis. We recommend maintaining a regular protectant spray program using mancozeb. Start spaying early in the fruit growth cycle (see Chapter 8 for regional spray programs).

3.3.6 Orchard management strategies

Similar orchard management strategies for controlling other leaf diseases.

3.4 ANTHRACNOSE

3.4.1 Symptoms

There can be a variety of symptoms. In the early stages, the disease appears as 'pepper spots' which are very small and discrete with well-defined margins (Plate 1). The most likely disease organism producing this symptom is *Colletotrichum gloeosporioides.* Pepper spot also occurs in avocado and custard apple fruit and has been shown to be associated with a stress factor that limits the disease to pepper spots rather than the quite large sunken spots normally characteristic of anthracnose. As the disease progresses, the spots become larger and can merge. Sunken spots may also occur on the leaves and fruit (Plate 2). These symptoms may be caused by a different species, *Colletotrichum kaki*.

Plate 1. Various stages of anthracnose development. Top: Pepper spot caused by *Colletotrichum gloeosporioides.* Bottom: More advanced stage.

Plate 2. Anthracnose symptoms caused by *Colletotrichum kaki* include sunken spots on the fruit and leaves.

3.4.2 Causal organism

Most likely organism is *Colletotrichum gloeosporioides* which produces the pepper spot symptom. Symptoms such the sunken spot may also be caused by a different species, *Colletotrichum kaki* which may also be present in Australia. *Colletotrichum* spp. attacks a wide range of fruit, including avocado, custard apple, mango, banana, passionfruit, fig and papaw.

3.4.3 History

Anthracnose disease has become more significant over the past five years. This fungal disease has been recognised in Queensland since the mid 1950's. It could become an ongoing major disease problem.

3.4.4 Occurrence and distribution

Anthracnose is major problem especially in wet seasons in Queensland and NSW production regions. It is a minor problem in Victoria, South Australia and Western Australia presumably due to the drier climate in the production regions of these States. Overseas research indicates that some varieties are more susceptible than others.

Spores of the fungus are produced on dead twigs, leaves and fruit. Given overhead irrigation, heavy dews or warm showery weather, these spores will spread through the orchard. Fruit is susceptible to infection from fruit set to harvest. The fungus penetrates the peel of the fruit where it normally remains dormant until the fruit ripens. The fungus may also start to grow and produce symptoms if the fruit is injured or stressed. Wet conditions increase severity of the disease. There are a number of factors which probably contribute to anthracnose in persimmon:

- Wet and windy conditions favour the disease
- Many orchards in NSW and Queensland are now 20-25 years old, and there is likely to have been a build-up in anthracnose inoculum in these large trees
- Older trees have higher levels of dead/dying tissue on which the fungus proliferates
- Larger older trees are more difficult to spray properly, especially the inner top one third of trees
- Older trees, particularly those which are lightly pruned, retain moisture on the leaves and fruit for longer, and hence favour infection and fungus development
- Fruit that are left to hang on the trees and not picked are sources of fungal spores.
- Fruit hanging on the tree continuously for several months, and it more likely that fungal spores can build up within the tree, and move to uninfected fruit. In contrast, after fruit are harvested in orchards in Queensland, leaves drop from the tree in winter, so that there is a distinct break in the disease cycle.
- Higher levels of infection can occur where orchards are located in close proximity to neglected avocado orchards.
- Prunings may also be a source of inoculum, if they are placed under the tree and tree skirts are kept low or weight of fruit brings branches down to ground level. This inhibits movement of drying air.
- Some growers suggest that the disease is spread by birds/bats but this needs to be verified.

3.4.5 Chemical control

- No chemicals registered or permitted.

3.4.6 Orchard management strategies

Orchard management strategies are the same as for Pseudocercospora leaf spot.

3.5 TWIG BLIGHT (PHOMOPSIS?)

3.5.1 Symptoms

The most apparent symptoms are sporadic and delayed budbreak after trees break dormancy in the spring. The new shoots have smaller yellow leaves and etiolated shoots (Plates 1 and 2). New season's laterals dieback from the tip. Sub-leaders may also dieback towards the main leader or trunk with little or no emergence of dormant buds. The one-year old shoots may exhibit ink-dark cankers and the internal wood may be necrotic or stained (Plates 3 and 4).




Plate 1. Symptoms of twig blight at Maroochy Research Facility. Top left: dead laterals. Top right, tree severely affected with dieback. Bottom left: new shoots wilted. Bottom right: total dieback of new season laterals.

3.5.2 Causal organism

DAF plant pathologists have isolated the disease organisms *Phomopsis* spp. and *Diplodia* spp. from tissue at the margins of shoot necrosis however pathogenicity of these organisms has not been proven. Exact species of *Phomopsis* is still to be determined.

3.5.3 History

The disease was first observed at Maroochy Research Facility in 2009-10. In the same year, a second orchard at Blackbutt also exhibited similar symptoms. 'Fuyu' trees were more affected than 'Jiro'. Phomopsis has now been observed in orchards in Queensland, NSW and WA. Some nurserymen have also observed this disorder in nursery trees. We suggest that this disorder has been recently introduced into Australia.

Plate 2. Symptoms of twig blight at Blackbutt. Cv. Fuyu severely affected. Leaves of 'Fuyu' are small, yellow and elongated. Note bare sections along sub-leaders.

3.5.4 Occurence and distribution

Twig blight is most often observed in early spring following bud break. Cv. Fuyu is far more susceptible than 'Jiro". Symptoms include wilt and death of leaves on new shoots. Wilt and death of blossoms and young fruit on fruiting wood also occur. A diffuse canker, often with a concentric appearance and exuding gum, can be found on the fruiting wood at the base of the blighted shoots. The canker is usually centered on a dead bud, which is believed to be the infection point for the pathogen.

We believe that most bud infection occurs during the previous fall or winter as the organism can enter fresh leaf scars when the trees are defoliating in late autumn. New infections can also occur in the spring, leading to twig blight during early summer.

Superficially, twig blight can be confused with other causes of twig death (e.g., Cytospora canker), but can be distinguished by close examination of the canker and by laboratory culture. *Cytospora* spp. and *Botrysphaeria* spp. often invade cankers and shoots killed by Phomopsis infection. We would expect that wet weather would exacerbate this problem.

Plate 3. Staining of internal wood on persimmon.

Plate 4. Left: Ink-dark canker of *Phomopsis diospyri* found on persimmon in Greece. Bottom: Canker on persimmon shoot at Nambour showing pynidia?

3.5.5 Chemical control

No chemicals permitted or registered

3.5.6 Orchard management strategies

- Treat nursery stock before planting with fungicides.
- Cv. Jiro is much less susceptible
- Prune off and burn infected wood to prevent carry over of spores into the next season
- Disinfect pruning equipment (pruners, lopers, saws) regularly before moving between trees

3.6 GREY MOULD (BOTRYTIS)

3.6.1 Symptoms

The disease appears as discrete grey coloured lesions on younger leaves and calyces (Plate 1). These enlarge and coalesce to infect whole leaflets which later senesce, and fall to the ground. Damage to calyces can reduce fruit size significantly. Fruit can also be damaged due to infected petals.

Plate 1. Top left: Botrytis on leaves (Photo: Yuan-Min Shen, Taichung District Agricultural Research and Extension Station, Bugwood.org). Top right: Botrytis on calyx. Bottom: scarring of fruit due to infected petals.

3.6.2 Causal organism

The fungal pathogen *Botrytis cinerea.*

3.6.3 History

This disease is present in most persimmon growing countries including Japan, Korea and New Zealand. When it was first introduced into Australia is not known.

3.6.4 Occurence and distribution

The disease is present in all States but it is more likely to occur under cooler conditions of southern States. In most persimmon growing regions, grey mould is a minor disease problem. Humid conditions after rain favour the development and further dispersal of the botrytis grey mould pathogens. The grey mould fungus survives on plant debris and in the soil. Four to six hours of free water on the plant surface is required for spores to germinate and infect the plant.

3.6.5 Chemical control

Mancozeb

There are a range of fungicides available to control Botrytis, and selection of the most appropriate fungicide could depend on the level of disease pressure present. Fungicides containing mancozeb have activity against Botrytis.

Protectant fungicides only provide a protective barrier to the outside part of the plant that discourages fungal spore development. They do not cure the disease once it has developed.

3.6.6 Orchard management strategies

- Prune trees to develop open canopies.
- Practise good orchard hygiene.
- Remove diseased prunings from the orchard.

3.7 SOOTY MOULD

3.7.1 Symptoms

Sooty mould is superficial and may grow on leaves, twigs and fruit (Plate 1). Sooty mould is the common name applied to several species of fungi that grow on honeydew secretions on plant parts and other surfaces. The fungi's dark mycelium gives plants or other substrates the appearance of being covered with a layer of soot.

Honeydew is a sweet, sticky liquid that is excreted by plant-sucking insects as they ingest large quantities of sap from the plant. Because the insect cannot completely utilize all the nutrients in this large volume of fluid (which is a dilute solution of carbohydrates, amino acids, minerals, and other substances), it assimilates what it needs and excretes the rest as "honeydew." Wherever honeydew lands (e.g., leaves, twigs, fruit), sooty moulds can become established.

Although sooty moulds do not infect plants, they can indirectly damage the plant by coating the leaves and calyces to the point that sunlight penetration is reduced or inhibited. Without adequate sunlight, the plant's ability to carry on photosynthesis is reduced, which may stunt plant growth and reduce fruit growth (Plate 2). Coated leaves may also prematurely senesce and die, causing premature leaf drop. Fruits or vegetables covered with sooty moulds are still edible.

Plate 1. Sooty mould growing on honeydew secreted by scale or mealybugs

3.7.2 Causal organism

Fungi that most commonly cause sooty moulds are in the genera Capnodium, Fumago, and Scorias. Less common genera include Antennariella, Aureobasidium, and Limacinula. The species of sooty moulds present are determined by a combination of the environment, the host, and the insect species present. Some sooty mould species are specific to a particular plant or insects, while others may colonize many types of surfaces and use honeydew produced by several kinds of insects.

Plate 2. Effects of calyx removal on fruit size. Loss of photosynthetic capacity of the calyx due to sooty mould or loss of calyx area due to chewing caterpilalrs can have the same effect.

3.7.3 History

Not applicable.

3.7.4 Occurrence and distribution

A number of insects can produce the honeydew needed by sooty moulds to grow. Most of these are plant-sucking insects in the order Homoptera, which includes aphids, mealybugs, soft scales, whiteflies, leafhoppers, and psyllids. Immature and adult stages of these insects feed by sucking sap from plants, producing honeydew. If these pests are controlled, then usually sooty mould is controlled.

3.7.5 Chemical control

Treat the scale or mealybug infestation and control ants. Use appropriate chemicals such as ant bait (see sections on mealybug and ant control in Chapter 4).

3.7.6 Orchard management strategies

The most important control measure is to restrict the movement of ants into the tree canopy through the use of ant baits or sticky bands placed around the trunk of the tree in spring (see Chapter 4). If the fruit does become covered with sooty mould it will need to be cleaned with water containing detergent and lightly brushed.

Various methods have been used to clean the fruit (Plate 3). One grower has developed a semi-automated system with the fruit being sprayed with pressurised water to remove mould.

Plate 3. A high pressure sprayers used to clean fruit.

3.8 POST-HARVEST ROTS

3.8.1 Symptoms

Initial infections appear as discolored, water-soaked spots on fruit (Plate 1). These lesions enlarge rapidly, releasing enzymes that leave the fruit limp, brown, and leaky. Under conditions of high relative humidity, the fruit rapidly becomes covered with a coat of mycelium and sporangiophores of various colours depending on the invading species.

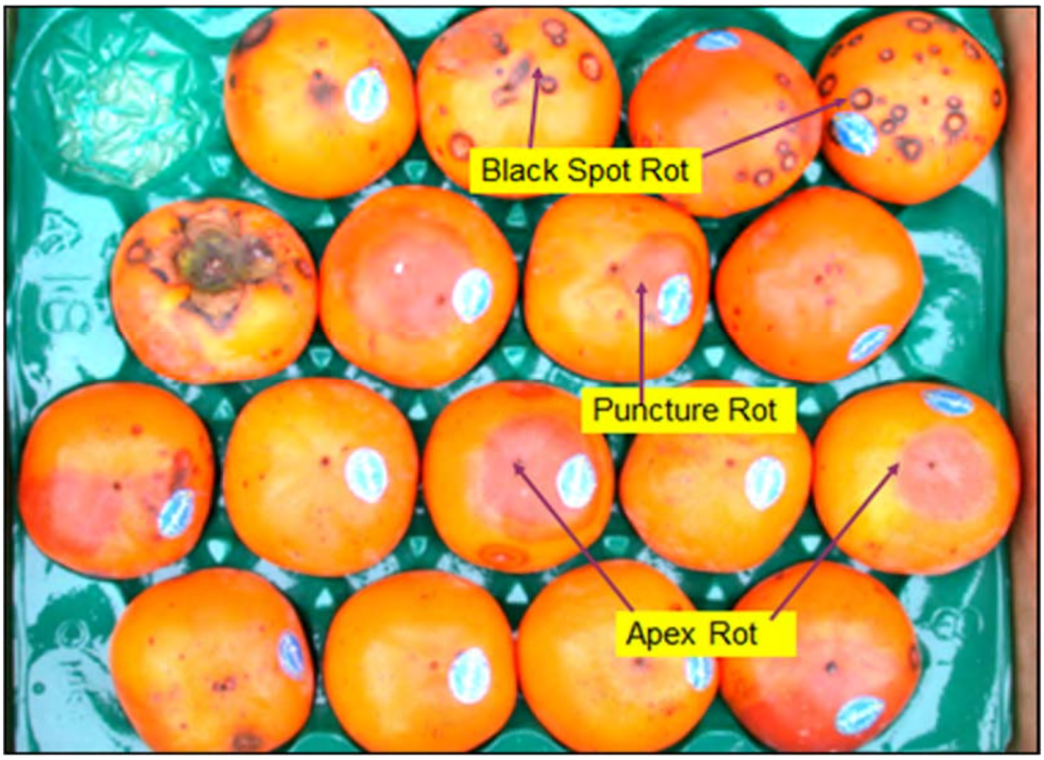


Plate 1. Post-harvest diseases: Black spot (*Alternaria* spp.); puncture and apex rots (*Penicillium* spp., *Rhizopus* spp.). (Photo Allan Woolf, HortResearch, NZ).

3.8.2 Causal organism

Various organisms including:

- Alternaria spp. (Black spot) (Plate 1)
- Rhizopus spp. (Transit rot) (Plate 2)
- Penicillium spp.(Blue mould) (Plate 2)

These fungi are excellent saprophytes that live on and help break down decaying organic matter. They invades persimmon through wounds and secrete enzymes that degrade and kill the tissue ahead of the actual fungal growth. Spores are airborne. The pathogen has a large host range and is prevalent worldwide.

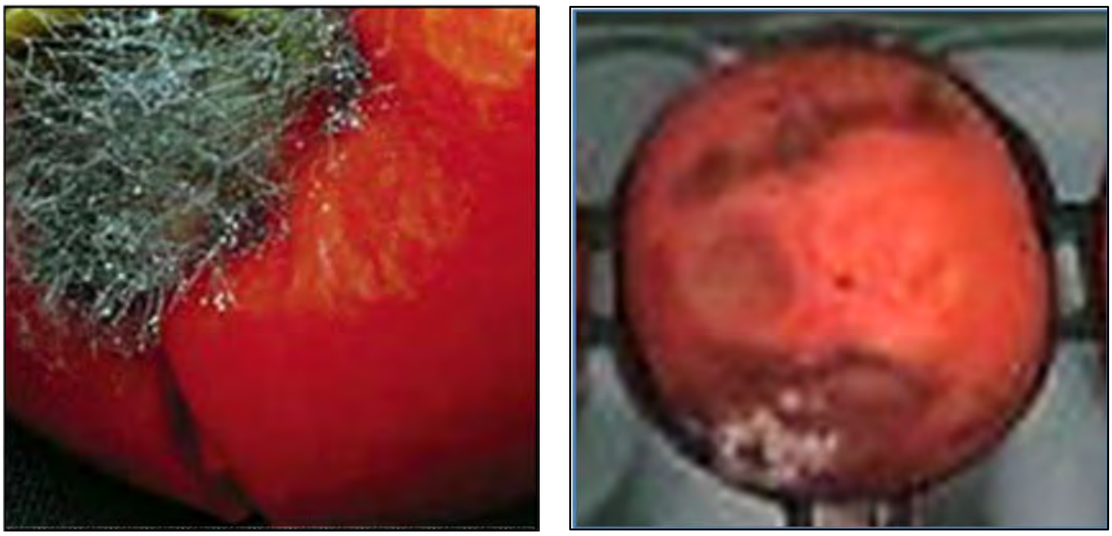


Plate 2. Left: Rhizopus mycelium. Right: Penicillium spp.

3.8.3 History

These are commonly occurring disease organisms found in damaged fruit after harvest.

3.8.4 Occurrence and distribution

Rain splashes overwintering spores from soil and crop debris onto developing fruit. Symptom development is favored by high humidity. Fruit rots occur during warm, wet weather. *Rhizopus* stops growing at temperatures below 8° to 10°C, so rapid postharvest cooling of fruit is essential for disease control. These diseases can spread from fruit to fruit and from contaminated packaging material such as wood wool. There are a wide range of host species including most fruit and vegetables.

3.8.5 Chemical control

There are some benefits in the use of protective fungicides, but unless the disease is widespread throughout the field, this pathogen should not cause excessive damage.

All harvest equipment, the packing line and packing boxes should be sanitized regularly. There are a range of techniques available to sanitise packhouses including use of:

- ozone generators
- UV-C lights
- vaporous hydrogen peroxide
- Bactigas® (contains Tea Tree oil)

These methods are described in more detail in an article by Peter Tavener, SARDI, ‘Decontamination of cold storage facilities’ in Packer Newsletter, Vol 89, December 2007. The efficacy of these methods is still under investigation.

No post-harvest fungicide dips are currently approved for control of post-harvest rots in persimmon.

3.8.6 Orchard management strategies

- Be sure when fruit are being picked that the entire fruit is removed from the stem, not leaving behind the fleshy receptacle of the fruit as it can serve as a site for invasion by fungus.
- Fruit injury during harvest and packing should be avoided – use padding in harvest trays and handle gently
- Improved sanitation in the field and in the packinghouse is effective at reducing losses due to fruit rots.
- Culling infected and injured fruit during packing reduces losses due to post-harvest decays. It may be advantageous to store fruit for 3-5 days before grading and packing to allow symptoms on damged fruit to appear so that can be more easily identified.
- Wet surfaces should be dried promptly before packing and fruit should be cooled quickly to 10ºC.

3.9 CROWN GALL

3.9.1 Symptoms

The galls are usually underground but can creep up the lower part of the tree (Plate 1). Trees infected with crown gall experience rapid cell development within these infected areas. This rapid development forces the production of enlarged tissue that forms into galls. The growths are irregular or slightly round with textured surface. The sizes can vary from 0.5cm up to several centimeters. The roots will have galls on them, which can be heavily infested or just bear one or two tumors.

The galls girdle the infected area, inhibiting the tree's ability to transport nutrients and water. This girdling results in the slow death of the tree. Along with developing galls, trees severely infected with crown gall can experience wilt, premature defoliation and dieback. . The disease hits young plants the hardest and can often annihilate them, while older plants weaken, but most often survive the infection.

Plate 1. Major roots showing crown gall nodules.

3.9.2 Causal organism

Crown gall is a soilborne bacterium, *Agrobacterium tumefaciens* that develops and germinates when the soil is moist and warm. *Agrobacterium tumefaciens* is an alphaproteobacterium of the family Rhizobiaceae, which includes the nitrogen fixing legume symbionts. Unlike the nitrogen fixing symbionts, tumor producing *Agrobacterium* are pathogenic and do not benefit the plant. The wide variety of plants affected by *Agrobacterium* makes it of great concern to the agriculture industry.

Resistant bacterium can lie dormant in the soil, awaiting a host, for two years or more. When a plant is introduced into the infected soil, the crown gall bacterium attacks the plant's roots (Plate 2). The bacterium can also spread above the surface by rain and wind, infecting plants through its wounds. The *Agrobacterium tumefaciens* infects the plant through its Ti plasmid. The Ti plasmid inserts a segment of its DNA, known as T-DNA, into the chromosomal DNA of its host plant cells. *A. tumefaciens* have flagella that allow them to swim through the soil towards photoassimilates that accumulate in the rhizosphere around roots. Some strains may chemotactically move towards chemical exudates from plants, such as acetosyringone and sugars.

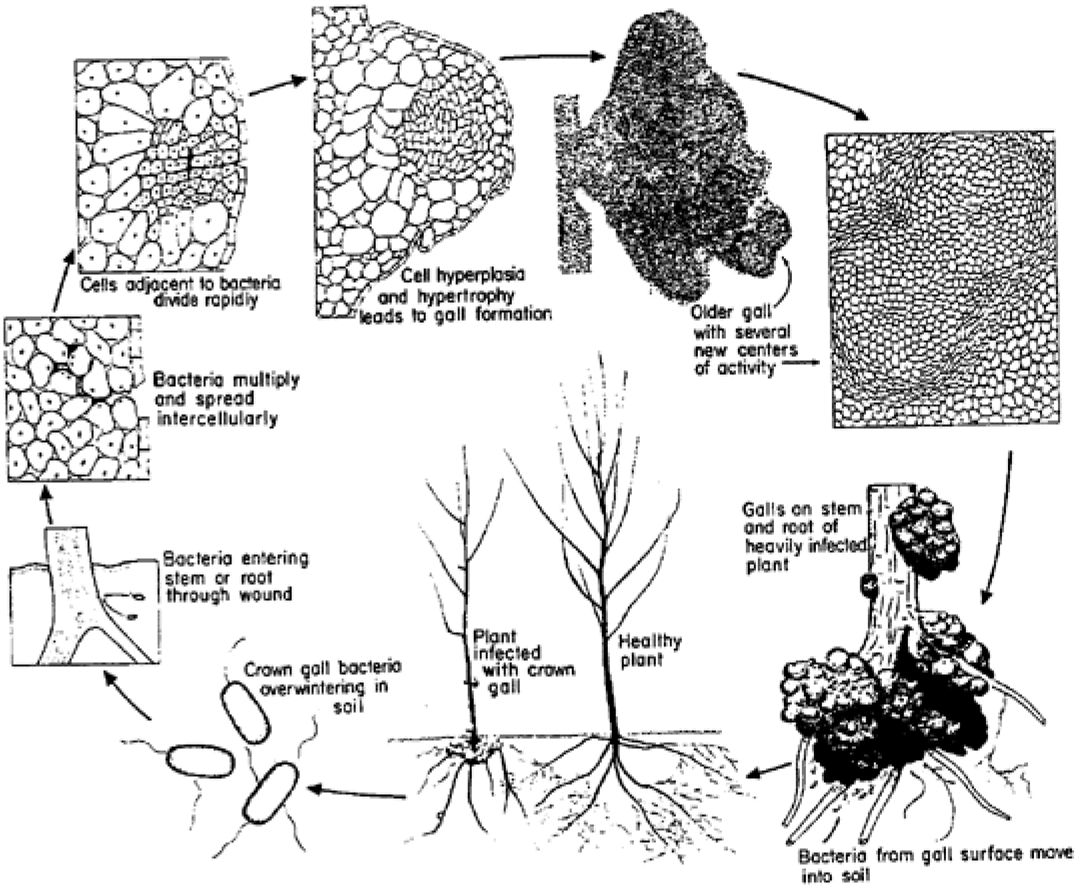


Plate 2. Life cycle of crown gall (Hortnet.co.nz)

3.9.3 History

Among highly susceptible agricultural plant species, a great deal of effort has been focused on the identification and selection of crown-gall-resistant individuals or cultivars. Again, the mechanisms of this genotypic and cultivar-level resistance are generally poorly understood. Varying levels of disease susceptibility have been observed in persimmon. *Diospyros kaki* is the most resistant of the *Diospyros* species to crown gall.

3.9.4 Occurrence and distribution

Crown gall is a minor disease in Australia. It is rarely seen in persimmon orchards. Although *A. tumefaciens* has perhaps the broadest host range of any plant pathogenic bacterium, the agricultural impact of crown gall disease is limited to a relatively small subset of horticultural crops (grapes, stonefruit, persimmon, walnut, kiwifruit). Many cultivated monocots and legumes are not hosts for *A. tumefaciens*. The molecular bases of non-host resistance to *A. tumefaciens* are unknown,

3.9.5 Chemical control

Treatments designed to eliminate *Agrobacterium* directly must necessarily be exercised before infection, because disease development will progress independent of the causal agent following the initial transformation event. In situations in which wounding is inevitable, such as grafting and transplanting, copper- or bleach-based bactericides can reduce *A. tumefaciens* populations on plant surfaces, minimizing disease.

However, biocontrol treatments using avirulent *Agrobacterium* strains that act as *A. tumefaciens* antagonists have proved to be the most effective means of controlling the crown gall pathogen. *Agrobacterium radiobacter* strain K84 and its plasmid-transfer-deficient derivative K1026 are the most widely used and best studied crown gall biocontrol.

When susceptible plant material is dipped in a suspension of NOGALL™ prior to planting, the NOGALL™ K1026 bacteria act by colonizing the wounds and producing antibiotics, which inhibit the pathogen. Note: NOGALL™ containing K1026 is ineffective against strains causing crown gall disease in grapes, apples, pears and some ornamentals. NOGALL supplies over 1000 million *Agrobacterium* strain K1026/g equivalent to over 20 million K1026 bacteria/mL of dip.

3.9.6 Orchard management strategies

- Plant persimmon trees with resistant rootstock. *Diospyros kaki* is the most resistant species to crown gall.
- In areas which were previously infected with the disease, plant grasses for up to three years, at which point the disease will have cleared from the soil, and it will be safe to replant
- Infections spread to open wounds on trees, so treating existing cuts and bruises on mature trees and being careful to avoid additional damage is the best treatment.
- Young trees that are infected may need to be destroyed.

3.10 COLLAR ROT (BACTERIAL WILT)

3.10.1 Symptoms

Young trees

Young trees may rapidly wilt and decline, often preceded by severe defoliation (Plate 1). Leaves that stay on the tree are dull green and hang almost vertically.

Plate 1. Vascular staining in young branch.

Older trees

In older trees, a slow decline occurs over about two years, generally with little or no yellowing of the leaves. On affected limbs, mature leaves are shed and the expanding juvenile leaves appear less vigorous, pale green and smaller in size. Branches become sparsely foliated and subject to sunburn. The subsequent spring and summer flushes are unthrifty, but flowering and fruit set may be prolific. However, these fruit remain small and fail to reach marketable size.

Root symptoms

Affected trees have a dark discolouration of the water-conducting tissues in the basal trunk and large roots. A transverse and longitudinal section of the trunk at ground level will show extensive discolouration of the outer growth rings (Plate 2). Dark streaking of the wood is rarely seen in the branches above the graft union. Roots may also be severely diseased (Plate 3). Wilting is most common in late summer.

Plate 2. Black staining of vascular tissues of roots due to bacterial wilt.

3.10.2 Causal organism

The bacterium *Pseudomonas solanacearum.*

3.10.3 History

Bacterial wilt has been present in orchards since persimmons have been grown in Australia.

3.10.4 Occurrence and distribution

Wilting is most common in late summer or early autumn when the fruit are approaching maturity. We suspect that the fruit crop load reduces root growth so that susceptible rootstocks cannot escape the disease pathogens quickly enough. Due to the genetic variability in rootstocks, only some rootstock trees are susceptible.

3.10.5 Chemical control

None available.

3.10.6 Orchard management strategies

Host plants

Delay growing persimmon for one to two years in sites that have grown vegetables susceptible to bacterial wilt, such as tomatoes, capsicum, eggplant and potatoes. Weeds that host the bacteria such as cobblers peg, blackberry, night shade, cape gooseberry and wild tobacco tree should be eliminated from orchards.

Drainage

Construct low mounds and install sub-surface drainage if soils are marginal in depth or drainage.

Rootstock selection

The selection of rootstock may also be important for control. Some rootstock lines may be less susceptible than others.

Mulching

Mulching and reducing crop load may help to prolong the life of affected trees.

Plate 3. Black staining of vascular tissues due to bacterial wilt.

3.11 OTHER ROOT DISEASES

3.11.1 Symptoms

Trees affected with root diseases show pale yellow foliage and weak vegetative flushes. With severe infections, trees can die quickly (Plate 1). Roots of the affected tree are black with rotting of the fine root tips (Plate 2).

Plate 1. Tree death caused by Phytophthora spp.

Plate 2. Left: Healthy feeder roots. Right : Diseased roots

3.11.2 Causal organisms

Various fungi. The fungi *Cylindrocladium* spp., *Pythium* spp. and possibly other fungi are often associated with root damage. *Phytophthora cinnamomi* is a common cause of root rot in a range of subtropical fruit crops. Despite repeated attempts, the pathogen *Phytophthora* spp. has been rarely isolated from persimmon roots.

3.11.3 History

This disease occurs sporadically.

3.11.4 Occurrence and distribution

Root rot diseases are not prevalent throughout Australia and they can be considered minor diseases of persimmon. It is common for most persimmon orchards to lose between 5-10% of trees over a ten year period. This disease can occur on trees of all ages.

3.11.5 Chemical control

No chemicals permitted or registered.

3.11.6 Orchard management strategies

- Transplant potted plants into the field as soon as possible as young trees left too long in pots commonly have twisted root systems that do not grow normally after transplanting. In less severe cases, water and nutrient uptake are reduced; in severe cases, trees die.
- As yet, kaki rootstocks have not been specially selected for resistance to soil fungi and bacterial wilt. In any group of grafted plants, a small percentage will be susceptible to root diseases, and every year, some trees may die. Research is being conducted to identify elite rootstocks.
- In poorly drained areas, mound rows and install drains to improve drainage.
- Mulch trees at least annually to maintain a favourable root environment. Addition of an organic fertiliser such as pelleted poultry manure is beneficial.
- Ensure irrigation is adequate. The best way to do this is to use a soil moisture monitoring system such as tensiometers, gypsum blocks, neutron probe or capacitance probes.

Chapter 4

Pests

4.1 MEALYBUGS

4.1.1 Damage

Mealybug infestation occurs on persimmon fruit calyces and in fruit crevices (Plate 1). The black patches of sooty mould grow on the honeydew secreted by the mealybugs. In some cases, mealybugs may cover the entire fruit surface. The coastal brown ant (*Pheidole megacephala*) tends the mealybugs for their honeydew. They move the mealybugs around and fend off their natural enemies. The black house ant (*Iridomyrex glaber*) acts similarly.

Plate 1. Mealy bug on the calyx of persimmon fruit.

4.1.2 Species and description

Three species of mealybug attack persimmon (Plate 2). These are:

- Citrus mealybug *(Planococcus citri).*
- Longtail mealybug *(Pseudococcus longispinus)*
- Citrophilus mealybug *(Pseudococcus calceolariae)*

These three species look somewhat similar except that the longtail mealybug has a longer tail. Adult female citrus mealy bugs are white, about 3 mm long, and covered by a white mealy wax. There are 18 pairs of short waxy filaments around the margin of the body. These are shorter at the head end, and lengthen progressively towards the rear end. The last pair is one quarter the length of the body. They have yellow body fluid observable if the insect is crushed. The males are short-lived insects. They are similar to the males of armoured scales, with one pair of fragile wings and non-functional mouth parts. They have two long filaments at the rear end.

Plate 2. Top left: Long-tail mealybug. Top Right: Citrus mealybug (Photo: University of Minnesota). Bottom Citrophilus mealbug (Photo: David Madge).

4.1.3 Life cycle

During summer, the life cycle of the mealybug takes about 4-6 weeks (Figures 1 and 2). In Queensland, there are about 6 generations of the mealybug per season whilst in southern states there may only be four or five. Over about a fortnight, the mature female lays up to 600 eggs in a loose cottony mass. The pale yellow eggs hatch in about a week and the light yellow crawlers (young mealybugs) move away and settle in protected areas such as creases in the fruit. They pass through three moults (or instars) before reaching the mature female stage or four moults before the adult male stage. The adult male is a fragile, short lived insect with one pair of wings and aborted mouthparts.

4.1.4 Importance and distribution

Mealybugs are a major pest of persimmon in Australia. Export shipments can be condemned or downgraded if mealybugs are found beneath the calyces of fruit. Therefore, fruit need to be regularly inspected for the pest.

Citrus mealybug occurs throughout Australia but is much more common in coastal districts and in the areas north of Sydney in the eastern states (Figure 3). Longtail mealybugs are more prevalent in Victoria and South Australia. Mealybugs are normally found from mid-November with reasonable populations tending to build up by mid-December. Higher populations seem to be building up earlier in recent years. If left untreated, very high populations will be present by mid-January on most persimmon blocks. Extensive sooty mould will develop in many trees. The mealybug infestation becomes economically serious when 25% or more of the fruit has one or more adult female mealybugs present.

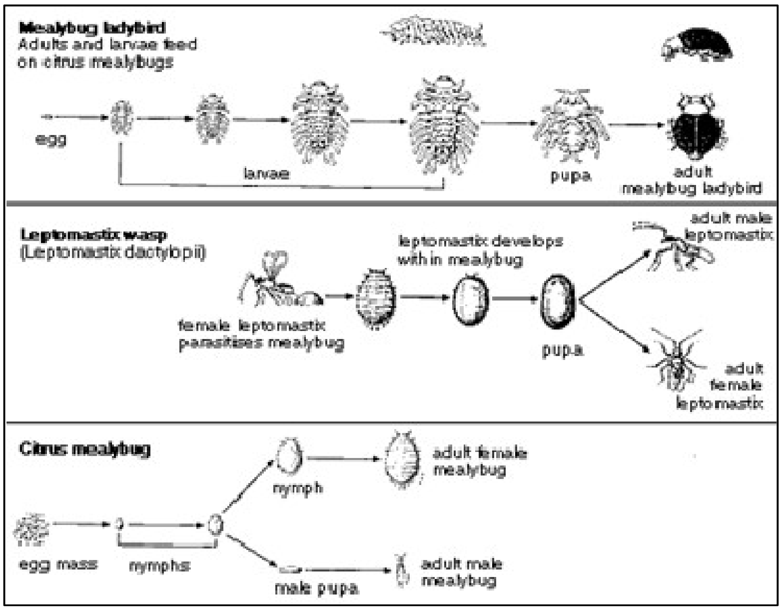


Figure 1. Lifecycle of the citrus mealybug *(Planococcus citri*), of the parasitic leptomastix wasp, and the predatory mealybug ladybird.

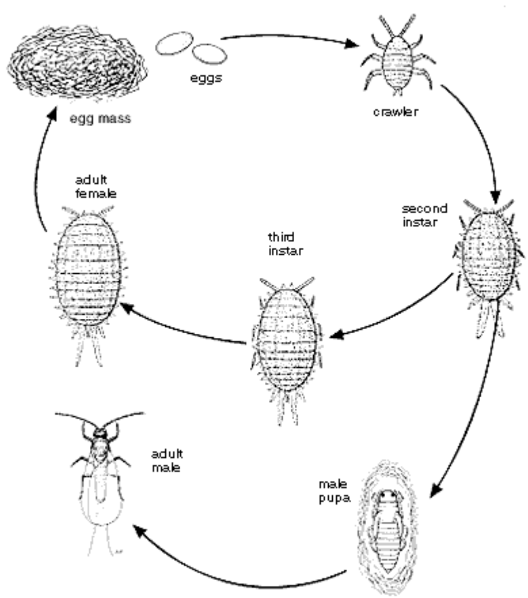


Figure 2. Life cycle of Citrophilus mealbug.

4.1.5 Monitoring

Before you decide to spray, you need to know whether the mealybug infestation is severe enough and whether their natural enemies are active. The mealybugs and their natural enemies can generally be easily seen with the naked eye; using x 10 hand lens will also help.

To monitor the population of mealybug, select 20 trees at random per hectare and record the presence or absence of mealybugs on 10 randomly selected fruit per tree (without picking the fruit). Do this once every two weeks between December and April. While recording mealybug presence, also record the presence of natural enemies on the same fruit. Look for Leptomastix wasps, their cylindrical brown pupae amongst the mealybugs, and their remnants. Also look for Cryptolaemus ladybird larvae and lacewing larvae and eggs. Also monitor ant activity.

Action level

Make sure that the damage is serious enough to warrant treatment. At least 25% of sampled fruit need to have one or more large mealybugs to make it worth treating. The decision to act then depends on the activity of natural enemies. Action is recommended when natural enemies are present on less than 20% of sampled fruit (less than 50% from March to May). Action involves either releasing Leptomastix wasps or spraying with an appropriate chemical. For export fruit, it may be necessary to check beneath the calyx for mealybugs (Plate 3).

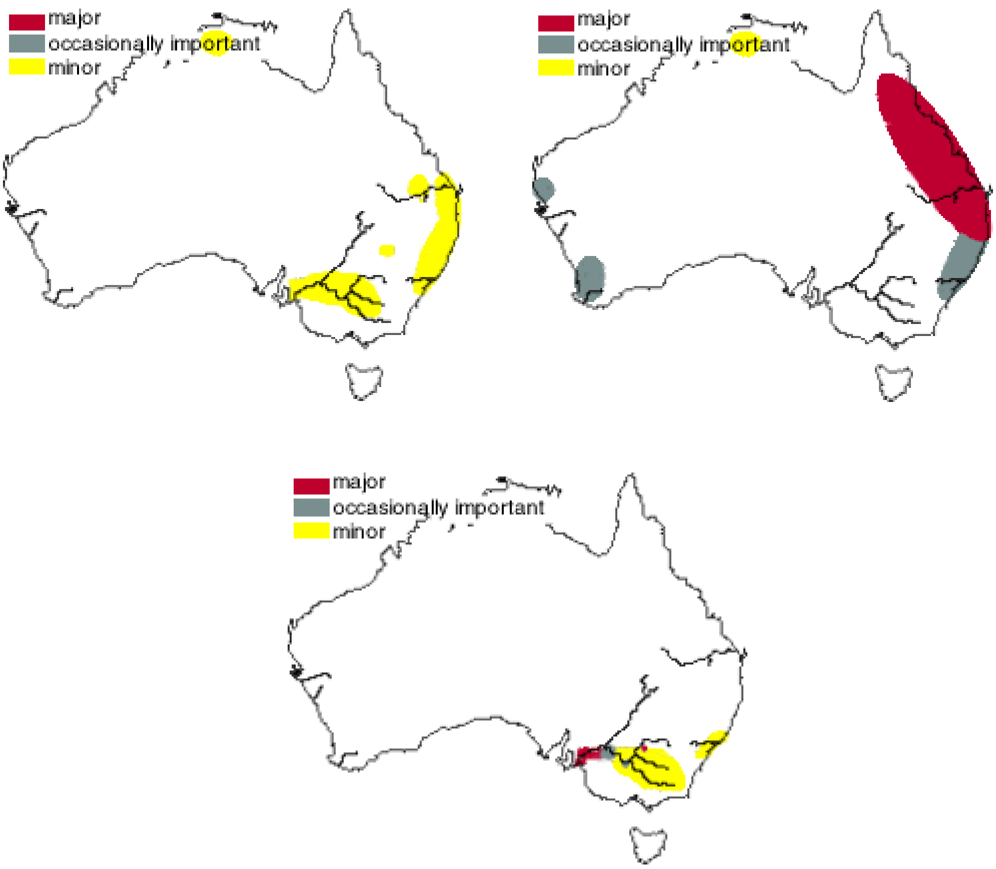


Figure 3. Distribution of mealybug in Australia. Top left: Longtail mealbug. Top right: Citrus mealybug. Bottom: Citrophilus mealybug.


Plate 3. Checking beneath the calyx for mealybugs for export quality fruit.

4.1.6 Chemical control

Methidathion (e.g. Suprathion® 400EC)

Methidathion is a non-systemic, broad-spectrum, organophosphate insecticide for the control of mealybugs in persimmon orchards (PER13694; valid to September 2022). Direct contact is required for methidathion to be effective. Good spray coverage is necessary for achieving good control of mealybug with methidathion, and can be difficult where mealybug are protected by dense canopies, bark crevices or the fruit calyx.

Methidathion can be detrimental to many naturally occurring beneficials and technical advice should be obtained before applying methidathion, particularly if the release of reared beneficials is planned. The timing of an early season (ie December) methidathion application may need to be adjusted to allow a sufficient interval before the release of beneficial predators.

Buprofezin (Applaud®)

Buprofezin (Applaud®) is also registered for use in persimmon for control of mealybug and scale. Applaud® is a safer option than methidathion for the predators. However, there are a few issues associated with its use that requires careful consideration.

Applaud® is an insect growth regulator. The active ingredient, buprofezin (440 grams per litre), interferes with normal growth and development by mimicking the naturally occurring juvenile hormone of insects, levels of which normally fall prior to the moults between stages.
Applaud® only kills juvenile insects when they moult, and is best applied when crawlers and young juvenile stages of are abundant. The effects may take up to two weeks to become apparent. Applaud® will not provide effective control of mixed population of mealybug crawlers and adults.

Applaud® is recommended at 60 mL per 100 litres of water for dilute spraying at about 1,000-1,500 litres per hectare. Applaud® should not be applied more than twice per year in any crop. In most cases a single application will be effective; however, if infestations are very heavy, or persist after spraying, a second spray 14 days later may be required. The withholding period for Applaud® is 14 days

Applaud® should not be applied at least 60 days before the release of mealybug predators (i.e. Cryptolaemus), which means spraying from late October to early December (normally November) when there is no apparent mealybug activity. If fruit spotting bug is present at the same time as mealybug crawlers, the application of the broad-spectrum insecticide, methidathion (Supracide®), will negate the beneficial effects of Applaud® on beneficial predatory insects. Because of possible detrimental effects on *Cryptolaemus*, and the need to spray for fruit spotting bug, the best time to apply Applaud® will be mid-spring, when mealybug crawlers are just starting to become active and before *Cryptolaemus* numbers build up.

There are a number of species of parasites and predators which make a vital contribution to controlling pests of persimmon, and it is important to conserve them. Applaud® has been shown to reduce survival of late stage larvae of *Cryptolaemus* by about 20%, and will be more detrimental to smaller larvae. Adults are not affected, but egg hatch may be reduced for 2-3 weeks.

Adults of other beneficials, including the parasitic wasps *Aphytis*, *Leptomastix* and *Anagyrus*, lacewings and predatory mites are not affected. Juvenile *Leptomastix* and *Anagyrus* inside mealybug treated with Applaud®, however, will be killed.

Think carefully about the timing of Applaud® in your persimmon orchard, and particularly its effects on *Cryptolaemus*. Careful monitoring and inspection of infested fruit is required to detect the very small *Cryptolaemus* larvae likely to be present in spring. Because they look like mealybug they are very easy to miss, and often much more abundant than a quick inspection reveals.

Clothianidin (Samurai®)

Samurai® is a systemic insecticide for the control of mealybug species (PER14779; valid to June 2018). The advantages of Samurai® is it provides long-lasting control, is low impact on beneficial predators and parasitoids, and can control mealybug in protected areas on the tree.

An application at flowering is the optimum time for control of mealybug. For persimmon grown in south-east Queensland, this equates to October ('Jiro') or November ('Fuyu'). Samurai® is applied as a soil drench at a rate of 5 g/tree in a single application per season.

The introduction of Samurai® (4A) has assisted growers in managing pesticide resistance, as clothianidin is of a different chemical group to Applaud® (16) and methidathion (1B).

Samurai® is highly effective in the control of mealybug in persimmon orchards.

Sulfoxaflor (Transform®)

Transform® (4C) is another new product available for the control of mealybug in persimmon (PER80378; valid to March 2022). Transform® is applied as a foliar spray, and has the ability to move across the leaf (ie translaminar). The systemic nature of Transform® enables improved control of mealybug, and overcomes the necessity for good spray coverage and application before mealybug take refuge in protected sites on the tree, as is required for contact insecticides. The relatively short withholding period (7 days) provides the flexibility for a pre-harvest application where monitoring indicates a late season increase in the mealybug population.

A new strategy for the effective control of mealybug consists of a Samurai® soil drench at flowering with the option of a Transform® foliar spray before harvest, where monitoring of mealybug numbers indicates a late season population outbreak.

Chlorpyrifos (Lorsban®)

Application of Lorsban is permitted for the control of mealybug (PER14547).

Critical Use Comments:
Apply initially at petal fall and then 10 – 14 days later. Apply a follow-up application if necessary 2 – 3 weeks prior to harvest.
Ensure thorough coverage of all branches, foliage and developing fruit.
Apply dilute spray to the point of run-off using an accurately calibrated air-blast sprayer or similar equipment.
Use higher application rate at times of high pest pressure.
DO NOT apply more than three (3) applications of chlorpyrifos to persimmons per season.
DO NOT apply if bees are actively foraging.
Withholding Period:
Harvest: DO NOT harvest for 14 DAYS after final spray application.
Grazing: NOT REQUIRED when used as directed.

4.1.7 Biological control

Natural control of citrus mealybug is very important, though not always completely effective. The main parasite is a small wasp (*Leptomastix dactylopii*). Other important natural enemies are the mealybug ladybird (*Cryptolaemus montrouzieri*) and the lacewing (*Oligochrysa lutea*). Natural enemies of minor significance are the small wasp (*Leptomastidea abnormis*), which parasitises second instar mealybugs, and syrphid fly larvae, which feed on young mealybugs.

Leptomastix wasp

Leptomastix are specific parasitoids of the citrus mealybug *Planococcus citri* and will only attack this species. Cryptolaemus beetles are the preferred biological control agent where other mealybug species occur.

Leptomastix wasps originated in Brazil, and are adapted to tropical climates. They perform best at temperatures of 25°C and above. Sunshine and warmth will keep them active.

The Leptomastix wasp is 3 mm long and honey-coloured (Plate 4). The male is slightly smaller than the female. The female wasp parasitises mealybug by inserting a single egg into the body of the mealybug. The developing wasp larva devours the contents of the mealybug, pupates and emerges.

The life cycle from egg to emerged adult takes about three weeks. Leptomastix populations usually decline to very low levels over winter in south-east Queensland, and are slower to increase in spring than the citrus mealybug. For this reason, and if available, we recommend releasing 10,000 wasps per hectare during late-December to late-February.

Be careful with the use of insecticide sprays once wasps are released, as most are toxic to the wasp adults. The young stages, being inside the mealybugs, are usually protected. Where sprays are being applied for fruit spotting bugs, it is best to delay releasing the wasps until one week after the last insecticide spray. Also, do not use insecticides on the day of the wasp release. If spraying is necessary after the release, the most opportune times are one to two weeks after the release and again, if necessary, about four to five weeks after the release. This timing should avoid periods when the successive generations of adult wasps are emerging from the parasitised mealybugs. Where sprays are required for fruit fly, use bait sprays and avoid cover sprays. With bait sprays, avoid releasing wasps on the same day as a bait spray is applied.

Plate 4. Adult and pupae of *Leptomastix dactylopii.*

Cryptolaemus ladybird

The most effective natural enemy of mealybug is *Cryptolaemus montrouzieri*, an Australian native ladybird. For the best control of mealybug, Cryptolaemus should be released at the first sign of mealybug and before the population builds up, causing damage to fruit. Both adults and larvae feed on mealybug eggs and crawlers. The adult ladybird is about 4 mm long, black with orange on both ends (Plate 5). The 10 mm long larvae are white and mealy with long waxy appendages. Younger larvae are often mistaken for the mealybug, but closer examination will show that the ladybird larva has much longer waxy filaments than its host and grows much larger. The life cycle takes about four weeks to seven weeks depending on temperature.

Cryptolaemus adults and larvae survive at temperatures of 16°C to 33°C, but are most active at around 28°C. Cryptolaemus is available for purchase (www.bugsforbugs.com.au), as either adult beetles or larvae. Larvae are ideal for treating mealybug ‘hotspots’, and avoid the likelihood of adult beetles taking flight before laying eggs.



Plate 5. Top left: Adults of the mealybug ladybird (*Cryptolaemus montrouzier*). Top right: white cottony larvae. The larvae resembles mealybug but when mature is much larger. Bottom, close up of larvae of Cryptolaemus.

Release strategy

- Releases of 25 adult beetles per tree guarantee rapid establishment of the predator. Small releases of 5 beetles per tree may suffice to establish the predator but should be done as early as possible to allow beetle numbers to naturally increase and catch up.
- Concentrating releases in mealybug 'hot spots' will improve the level of control and enable the Cryptolaemus population to establish.
- Released beetles spread but do tend to settle where released, if there are mealybugs for them to feed on.
- A release early in the season before mealybugs are present is at risk of failing, as Cryptolaemus beetles are likely to fly off to better food sources. Late season releases when natural populations are high are redundant and probably not very effective in further reducing the mealybugs (and sooty mould) in time for harvest in March-April.
- Releases should be made from mid-January to mid-February on fruit at least 5 cm in diameter and showing some sign of mealybug infestation.
- Releases are best made in the mornings when conditions are neither wet, nor hot and sunny.

After release, it may take 6-8 weeks to bring the mealybug under control.

Lacewings

The green lacewing *Mallada signatus* is available from Buds for Bugs, and is supplied as eggs for release in orchards.

Life cycle
The adult lacewing is a slender, delicate, green insect. Its body is about 10 mm long and its wings, held in a tent-like position when at rest, extend back for a further 10 mm (Plate 6). Its long antennae extend forward about 10 mm. The adult feeds on nectar and honeydew, but the larvae are voracious predators of young scales and mealybugs. Adult female lacewings live for approximately three or four weeks and lay up to 600 eggs. Lacewing eggs are laid singly or in clusters of about a dozen on the surface of leaves or fruit. Characteristically, each egg sits on a long stalk, so they are easily identified. The eggs take approximately four days to hatch. The young larva is soft bodied, spindle shaped and has a pair of prominent sickle shaped jaws. Larvae range in size from 1 mm at first emergence up to 8 mm just before they pupate. Larvae pass through three moults over a period of 12 days before pupating inside a silken cocoon. Adults emerge after nine days and start laying eggs seven days after emergence. After it has devoured its prey, the remnants of the meal are attached to its back and soon the lacewing larva looks like a fluffy white mound 5 mm or more in diameter. The life cycle takes about three to four weeks.

Target pests
- Aphids (various species)
- Two spotted mite *Tetranychus urticae*
- Greenhouse whitefly (*Trialeurodes vaporariorum*)
- Scales (various species)
- Mealybugs (various species)
- Moth eggs and small caterpillars

Suitable crops/environments
The green lacewing is one of the most common and widely distributed native lacewings in Australia. It is well suited to a wide variety of crops and habitats, including greenhouses, and is most active in warm climates. Lacewings are probably best suited to tree and shrub crops. Adult lacewings feed on nectar and pollen, so the presence of flowers after release will assist in keeping the lacewings within the crop. Cool temperatures slow down green lacewing activity and may initiate diapause (hibernation).

Before release (following information is supplied by Bugs for Bugs, with permission)
Lacewings should be released before pests can reach damaging levels. As with other beneficial insects, it is better to release them earlier rather than later. Do not use residual pesticides within three to four weeks of release.

At release
Lacewings are despatched as eggs and larvae should emerge during transit. Eggs are packed with lucerne chaff, in lots of 100 or 500, and are accompanied by a small quantity of sterilised moth eggs for food. Once the larvae begin to emerge, they should be dispersed by placing the lucerne chaff containing the larvae into the crop.

Recommended release rates
Release rates vary considerably depending on the crop, the pest to be controlled and its density. For large areas, we suggest a minimum of 2,000 lacewing larvae per hectare. The number of lacewings needed for an individual situation can be determined after consultation with the suppliers.

Plate 6. Top left: Lacewing eggs (Photo: Dan Papacek). Top right: Newly hatched lacewing larvae. (Photo: Denis Crawford). Middle left: A lacewing larva - note the prey remains attached to its back as camouflage. Middle right: Adult lacewings. Bottom left and right: Adult lacewings.

It is best to release larvae in pest ‘hot spots’, to ensure larvae have and immediate food supply. It is preferable to make two or three releases 10 - 14 days apart to establish constant larval populations of green lacewings in the field. Larvae take about 12 days to develop before they pupate in cocoons. After this time, there will be few lacewing larvae in the field, as it takes 16 days before adults emerge and lay eggs.

A second release of lacewings should be made 12 days after the initial release to ensure additional larvae are present while the first generation completes its development. Specially designed release boxes are now available to assist lacewing establishment (Plate 7). They are recommended in many situations to facilitate easy access to the crop for emerging lacewing larvae.

Since lacewing larvae camouflage themselves with dead prey items, some practice is needed to find them in the field. Normally they are more mobile than the pest, and can often be seen moving over plant leaves and stems. The lacewing cocoons are usually well hidden and difficult to find. Adults fly at night and are attracted to lights, so avoid leaving lights on at night.

Cultural practices to aid establishment
Adult lacewings will persist in the crop if nectar and pollen are present. Practices such as strip intercropping and encouraging flowering plants will give best results.

Chemical use
Little is known about insecticide toxicities to lacewings. It is reasonable to assume that unless the pesticide is specific to one particular group, for example a miticide; it will have some sort of harmful effect on lacewings.

Plate 7. Lacewing release box allows larvae easy access to the host tree (Photo: Dan Papacek, Bugs for Bugs).

Anagyrus agraensis

Anagyrus parasitises first or second stage mealybugs, and emerges from either fully grown juveniles or adults. The adult wasps are about 2 mm long, and produce ‘mummies’ similar to those of Leptomastix (Plate 8). The mummies are the brown pupal cases of the Anagyrus which are formed inside the devoured mealybug. There is one pupal case per mealybug. Anagyrus is quite common in persimmon, but is thought to be not as effective as Cryptolaemus or Leptomastix.

Plate 8. *Anagyrus agraensis* a parasite of mealybugs.

Diadiplosis koebeli

Diadiplosis koebeli is a small midge from the fly family Cecidomyidae. Diadiplosis is probably an under-rated predator, with recent evidence indicating that this tiny midge (about 2 mm long) can be quite effective in controlling high populations of mealybug. The fragile adult flies (Plate 9), which have grey-black wings and a reddish body, probably do not feed, and are easily overlooked. The numerous, tiny red eggs are laid amongst the mealybugs on the fruit. The number of eggs laid is not known, but is probably around 100 per female. Legless maggots hatch from the eggs within a few days, and at first probably feed on small mealybugs, but extend their feeding to older mealybugs as they grow. The mature larvae pupate amongst the mealybugs (Plate 9), often in large numbers, and it is from these that the adults emerge to mate and continue their life cycle.

Other beneficials

Other beneficials reducing mealbug numbers include tree frogs and spiders.

4.1.8 Orchard management strategies

Control ant movement and populations

(see Section 4.2)

Skirting

Trim lower branches up off the ground in winter and again in mid-summer (Plate 10) to reduce ant access to the fruit.

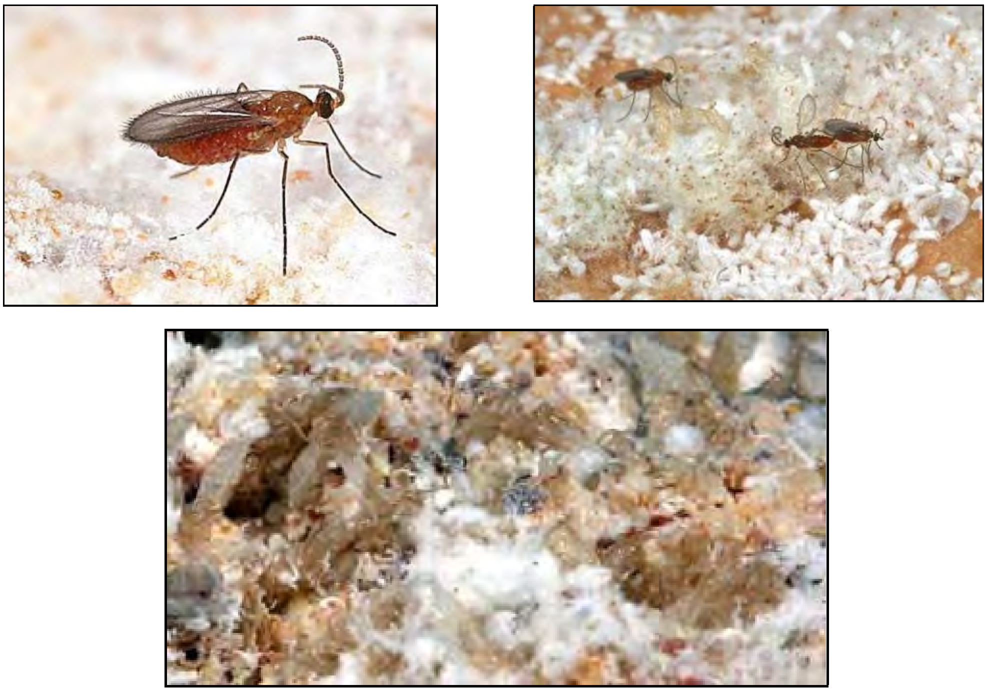


Plate 9. Top left: Adult predatory *Diadiplosis* midge sitting on mealybugs. Top right: Mating adult midges - shows the empty, light brown pupal cases. Bottom: Close-up of numerous light brown and grey pupal cases from which *Diadiplosis* midges emerged.

Plate 10. Persimmon tree skirted to prevent ant movement into the tree.

Brushing of fruit

While brushing or using pressurised air will easily remove mealybugs after harvest, sooty mould cannot be easily removed. When a fruit becomes infested with about 10 or more adult female mealybugs, the combination of mealybugs and sooty mould will usually result in downgrading of the fruit after harvest.

4.2 ANTS

4.2.1 Damage

Mealybugs and scale

Persimmons are very susceptible to mealybug and scale infestation. Infestation occurs under the fruit calyces. In some cases, mealybugs and scale may cover the entire fruit surface. During summer, the life cycle of the mealybug takes about 4 to 6 weeks. In Queensland, there are about 6 generations of the mealybug per season whilst in southern States there may only be four or five. Over about a fortnight, the mature female lays up to 600 eggs in a loose cottony mass. Mealybugs are normally found from mid-November onwards with reasonable populations tending to build up by mid-December. Higher populations seem to be building up earlier in recent years. If left untreated, very high populations may be present by mid-January.

Honeydew

Honeydew secreted by mealybugs and scale is a favoured food source for several common ant species. Ants entering persimmon canopies in search of honeydew will interfere with the predators and parasites that are seeking out and destroying the mealybugs and scale species, defending the honeydew-producing pests from attack. The ants tend the mealybugs and scale for their honeydew (Plates 1 and 2).

Ants move the mealybugs around, even from tree to tree, and fend off the mealybugs' natural enemies. Fruit touching the ground is often covered with tunnels of dirt from ant activity. Although ants remove some honeydew and dead scales from trees, and occasionally carry live scales back to the nest for food, these potential benefits are generally outweighed by the detrimental effects of high ant populations.

Ants do not cause direct damage to persimmon in Australia. However, some species of ants, at high densities, can severely disrupt integrated pest management (IPM) programs, particularly those directed towards the control of honeydew-producing insects and sooty mould. They move the mealybugs around, even from tree to tree, and fend off the mealybugs' natural enemies. Fruit touching the ground is often covered with tunnels of dirt from ant activity.

Plate 1. An ant searching for honeydew produced by green coffee scale.

Plate 2. An ant tapping hemispherical scale with its antennae. This induces the scale to produce honeydew.

Sooty mould

By protecting honeydew producers, ants also contribute to the development of sooty mould. Sooty mould results when fungi grow on the honeydew, forming a superficial coating of dark fungal growth on twigs, leaves and fruit. While not normally a serious problem, it can prevent fruit from colouring normally. Fruit may also need to be washed, which only partially removes the sooty mould, and also adds to costs.

Economic damage

It should be noted that if ants can be properly managed, populations of scales and mealy bug can be reduced by 80%.

4.2.2 Species and description

There are many local and introduced species of ants in Australia. The main species affecting persimmon are the coastal brown ant (*Pheidole megacephala*) and the black house ant (*Iridomyrex glaber*) (Plate 3). Workers of the coastal brown ant are 1.5-2.5 mm in length and soldiers 3.5-4.5 mm in length. They are shiny light yellowish brown to dark brown in colour. In areas where they are present, they seem to out-compete other ant species due to their aggressive behaviour and large colonies

Coastal brown ants travel in trails from the nest to food. The ant has four castes or body forms. The largest form is the queen, which lays eggs. Unfertilised eggs produce males and fertilised eggs produce females. There are many queens in coastal brown ant nests. Males are the next largest form and are elongated in shape. By far, the most numerous forms are the workers. Workers are sterile females who care for the young, collect food, build and defend the nest (Plate 4). There are two worker castes, a more numerous form with a small head and the other less numerous with a large head. The large headed form defends the colony and is sometimes known as the soldier caste.

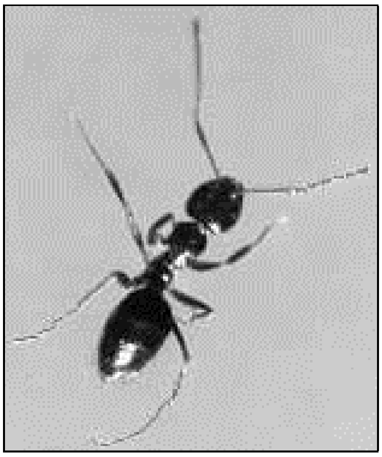


Plate 3. Left: Coastal brown ants (*Pheidole megacephala*) minor and seed crushing workers. Right: black house ant (*Iridomyrex glaber*)

4.2.3 Life cycle

This ant has a complete life-cycle, and developmental time and longevity of each stage is highly dependent on temperature. Incubation time of eggs ranges from13-32 days. Duration of the larval stage ranges from 23-29 days. Duration of the pupal stage ranges from 10-20+ days. Lifespans of minor workers have been shown to be 78 days at 21°C, and 38 days at 27°C (Hoffmann, CSIRO).

The coastal brown ant differs from the generalised life history of other ants in one important exception. This species does not have a mating flight as mating occurs within the parent colony. Wingless queens accompanied by workers carrying larvae and pupae walk to a new nest site, which is quite close to the original nest.

Plate 4. Ants nest at the base of a fruit tree.

4.2.4 Importance and distribution

The coastal brown ant *Pheidole megacephala* is one of the world's worst invasive ant species. The ant is thought to have originated in southern Africa and has now spread all over the Old

World tropics and into many temperate areas. In Australia, the ant has long been established along the east coast of Australia.

The coastal brown ant avoids bright sunlight and prefers lower temperatures and high humidity. As a result, the ant is more numerous in moist shaded areas. When temperatures are high workers forage only at night. Covered galleries or runways made of soil and organic matter are constructed on the trunks of shrubs and trees. This allows workers to travel up and down the trunk without being exposed to the high temperatures and lower humidities outside the runways. Heavy rainfall and waterlogged soils are unfavourable to the coastal brown ant. Ant activity and populations are lowest during the wet season.

Ants have a preference for fatty foods but will attack seeds, meats, insects, fruit, honeydew from aphids, sweet foods, fats and grease. Adults cannot ingest solid food particles but ingest liquids which are pressed out of food material. Larvae depend entirely on workers for food. Young larvae are fed in liquids; the older larvae are fed on small food particles which they can ingest. Adults will also feed on excretions from larvae

Soft scales, mealybugs, whiteflies, plant hoppers and aphids excrete honeydew, a sugar-rich solution derived from the plant sap on which they feed. This honeydew is a favoured food source for several common ant species. Ants entering persimmon canopies in search of honeydew will interfere with the predators and parasites that are seeking out and destroying pest species, defending the honeydew-producing pests from attack.

Although ants remove some honeydew and dead scales from trees, and occasionally carry live scales back to the nest for food, these potential benefits are generally outweighed by the detrimental effects of high ant populations. High ant densities can greatly reduce the levels of parasitism and predation, while low ant densities do not appear to have much effect.

By protecting honeydew producers, ants also contribute to the development of sooty mould. Sooty mould results when fungi grow on the honeydew, forming a superficial coating of dark fungal growth on twigs, leaves and fruit. While not normally a serious problem, it can prevent fruit from colouring normally. Fruit may also need to be washed, which only partially removes the sooty mould, and also adds to costs.

4.2.5 Monitoring

Monitoring should be carried out from September to May in all States Trees should generally be examined during the warmer part of the day, although there is evidence that certain ant species are active at night.

Action level

When ant populations are very high, the numbers of soft scales, in particular, increase dramatically. Action should be taken to control ants if they are present on 50% or more of shoots examined for scales, mealybugs or other pests.

4.2.6 Chemical control

No chemicals permitted or registered

Baits

Sticky bands

Sticky bands are applied to the base of the tree to prevent ant movement up the tree (Plates 5 and 6). An inert sticky band (e.g. Stickem or Tac-gel) applied around the lower trunk will reduce ant numbers. It should not be exposed to full sunlight. Direct contact of Stickem or Tac-gel with the bark of trees can be avoided by first wrapping an area of straight trunk with 100 mm wide soft polyester fibre padding, allowing a 20-30mm overlap. The padding fastened in place with thumb tacks. The padding is then covered with two or three lightly wrapped layers of polythene film. (Do not apply the polythene film directly to the bark surface). Strips of Stickem or Tac- gel are then applied to the polythene film to provide continuous bands around the trunk. Although barrier application is an extremely labour-intensive process, some barrier types will provide at least three years' protection from *Iridomyrmex* spp.

4.2.7 Biological control

Although ants may be parasitised by other insects such as strepsipterans and pteromalid wasps, there are currently no effective biological control agents available for controlling the ant species associated with persimmon in Australia.

Plate 5. Stick gels applied to the trunks of fruit trees to prevent ant movement. Wadding is first wrapped around the trunk, covered with polyethylene cling wrap and then a narrow band of gel is applied on top of the cling wrap around the trunk of the tree.

Plate 6. Stick band trap to prevent ant movement into the tree.

4.2.8 Orchard management strategies

- Physical destruction of ant nests.
- Skirting of trees.

4.3 CLEARWING MOTH

4.3.1 Damage

The 10-15mm long, creamy white larvae tunnel under the bark, but do not bore into the wood (Plates 1). They cause severe lesions to develop in the crotches of limbs. In severe cases, branches are girdled at the point of attachment to a larger branch or the trunk, and the weight of maturing fruit or strong wind snaps them off. Successive generations of larvae continue to tunnel in old wounds and trees can eventually be killed. Clearwing moth larvae create dark, moist frass under damaged bark. The larvae pupate in the bark tunnels and wasp-like adults mostly emerge in spring. Adults have also been found emerging in autumn.

Plate 1. Clearwing moth larvae under bark

4.3.2 Species and identification

The species identified in persimmon in Queensland and northern NSW is *Ichneumenoptera chrysophanes* (previously named as *Carmenta chrysophanes*) (Plate 2). Borer species present in Victoria and South Australia are not known. They may be clearwing moths. Futher studies are needed to correctly identify these species.

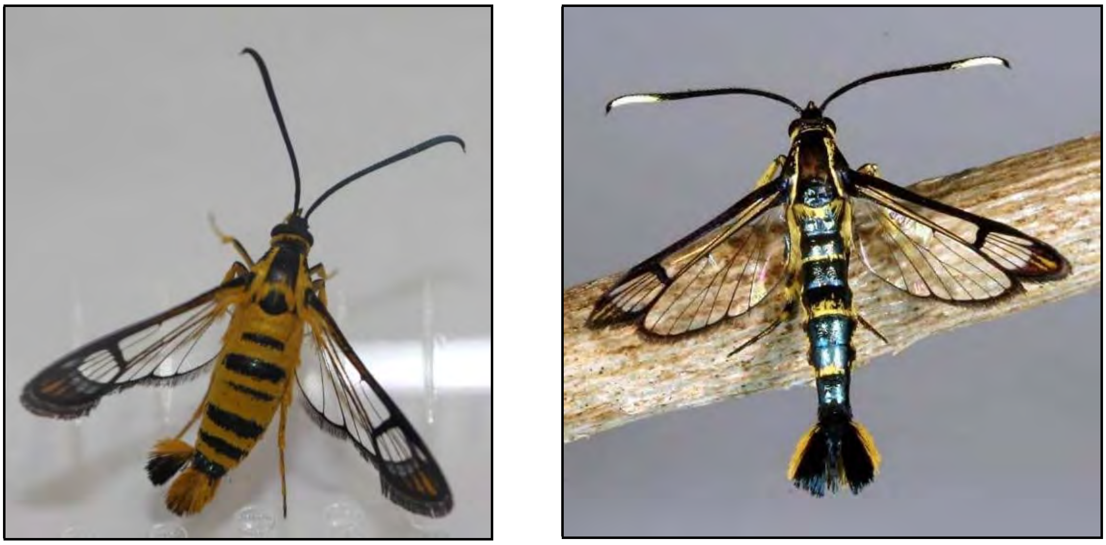


Plate 2. Left: female clearwing moth. Right: male clearwing moth (*Ichneumenoptera chrysophanes)*.

4.3.3 Life cycle

Little is known about the life-cycle of clearwing moth. The larvae are 10-15mm long and creamy white in colour (Plate 3).

Plate 3. Larvae of clearwing moth *(Ichneumenoptera chrysophanes)*.

4.3.4 Importance and distribution

Various species of borer moth have caused, and continues to cause, alarming damage to persimmon trees in eastern Australia and South Australia. Persimmon trees can be completely killed by the borer moth larvae ring-barking the trunk below the graft, and/or branches severely damaged by larvae tunnelling around the crotches. Cultivars attacked vary between orchards and at this stage no cultivars or rootstocks can be considered resistant.

Hosts

Alternative hosts for clearwing moth include: bark of red ash (Alphitonia excelsa RHAMNACEAE), the bark of gum trees (*Eucalyptus* spp. MYRTACEAE), branches of figs (Ficus MORACEAE), galls of native cherry (*Exocarpus cupressiformis* SANTALACEAE). This is undoubtedly an incomplete list, but represents very common species.

Varietal variation

Based on grower surveys, about 50% growers reported no incidence of clearwing moth, whilst 19% reported very high infestation (>80% trees damaged). More specifically, only 5% of 'Jiro' growers reported very high incidence (>80% trees damaged), whilst over 50% of 'Izu' growers reported very high incidence.

In terms of both incidence and severity of clearwing moth damage, 'Izu' is highly susceptible to clearwing moth, 'Fuyu' moderately susceptible and 'Jiro' mildly susceptible (Figure 1). Izu may be more susceptible because of its rough bark.

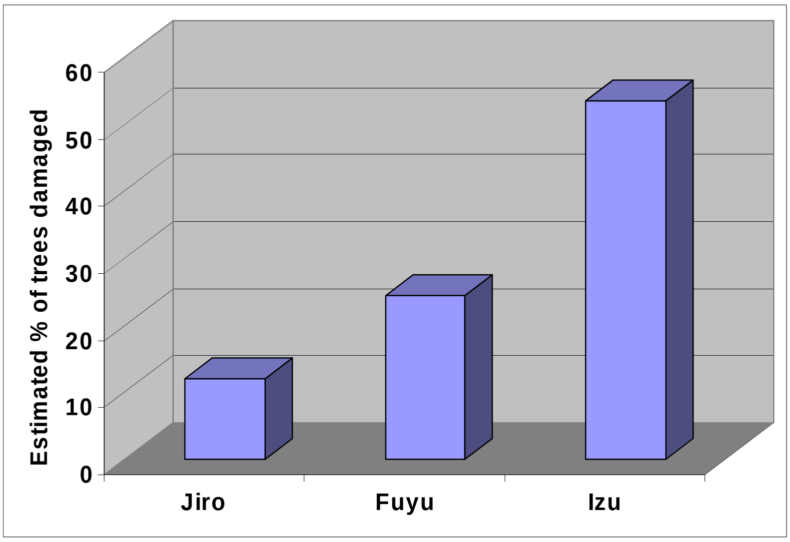


Figure 1. Varietal differences in incidence of damage due to clearwing moth. Mean of all orchards in all regions.

When highly susceptible cultivars, such as 'Izu', are grown in the same orchard as less susceptible cultivars, the incidence and severity of clearwing moth damage increases in the less susceptible cultivar by two- to three-fold (Figure 2). Therefore, we strongly advise, that in high infestation regions, that 'Fuyu' or 'Jiro' be planted alone.

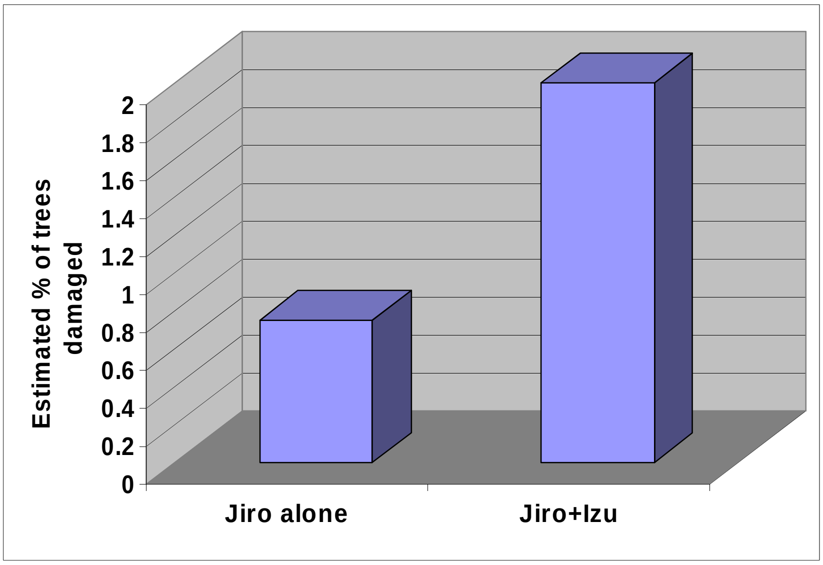


Figure 2. The effects of growing selected varieties together in the same orchard on incidence of clearwing moth damage.

Regional differences

Growers in several regions of Australia including north-east Victoria, north-west Victoria (Sunraysia district) and Western Australia reported no incidence of clearwing moth. Central NSW reported only a low level of incidence. High levels of infestations (species unknown) were reported in south-east Queensland and South Australia (Riverland) (Figure 3). We suggest that the pest may not have spread to the infestation-free regions of Western Australia or, alternatively, that climatic conditions in these regions are not suitable for the pest to breed and multiply. If the former is the case then it will be important to maintain exclusion of the pest from the pest-free regions by: careful scrutiny of new planting material brought into these regions from nurseries from pest-infested regions; yearly monitoring and early intervention to prevent any potential pest outbreaks.

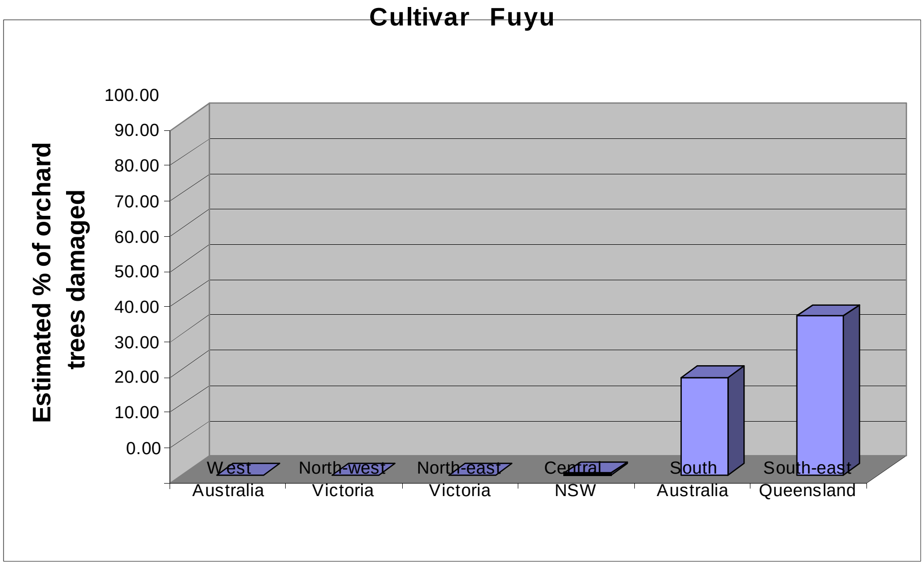


Figure 3. Regional differences in the incidence of clearwing/borer moth damage.

Within regional variation

There also appears to be large variation in severity of infestations between orchards even within a district/region as indicated by trap catches. Vickers (2002) reported up to an 8-fold difference between orchards at Palmwoods and Amamoor in south-east Queensland.

Climatic factors

Temperature appears the controlling factor affecting rate and timing of development stages of the moth. Compared with temperate fruits and plantation trees such as ash, where there is only one distinct peak in moth numbers in spring-early summer, it appears with persimmon clearwing moth that there are at least four major peaks in moth numbers occurring in about the same time periods each year in south-east Queensland:

- Mid spring (mid September – mid October)
- Mid summer (early January – late January)
- Early autumn (mid-February - early March)
- Early winter (mid-May - early June)

Spring temperatures of <8°C may delay the first cycle of pupal emergence and that cold autumn temperatures may also reduce the late autumn/early winter flight activity (Figures 4). Frost may also reduce egg and pupal survival.

Tree age

Growers observed damage on cultivar 'Izu' 2 to 3 years earlier than 'Fuyu' or 'Jiro', presumably because of the greater attraction and susceptibility of this cultivar to clearwing moth. It seems that clearwing borers build up about 5 years after an orchard is planted. Initial infestation rates are slow then increase rapidly.

It appears that control of clearwing moth borer is easier on smaller and younger trees, possibly because the bark has not been lignified too much so there is better spray penetration. It highlights the need for early intervention and control when trees are less than 4 years of age.

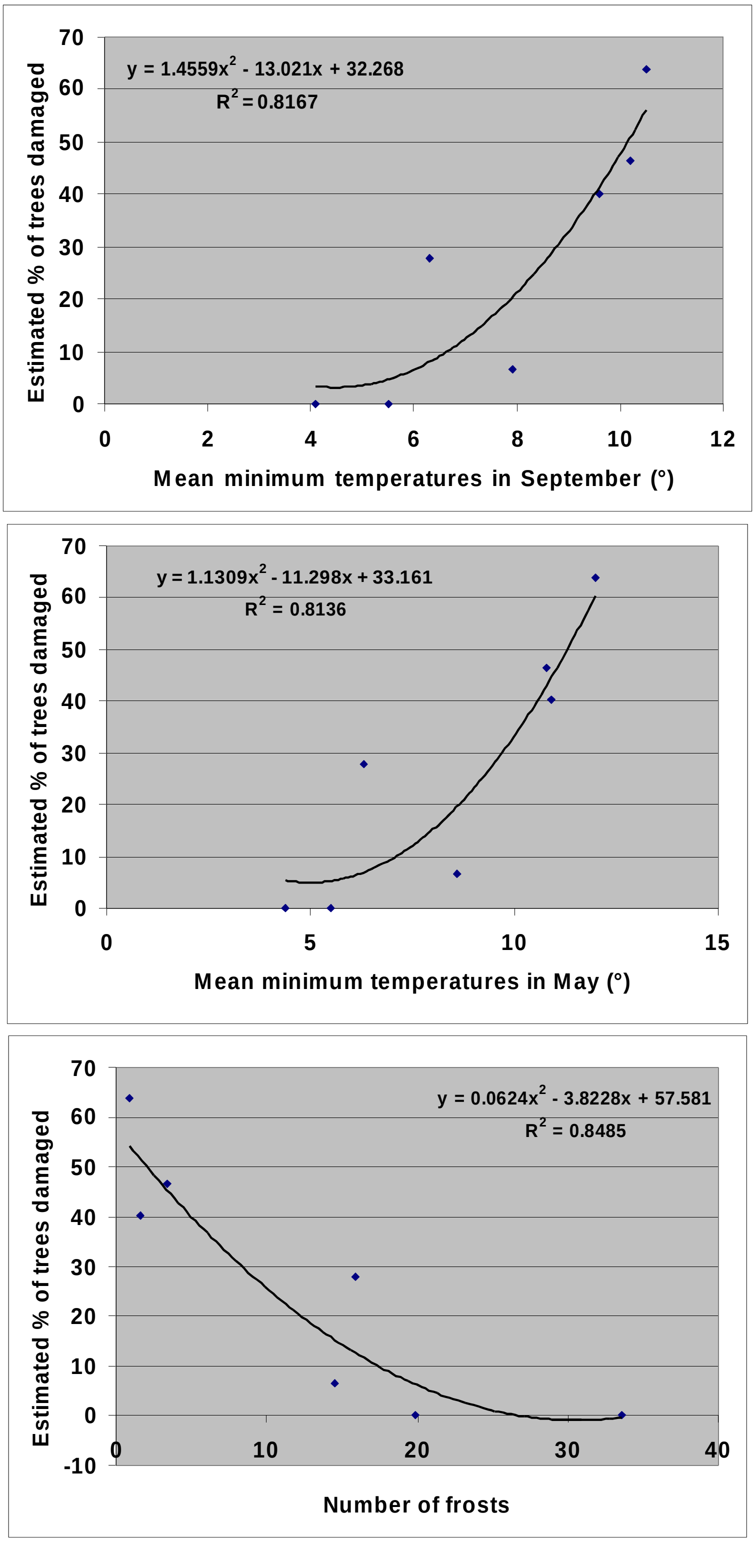


Figure 4. Relationship between clearwing moth damage and mean monthly temperature during September and May and no. of annual frosts.

4.3.5 Monitoring

Activity of clearwing moths can be monitored by using traps containing pheromone attractant (Plate 4). Seasonal flight patterns in south-east Queensland are shown in Figure 5.

Plate 4. Sticky trap placed in a persimmon orchard. Clearwing moth trapped in sticky trap.

We suggest that depression in flight activity in mid-summer may be due to high temperatures or heavy rainfall adversely affecting flight movement. Studies on the other clearwing species has shown that moths are killed during period of heavy rain. Under warm subtropical conditions, moths may be present all year round.

The spring flight peak highlights the need to control moths during this period as well as in early autumn and late autumn/early winter. Early spring applications of pheromones or insecticides are warranted. If applied too late, they will be ineffective and a large infestation will ensue. It also highlights the need to use monitoring traps on individual farms to correctly time pheromone applications for seasonal, regional and between orchard variations.

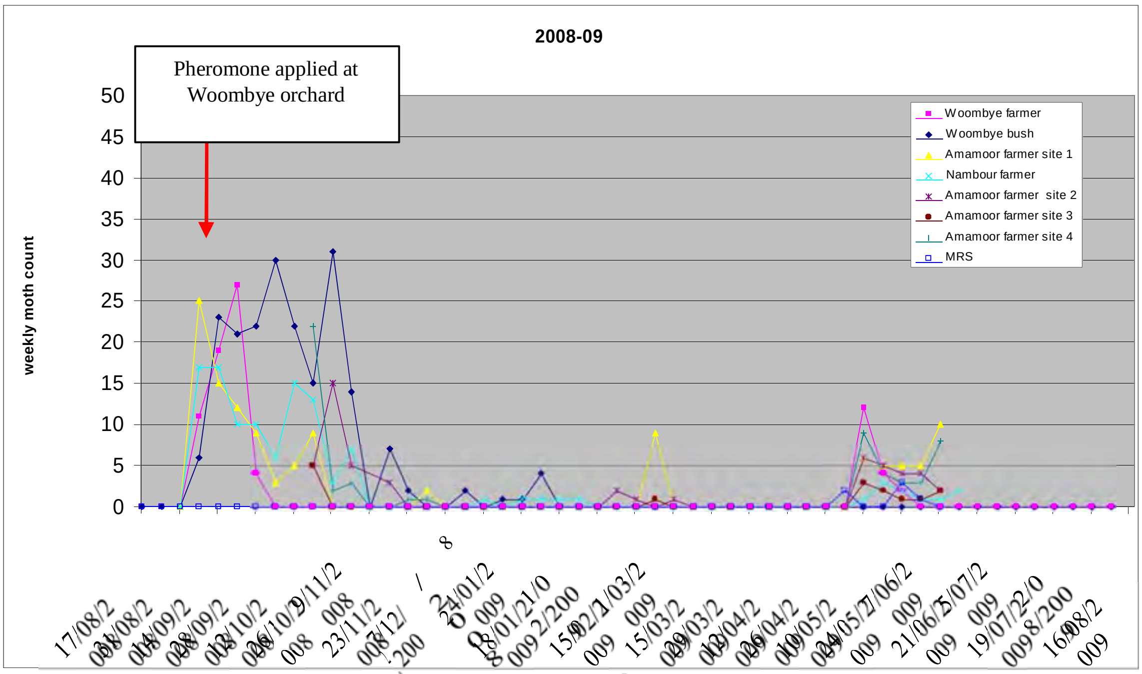


Figure 5. Seasonal flight patterns of adult clearwing moth in in south-east Queensland in 2008-09. Trapping was done on commercial persimmon farms and in isolated bush sites.

4.3.6 Chemical control

Mating disruption

Mating disruption relies upon the release of large quantities of synthetic sex pheromones to prevent males from finding females, resulting in unmated females either laying infertile eggs or none at all. Clearwing moths have been shown to be quite susceptible to mating disruption using pheromone dispensers. Significant reductions in both male moths and larvae were demonstrated in treated orchards with pheromone dispensers compared with the untreated (Vickers, 1997-2000). Although uptake of the dispensers by growers in southeast Queensland was initially quite promising, it appears that few, if any, growers are currently using pheromone mating disruption as a means of control. Efficacy of pheromones on borer species present in South Australia and Victoria is not known. Further studies are needed to correctly identify the species of these regions.

Many growers found that a single application of pheromone was ineffective in reducing infestations of clearwing moth compared with no applications. In contrast, growers who applied the pheromones twice during the season achieved near 100% control (Figure 6). They applied the first dose in September and the second in January. It is advisable to replace the pheromone dispensers (Shin-Etsu Carmenta MD Pheromone) after 90 days, and particularly where trap counts indicate continued clearwing moth activity in the orchard. Placing pheromone dispensers at the edge of native bush adjacent orchards is likely to enhance the mating disruption effect within the orchard, particularly for orchards less than three hectares in size.

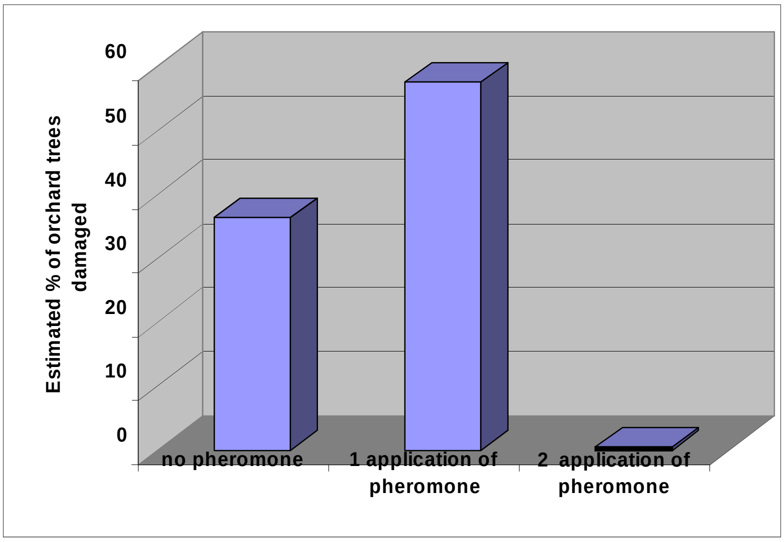


Figure 6. Effects of pheromone application on incidence of clearwing moth damage.

Place pheromone dispensers (Plate 5) in every tree for ‘Izu’ and ‘Fuyu’ and every second tree, staggered down each row for ‘Jiro’. The number per hectare will depend on tree and row spacings, but it is recommended that between 1,000-1,500 dispensers be used per hectare.

Plate 5. Pheromone impregnated dispenser.

High pressure water blasting

Grower experience has demonstrated high pressure water blasting during dormancy to be very effective in reducing the incidence of clearwing moth damage. The aim is to remove loose bark and reduce infestation sites on the tree for clearwing moth, Water blasting of trees every second winter is sufficient in all but very heavy pest pressure situations. The technique is to be used in combination with pheromone dispensers for mating disruption.

An effective unit for water blasting can be achieved with a 5 HP Honda-powered Karcher GH2500OH, with turbo head nozzle at 2500 psi (Plate 6). Water for the Karcher was supplied via the orchard irrigation system.

Plate 6. Treating trees with high pressure water (left) and a branch crotch with bark removed after treatment, showing clearwing moth damage (black area).

A summary of control techniques and their timing is presented in Table 1.

TABLE 1. *Suggested control schedule*

Growth stage	Date	Treatment	Comments
Dormancy	July	Remove loose bark with high pressure water.	Check all trees in orchard for damage; mark those that have obvious damage.
Early spring	Late August	Place pheromone traps in orchard – four per orchard, record the number of male moths weekly for the duration of the growing season.	Suggest traps are placed at the edge of native bush adjacent the orchard.
Early spring	Early September	Place first lot of pheromone dispensers in orchard (1000-1500 per hectare)	Mating disruption
Mid-summer	January	Place second lot of pheromone dispensers in orchard, leave first lot in place	Mating disruption

4.3.7 Biological control

Entomopaghous nematodes

Preliminary spray trials by Mr Henry Drew in the early 1990's showed that entomopaghous nematodes (*Steinernema feltiae*) at rates of 5-10 million applied to persimmon trees in August could infect larvae and achieve 20-30% mortality. New spray additives which improve nematode survival warrant further investigation.

Braconid wasps

Braconid wasps (Plate 7) have been observed to parasitize up to 80% of the larvae of clearwing moth in south-east Queensland. The wasps are active in the late spring. However, their rate of build up may occur after some damage by the clearwing moth larvae has occurred. It may be feasible to mass rear and release this species into the field at the appropriate times. This possibility should be investigated in the future.

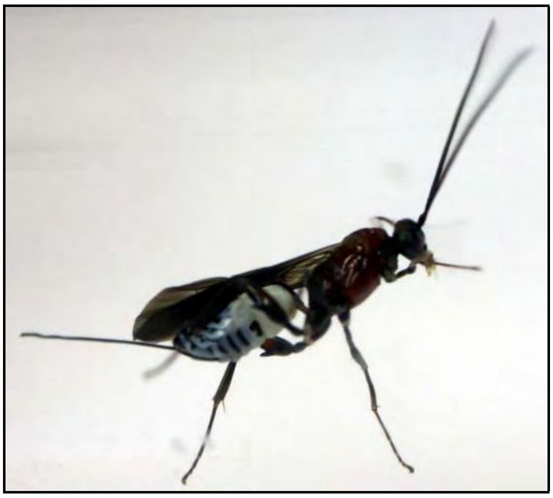


Plate 7. Braconid wasp parasitise larvae of clearwing moth.

4.3.8 Orchard management strategies

Irrigation system

Trees irrigated by drippers are more susceptible to clearwing moth attack that sprinkler- irrigated trees. Drip-irrigated trees may be more stressed, subsequently releasing phyto- chemicals such as ethylene and abscissic acid that may attract the moth. An alternative explanation is that stress has caused bark cracking making more sites suitable for egg laying.

Orchard Netting

Small mesh netting appears to reduce incidence of clearwing moth damage by nearly half and severity of damage by about 40% (Figure 7). Presumably this response is due to restriction of flight of gravid moths. We suggest that quad net with double cross hair strands should be used in high infestation regions to exclude moths.

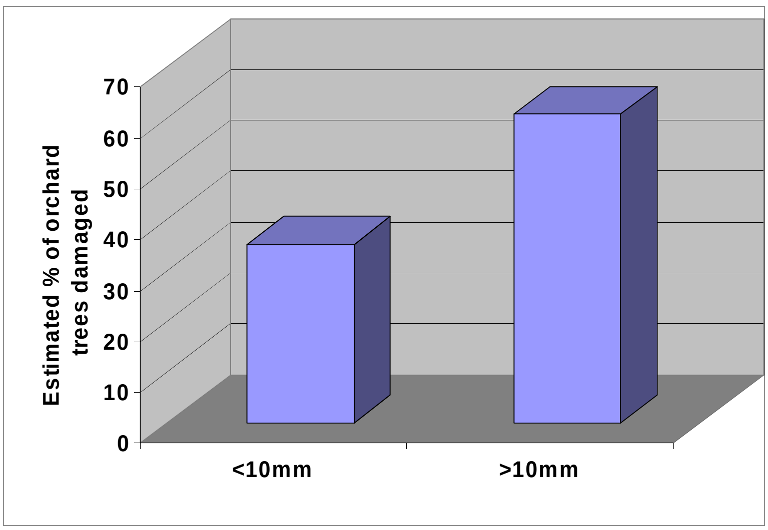


Figure 7. Effects of netting size on incidence damage in cultivar ‘Fuyu’ in infested regions only.

Removal of host trees

Many persimmon orchards are close to alternative host tree species such as *Eucalyptus* spp. Removal of alternative host trees within 50-100 metres of a persimmon orchard is likely to reduce clearwing moth pressure, however may not be possible in many situations due to tree clearing laws.

Topworking and grafting trees in the field

Top-working trees in the field can result in a surge of infestation of clearwing moth, with moths attracted to the tree stumps. This response is presumably due to the release of stress hormones by the tree.

Time of pruning

Winter pruning may elicit the same wound response as top working and that time of winter pruning may also be important given that there may be a late May/early June emergence of moths. We suggest that it be advisable to delay winter pruning until July/August the coldest months of the year.

SUMMARY

- Clearwing moth is a serious pest of persimmon grown in subtropical areas. Borer damage observed on persimmon trees in temperate areas is due to an as yet unidentified pest species.
- All varieties are susceptible to clearwing moth. ‘Izu’ is highly susceptible; ‘Fuyu’ is moderately susceptible and ‘Jiro’ has low susceptibility.
- Avoid planting ‘Izu’ with other varieties in the same orchard. Damage levels in ‘Jiro’ and ‘Fuyu’ are greater when planted alongside ‘Izu’.
- Mating disruption provides effective control of clearwing moth. Apply pheromone dispensers (Shin-Etsu Carmenta MD Pheromone; PER13176 valid to Sept 2020) in September and January, a frequency of one per tree for ‘Izu’ and ‘Fuyu’, and one every second tree for ‘Jiro’.
- Use high pressure water to remove loose bark and reduce sites for clearwing moth infestation. Treat trees during dormancy in every second year. The technique must be used in combination with pheromone dispensers for effective control.
- Use traps to monitor clearwing moth numbers throughout the growing season. Install traps before budburst. Check traps weekly. Record and graph numbers to determine peak activity periods.
- Clearwing moth damage is often increased following top working.
- Quad netting will reduce severity of infestation by exclusion of moths.
- Use of under-tree sprinklers, compared with drip irrigation, to reduce severity of infestation.
- Delay winter pruning to the coldest months when clearwing moth is not likely to be active.

4.4 BLACK SCALE

4.4.1 Damage

Heavy infestations can reduce tree vigour, and extensive sooty mould growth can reduce photosynthesis. However, the most significant effect is downgrading of fruit quality due to sooty mould.

- Fruit/calyces Superficial blemish from sooty mould
- Leaves Heavy infestations can cause leaf drop
- Twigs Heavy infestations can cause dieback

4.4.2 Species and description

Saissetia oleae. The mature female scale is dome-shaped, 3-5 mm long and black or dark-brown. Ridges on the back form a raised H-pattern in most stages (Plate 1). Young adults are dark mottled-grey, and are softer and less leathery than the mature adult. Male scales are more elongated than the females, and are not often seen. Black scale may be confused in the juvenile stages with citricola, hemispherical and soft brown scales. The characteristic H-pattern on the back becomes evident after the second moult in black scale. When reproducing, the scale is raised and rounded, and the H-pattern is less distinguishable.

Plate 1. Black scale with characteristic raised H pattern shell.

4.4.3 Life cycle

The female lays an average of about 2 000 pink eggs under her body. The newly hatched crawlers settle after a day or two on leaves, usually near the midrib or on young shoots. Where there are two generations per year, hatching occurs in December-January and again in autumn, but overlapping can occur. The second generation produces fewer eggs. Two nymphal (juvenile) stages are occur before the young adult is formed after two to three months. The scale cover is soft in the young adult, but later becomes more rigid and darkens. After the second moult, young scales move to the twigs where they settle permanently, except for the autumn generation which matures on the leaves. The life cycle takes 4 to 8 months in southern districts but is shorter in Queensland. Two generations occur each year in southern districts, and three to four in warmer northern districts.

4.4.4 Importance and distribution

Black scale is the scale most commonly found in persimmon orchards. The pest is widespread throughout all persimmon growing regions (Figure 1). The scale can be found on green twigs, leaves and young fruit. As they mature, the scales usually move off young fruit. Black scale infests a wide range of hosts. Commercially grown crop hosts include citrus, olives, custard apples, duboisia, peppers and ornamentals such as gardenias and oleander. Black scale is believed to be native to Africa, but now occurs throughout the world.

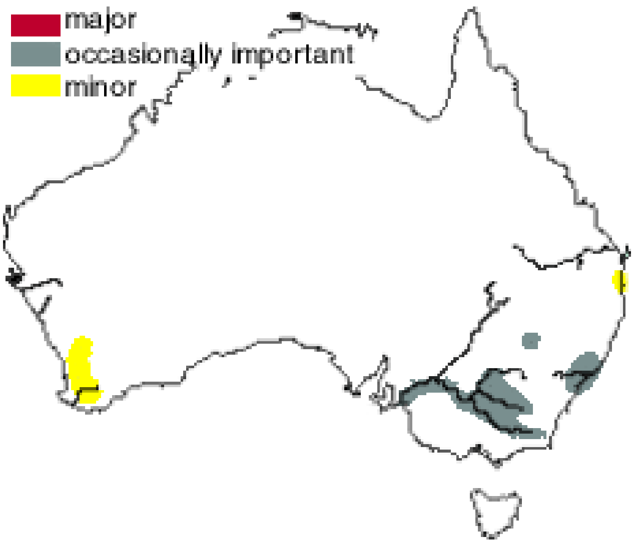


Figure 1. Distribution of Black Scale in Australia.

4.4.5 Monitoring

Select at least 20 trees per hectare at random and check for presence/absence of scale on 10 randomly selected twigs per tree. The number of trees from which samples are taken depends on block size. Additional care should be taken on blocks that have a history of infestation.

Action level

Action is required when 5% or more of new seasons' shoots are infested.

4.4.6 Chemical control

Apply petroleum spray oil when trees are dormant. Apply methidathion (Supracide®) during the growing season (PER13694). Higher spray volumes may be necessary to get good spray penetration if low- profile air-blast sprayers are used. If scale populations are low, it is preferable to release predators such as *Cryptolaemus montrouzieri*. Good scale control can also be achieved by controlling ant through ant baits (see 4.2).

4.4.7 Biological control

A number of species of parasitic wasps attack black scale, including *Metaphycus lounsburyi, Metaphycus helvolus* and *Scutellista caerulea* (also an egg predator) (Plate 2). The imported *Metaphycus bartletti* is being released.

Predators

The ladybirds *Rhyzobius near lophanthae, Parapriasus australasiae*, *Cryptolaemus montrouzieri*, and *Diomus* spp., and the lacewings *Micromus tasmaniae*, *Mallada* spp. and *Plesiochrysa ramburi* are predators of black scale. A scale eating caterpillar *Catoblemma dubia* also feeds on black scale.

Pathogens

In coastal regions, extensive death of scales in high density populations can be caused by *Verticillium lecanii* in humid conditions in late summer and autumn. White fungal growth can cover extensive portions of scale infested branches.

Plate 2. Left: *Metaphycus bartletti*, an imported wasp parasite of black scale. Right: *Metaphycus lounsburyi*, a wasp parasite of black scale.

4.4.8 Orchard management strategies

- Large ant populations interfere with the biological control of black scale and other pests. Ant populations should not be allowed to build up (see Section 4.2).
- Vigorous trees are more likely to suffer heavy infestations of black scale.
- Control strategies are similar to mealybug (see Section 4.1.8).

4.5 WHITE WAX SCALE

4.5.1 Damage

Sooty mould on leaves may interfere with photosynthesis, retard colour development of new fruit and is unsightly on fruit at harvest. Mould can be difficult to remove completely, even if fruit are washed and brushed before packing. Damage:

- Fruit/calyces — Honeydew deposits on fruit cause heavy sooty mould
- Leaves — Heavy sooty mould affects photosynthesis
- Twigs — Heavy infestation can cause dieback

4.5.2 Species and description

Ceroplastes destructor. The adult female has a soft white waxy covering about 6 mm in diameter (Plate 1). The body of the insect beneath the wax is light red to dark brown, plump and soft. Its hind end narrows into a process that lies flat on the leaf or twig. White wax scale is distinctly different from hard wax scale, pink wax scale and Florida wax scale. The wax of white wax scale is soft and moist compared with the harder drier waxes of the other scales.

Plate 1. White wax scale.

4.5.3 Life cycle

Males are unknown and reproduction is completed without mating. As many as 3 000 orange coloured eggs are produced per adult female. The crawlers, which hatch from the eggs, settle mainly along the midribs of leaves. Four weeks later, most migrate from the leaves to permanent positions on the twigs where they pass through the 'peak' and 'dome' stages before maturity. In Queensland and northern New South Wales there are two generations. Crawlers of the first generation appear in mid-October and continue emerging until late-February. Crawlers of the second generation first appear in early-April, and continue emerging until October. Hatching begins during late-October and is completed by early January. Two generations occur annually in Queensland and northern New South Wales. A single generation occurs elsewhere in New South Wales.

4.5.4 Importance and distribution

Distribution of this pest in Australia is presented in Figure 1. The adults are nearly always found on twigs and minor branches up to two years old. Direct effects of scale feeding are negligible, however, the scale produces honeydew and deposits may be abundant on foliage and fruit by late summer. In humid conditions, sooty mould fungi develop on the honeydew. Within orchards the crawlers are transported by wind, insects, birds and on the clothing of orchard workers. The hot dry conditions which prevail in southern inland regions are unfavourable for the scale and so its occurrence is mostly in coastal areas. Heat waves can decimate populations in the coastal districts if they occur when first and second instar scales are present. White wax scale can occur on numerous hosts including citrus, groundsel, white cedar, guava, mango, pear, quince, gardenia, lillypilly, pittosporum, pepperina and turkey bush. It originated in southern Africa, and has spread to Australia.

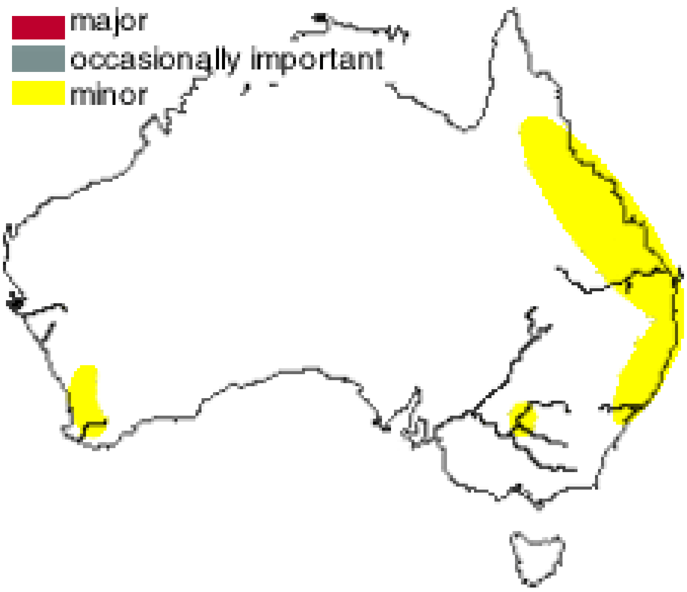


Figure 1. Distribution of White Wax Scale in Australia.

4.5.5 Monitoring

White wax scale occurs on most persimmon varieties. The pest and its natural enemies should be monitored once or twice in mid-October to early December, and once or twice, if required, in February-March, using a x10 hand lens. Select at least 20 trees per hectare at random and check for presence/absence of scale on 10 randomly selected twigs per tree. The number of trees from which samples are taken depends on block size. Additional care should be taken on blocks that have a history of infestation. In Queensland and New South Wales, white wax scale now rarely reaches a significant level, and infestations tend to be rare and they are very localised on one or two branches.

Action level

Action is required when 5% or more of green twigs are infested.

4.5.6 Chemical control

Apply petroleum spray oil when trees are dormant. Apply methidathion (Supracide®) during the growing season (PER13694). Higher spray volumes may be necessary to get good spray penetration if low- profile air-blast sprayers are used. If scale populations are low, it is preferable to release predators such as *Cryptolaemus montrouzieri*. Good scale control can also be achieved by controlling ant.

4.5.7 Biological control

Parasites

The wasp parasite *Paraceraptrocerus nyasicus,* was introduced from South Africa in 1968. It was established in Queensland by 1972 and since then, the scale has been a minor pest.
Paraceraptrocerus nyasicus is a dark blue wasp, 5 mm long. It lays eggs in young scales 1-2 months old, and completes its life cycle within the host. The adult wasp cuts a large neat hole through the wax to emerge. Parasitism levels of 90% are not uncommon.

In central coastal New South Wales, four parasites from South Africa have been established - *Paraceraptrocerus nyasicus*, *Anicetus communis, Tetrastichus ceroplastae* and *Scutellista caerulea* and the scale have been much less abundant since the early 1970s.

The dominant parasite in central coastal New South Wales is *Anicetus communis* (up to 85% of endoparasitism). Parasitism by *Scutellista caerulea* can exceed 60% in immature adult scales but a large proportion of parasite larvae die before their hosts produce eggs. This coincides with high host mortality which may be associated with diseases. The same race of *Scutellista caerulea* also attacks hard wax scale and the differences in the phenologies of the two hosts allows the parasite to move from one scale to the other.

The effectiveness of *Scutellista caerulea* (the larvae feed ectoparasitically on immature adult females scales but most prey solely on eggs laid by the host) in adult females scales is reduced as the size of the host decreases.

Predators

The most common predators are the ladybirds *Halmus chalybeus, Scymnodes lividigaster, Serangium bicolor* and *Micraspis frenata.* Birds also prey on mature scales and bees often remove the soft moist wax.

Pathogens

Fusarium stilboides can destroy entire egg masses in up to 10% of mature scales. Stored product pests (beetles and mites) may play a role in spreading the disease within scale populations. Other diseases of immature scales are suspected, but have not been confirmed

Plate 2. Left: The small wasp *Paraceraptrocerus nyasicus* laying eggs in white wax scale. Right: The small wasp *Anicetus communis* laying eggs in white wax scale.

4.5.8 Orchard management strategies

- Large ant populations interfere with the biological control of white wax scale and other pests. Ant populations should not be allowed to build up (see Section 4.2).
- Vigorous trees are more likely to suffer heavy infestations of black scale.
- Control strategies are similar to mealybug (see Section 4.1.8).

4.6 PINK WAX SCALE

4.6.1 Damage

Sooty mould on leaves may interfere with photosynthesis, retard colour development of new fruit and is unsightly on fruit at harvest. Mould can be difficult to remove completely, even if fruit are washed and brushed before packing.

Damage:

- Fruit/calyces — Causes sooty mould
- Leaves — Heavy sooty mould can affect photosynthesis
- Twigs — Causes twig dieback

4.6.2 Species and description

Ceroplastes rubens. The pink-red adult female scale is about 3 - 4 mm in diameter, globular and smooth in shape with two lobes either side and a depression in the top (Plate 1). Pink wax scale most resembles Florida wax scale and hard wax scale. Florida wax scale is much paler in colour, and hard wax scale mostly white and larger.

Plate 1. Pink wax scale on persimmon.

4.6.3 Life cycle

Reproduction occurs without fertilisation (male scales are very uncommon). Up to 900 brick-red eggs are laid and held in a cavity beneath the body of the female (Figure 1). The number of eggs is related to the size of females, and the average number of eggs is probably below 200 per female. Foliar nitrogen levels affect scale size. Eggs hatch into crawlers (small mobile stages with three pairs of legs, two eye spots and paired antennae).

In Queensland (where there are two generations each year), crawlers of the first generation emerge from mid-September until early-December but mostly from mid-October to mid-November. Crawlers of the second generation emerge from February until late-April.

The crawlers spread out over the tree settling mostly along the midribs of leaves and on green twigs. Caught by the wind, they are dispersed throughout the orchard. Once they settle, they lose their appendages and eye spots, and begin secreting a white and then pink waxy cap over their body. The wax covering is hard, and when fully formed, is globular and smooth with a depression on the top and two holes in each side.

On the central and south coast and inland regions of New South Wales (where there is a single generation), the first crawlers are seen in late October and egg hatch is completed by late December. There are two generations in Queensland and one in NSW.

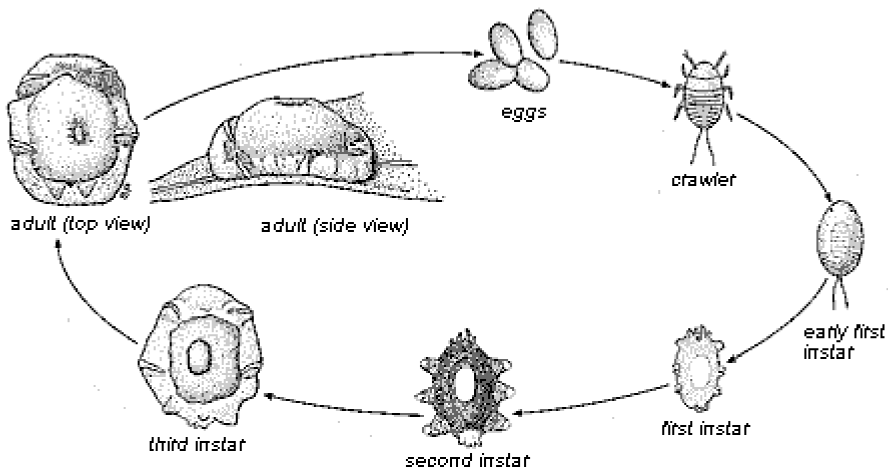


Figure 1. Life cycle of Pink Wax Scale.

4.6.4 Importance and distribution

Pink wax scale occurs on the calyces, leaves (mostly along the midrib on both surfaces) and young twigs but all stages favour leaves. It is accompanied by heavy honeydew production, and sooty mould levels can be high on fruit, calyces and leaves.

The hot dry conditions which prevail in southern inland regions are unfavourable for the scale and so its occurrence is mostly in coastal areas. Heat waves can decimate populations in the coastal districts if they occur when first and second instar scales are present.The scale infests a wide range of hosts including citrus, mango, avocado, custard apple and many native shrubs (lillypilly, pittosporum and umbrella tree).

It occurs also in south-east Asia, China, Japan, Islands of the Western Pacific, Spain and Florida and probably originated in Africa. Distribution of Pink Wax Scale in Australia is presented in Figure 2.

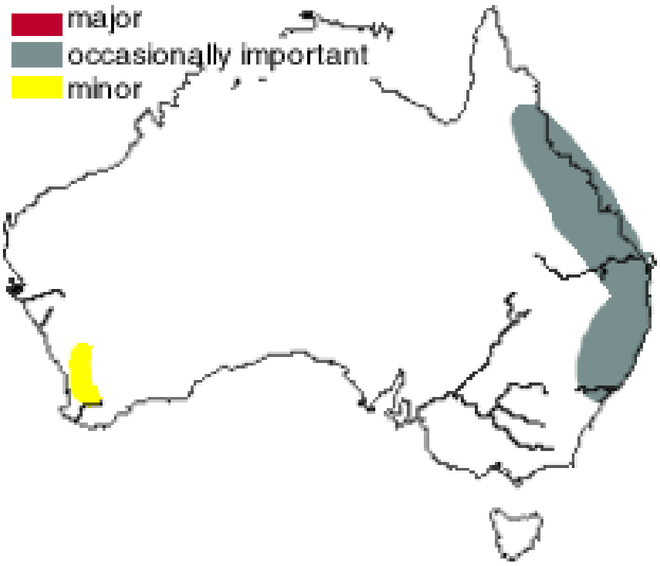


Figure 2. Distribution of Pink Wax Scale in Australia.

4.6.5 Monitoring

The pest and its natural enemies should be monitored once or twice in mid-October to early December, and once or twice, if required, in February-March, using x10 hand lens.

Select at least 20 trees per hectare at random and check for presence/absence of scale on 10 randomly selected twigs per tree. The number of trees from which samples are taken depends on block size. The number of trees from which samples are taken depends on block size. Additional care should be taken on blocks that have a history of infestation. Serious infestations of pink wax (though now much less common since the introduction of *Anicetus benificus*) still occur.

Action level

Action is required when more than 5% or more of leaves are infested.

4.6.6 Chemical control

Apply petroleum spray oil when trees are dormant. Apply methidathion (Supracide®) during the growing season (PER13694). Higher spray volumes may be necessary to get good spray penetration if low- profile air-blast sprayers are used. If scale populations are low, it is preferable to release predators such as *Cryptolaemus montrouzieri*. Good scale control can also be achieved by controlling ant.

4.6.7 Biological control

Parasites

The most important parasite is a small 3 mm long wasp *Anicetus beneficus*, introduced from southern Japan to Queensland in 1977. The female wasp is honey coloured with large lamellate antennae and the male is black. The main emergence periods for *Anicetus beneficus* are during November and February - March. The parasite completes its life cycle within the pink wax body and the adult, after emerging from its pupa, cuts a circular hole to the exterior through the wax. Just prior to emergence, parasitised scales are darkened in colour and the integument across the bottom of the scale is black instead of the usual pink. *Anicetus beneficus* now occurs in most areas of Queensland and is effective in controlling the scale in the absence of disruptive pesticides.

Other parasites commonly occurring are *Metaphycus varius*, (3 mm long, tan coloured), *Scutellista caerulea* (2 mm long, blue-black) and *Coccophagus ceroplastae*. The effectiveness of *Scutellista caerulea* (the larvae feed ectoparasitically on immature adult females scales but most prey solely on eggs laid by the host) in adult females scales is reduced as the size of the host decreases. Also recorded have been *Coccobius arhrithorax, Encarsia australiensis and Moranila californica.*

Predators

The ladybirds *Rhyzobius ventralis*, *Cryptolaemus montrouzieri, Diomus notescens, Diomus sp. Harmonia conformis,* together with the moth *Catoblemma dubia* and the lacewings *Chrysopa signata* are predators.

Pathogens

Verticillium lecanii may occur in high density scale populations under humid conditions.

Plate 2. The wasp *Anicetus beneficus*, parasitising a pink wax scale.

4.6.8 Orchard management strategies

Management strategies are similar to those for mealybug (see Section 4.1.8).

4.7 NIGRA SCALE

4.7.1 Damage

Persimmon fruit, calyces and leaves are disfigured with sooty mould which grows on the honeydew secreted by the Nigra scale. Sooty mould greatly reduces leaf photosynthesis.

4.7.2 Species and description

Parasaissetia nigra. The adult female Nigra scale is 3 - 4 mm long, an elongated oval in shape and a shiny, dark brown to black colour (Plates 1). Younger stages are light brown. The scale surface is smooth.

Plate 1. Nigra scale and associated sooty mould on a shoot.

4.7.3 Life cycle

Adult females each produce about 800 eggs which are protected under the scale body for about a fortnight before they hatch into crawlers. These young nymphs develop and pass through two moults before adulthood. The life cycle takes about 2 months in summer. There are 4 - 6 generations per year.

4.7.4 Importance and distribution

Nigra scale attacks citrus, custard apple, guava, avocado and hibiscus. It can become a major pest of persimmon. Distribution in Australia is presented in Figure 1.

Figure 1. Importance and distribution of Nigra scale.

4.7.5 Monitoring

Select at least 20 trees per hectare at random and check for presence/absence of scale on 10 randomly selected twigs per tree. The number of trees from which samples are taken depends on block size. Minimise spraying because it kills the natural enemies of Nigra scale.

Action level

An infestation of at least 20 live scales on any one-year old lateral is required to make it worth spraying.

4.7.6 Chemical control

Apply petroleum spray oil when dormant. During the growing season, where required, spray with an appropriate chemical such as methidathion e.g. Supracide® (PER13694). Correct timing of spraying is essential. Wait for hatching of all eggs under adult scales. Egg hatch is completed when young scales are noted on leaves, and no liquid exudes when the old adult female scale is squashed. At this point, the highly susceptible young scales line the midribs of outer foliage. Spot spraying of infested trees is recommended.

Control of ant movement will greatly reduce the problem (See Section 4.2).

4.7.7 Biological control

The most common parasite of Nigra scale is the wasp *Scutellista caerulea* (Plate 2 and 3). The fungus *Verticillum lecanii* commonly attacks Nigra scale in wet weather during the summer-autumn (Plate 4). Ladybirds such as the *Cryptolaemus montrouziera* (see section on mealybugs) and the larva of the moth *Catoblemma dubia* (Plate 5) also preys on Nigra scale.

Plate 2. Left: Scale parasite *Scutellista cyanea* adult. Right: Larvae on upturned scale.

Plate 3. Nigra scale parasitised by the wasp *Scutellista caerulea*. Note the hole through which an adult wasp has emerged (bottom centre), the pupa under a scale cover (top centre) and the pink, legless larva of a wasp (top right) which has been dissected out of a scale.

Plate 4. Nigra scale infected with the fungus *Verticillium lecanii*.

Plate 5. Moth *Catoblemna dubia* produces a scale eating caterpillar that feeds on scale.

4.7.8 Orchard management strategies

Management strategies are similar to those for mealybug (see Section 4.1.8).

4.8 GREEN COFFEE SCALE

4.8.1 Damage

Green coffee scale infests mainly the young leaves and green twigs, but will move onto fruit in heavy infestations. The scales are commonly attended by ants that feed on honeydew produced by the scales. Ants may reduce crawler deaths by preventing the accumulation of excess honeydew. Excess honeydew can cause disease in the crawlers, and they can also become trapped in it because it is sticky.

Persimmon fruit and leaves are disfigured with sooty mould which grows on the honeydew secreted by the scale. Sooty mould greatly reduces leaf photosynthesis.

4.8.2 Species and description

Coccus viridis (Green), Hemiptera: Coccida. The adult female green coffee scale is oval to elongate in shape, with a flattened profile. It is pale yellow-green in colour, and 3 to 4 mm long (Plate 1).

The roughly U-shaped gut is visible through the partially transparent top of the scale as a line of black spots. At the anterior (head) end, there are two distinctive black eye spots. The scales have antennae and well-developed legs, and, unlike most other scales, can move around the host plant.

Green coffee scale may be confused with other *Coccus* spp., e.g. soft brown scale. However, the pale yellow-green colour, oval shape, flattened profile, visible gut, and black eye spots are distinguishing features.

Plate 1. Green coffee scale along leaf midrib.

4.8.3 Life cycle

The female green coffee scale reproduces without mating. Eggs hatch within the scale or immediately after laying, and the crawlers (first instar nymphs) emerge to spread over the host. Crawlers develop into second instar nymphs, and these develop into adult scales. The life cycle takes 6 to 9 weeks. There are 3 to 4 generations each year.

4.8.4 Importance and distribution

Green coffee scale is a minor pest of persimmon in Queensland and northern NSW. Green coffee scale also occurs in East Africa, Central America, South-East Asia, Indonesia, Papua New Guinea and islands of the western Pacific, Hawaii and Florida. Green Coffee scale infests a wide range of hosts, including citrus, coffee, and ornamentals such as gardenia and ixora. Distribution in Australia is presented in Figure 1.

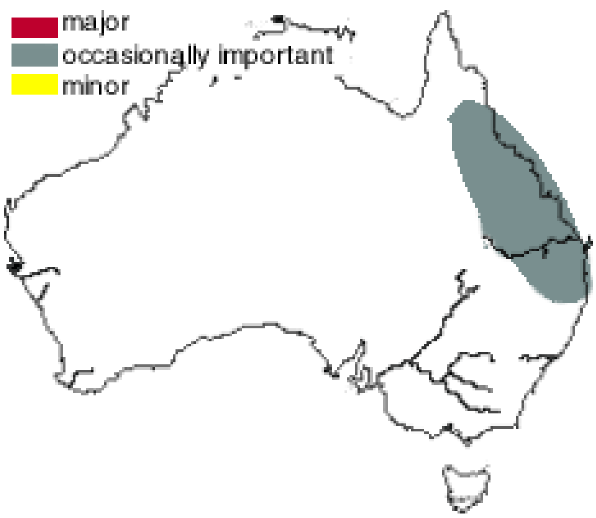


Figure 1. Importance and distribution of Green Coffee scale.

4.8.5 Monitoring

Green Coffee scale occurs on persimmon varieties in north Queensland. The pest and its natural enemies should be monitored from mid-October onwards. Select at least 20 trees per hectare at random and check for presence/absence of scale on 10 randomly selected twigs per tree. The number of trees from which samples are taken depends on block size.

Action level

There will be a problem with sooty mould if 5% or more of laterals are infested with one or more scales.

4.8.6 Chemical control

During dormancy only, a 1% petroleum oil spray should be applied as a high-volume spray (PER13933). During fruit set and early fruit development (early- to mid-summer), immediately after most crawlers have emerged, spray with an insecticide such as methidathion (PER13694).

4.8.7 Biological control

Parasites

One or two small parasitic wasps, e.g. *Coccophagus ceroplastae* and *Euryischomyia flavithorax* periodically parasitise this scale causing significant mortality (Plates 2 and 3). The Kenyan wasp (*Diversinervus stramineus*) has been established in Australia.

Predators

The mealybug ladybird, *Cryptolaemus montrouzieri*, preys on Green Coffee scale.

Plate 2. Parasitised Green Coffee scale. Note the pink-orange larva of the parasite *Coccophagus spp.*, which has been dissected from the large scale (centre). A parasite pupa is visible in the scale on the right. The smaller parasite *Encarsia* spp. is visible in the younger scales

Plate 3. The wasp, *Coccophagus* spp., a parasite of Green Coffee scale.

Pathogens

The fungus, *Verticillium lecanii* can cause up to 90% mortality of the scale during wet weather in late summer to autumn, particularly when populations of the scale are large (Plate 4).

Plate 4. The fungus *Verticillium lecanii* on Green Coffee scale.

4.8.8 Orchard management strategies

If scales are attended by large populations of ants, the ants should be controlled with a suitable treatment, e.g. basal trunk spray, or sticky bands around the trunk.

Also see section on orchard management strategies for control of mealybug and ants (See Sections 4.1.8 and 4.2).

4.9 LONG SOFT SCALE

4.9.1 Damage

Long soft scale infests twigs and leaves, and commonly occurs on water shoots and fruit stalks. Crawlers move onto the fruit stalks in the spring where they develop and produce large amounts of honeydew. Sooty mould then grows on the honeydew. Heavy infestations of long soft scale can develop by early autumn.

4.9.2 Species and description

Coccus longulus (Douglas), Hemiptera: Coccidae. The adult female Long Soft scale is an elongated oval in shape, 4 to 6 mm long, yellow to greyish-brown in colour, with visible eye spots (Plate 1).

Long Soft scale most closely resembles scale of other *Coccus* spp., e.g. Soft Brown scale, but can be distinguished by its greater length (up to 6 mm).

Plate 1. Long soft scale adults and nymphs.

4.9.3 Life cycle

Adult females produce living young (crawlers) over a period of about 4 weeks. These crawlers disperse and settle on twigs and leaves. They develop through two nymphal stages before reaching the adult stage. The complete life cycle takes about two months. There are 4 to 6 generations each year.

4.9.4 Importance and distribution

Long Soft Scale is a minor pest of persimmon in Queensland and NSW. Long Soft scale is distributed worldwide. Long Soft scale occurs on a wide range of hosts, including persimmon, custard apple, lychee, carambola, fig, leucaena, and many ornamentals. Distribution in Australia is shown in Figure 1.

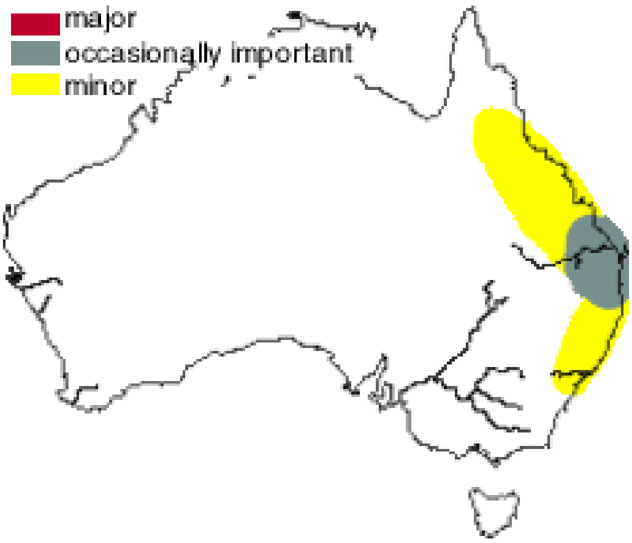


Figure 1. Distribution of Long Soft scale.

4.9.5 Monitoring

Select at least 20 trees per hectare at random and check for presence/absence of scale on 10 randomly selected twigs per tree. The number of trees from which samples are taken depends on block size.

Action level

There will be a problem with sooty mould if 5% or more of laterals are infested with one or more scales.

4.9.6 Chemical control

During dormancy only, a 1% petroleum oil spray should be applied as a high-volume spray (PER13933). During fruit set and early fruit development, spray immediately after most crawlers have emerged with a chemical such as methidathion (Supracide®) (PER13694).

4.9.7 Biological control

Parasites

The small parasitic wasp *Coccophagus ceroplastae* attacks Long Soft scale.

Predators

The mealybug ladybird (*Cryptolaemus montrouzieri*) preys on Long Soft scale.

Pathogens

During prolonged wet weather, the fungus *Verticillium lecanii* can kill many Long Soft scales (Plate 2).

Plate 2. Long soft scale infected by *Verticillium lecanii*.

Current levels of biological control of long soft scale are poor. Attempts are being made to collect more effective parasites from other countries

4.9.8 Orchard management strategies

- Minimise the use of disruptive pesticides, particularly carbamates and synthetic pyrethroids.

- If scales are attended by large populations of ants, the ants should be controlled with a suitable treatment, e.g. basal trunk spray, or sticky bands around the trunk.

- Also see section on orchard management strategies for control of mealybug and ants. (See Sections 4.1.8 and 4.2).

4.10 MUSSEL SCALE (PURPLE SCALE)

4.10.1 Damage

Mussel scale occurs on twigs, leaves and fruit causing disfigurement and dieback. Wood up to 25 mm in diameter is most severely damaged. Large limbs weakened by Mussel scale and part or the entire limb may die. Infested fruit are difficult to clean.

4.10.2 Species and description

Lepidosaphes beckii (Newman), Hemiptera: Diaspididae. The scale cover of the adult female mussel scale is shaped like a mussel shell, 3 to 4 mm long, and light brown (Plate 1). The scale cover of the male is half as long, narrower, and lighter in colour. The body of the female scale is white, and held in place under the scale by a thin white membrane.

Citrus Snow scale and Glover's scale are similar in appearance to Mussel scale. However, the adult female citrus snow scale is dark brown and smaller (2 mm long), with a longitudinal ridge, and Glover's scale is longer (5 mm long) and thinner.

Plate 1. Mussel scale. Males are thin and females broad. Note the emergence holes made by the small parasitic wasp Aphytis.

4.10.3 Life cycle

A mass of about 50 to 100 pearly white eggs is deposited in two rows under the female scale cover. They hatch after 2 weeks. The crawlers settle in sheltered sites, on older leaves and beneath fruit calyx lobes. The life cycle takes 6 to 8 weeks. In Queensland and the Northern Territory, there are five to six generations per year. In New South Wales there are two to five generations per year.

4.10.4 Importance and distribution

Mussel scale is found throughout the world. It is a minor pest of persimmon in Queensland. Hosts include custard apple, avocado, eucalyptus, fig, pecan and many ornamental plants. Single scales may be scattered over infested fruit, or clumps of scales may gather where two or more fruit touch. Typically, Mussel scale enters an orchard on young trees at planting. Infested buds or grafts can carry scale to new trees in nurseries. Mussel scale is adversely affected by extremely hot, dry weather, and is more common in coastal areas. Distribution in Australia is shown in Figure 1.

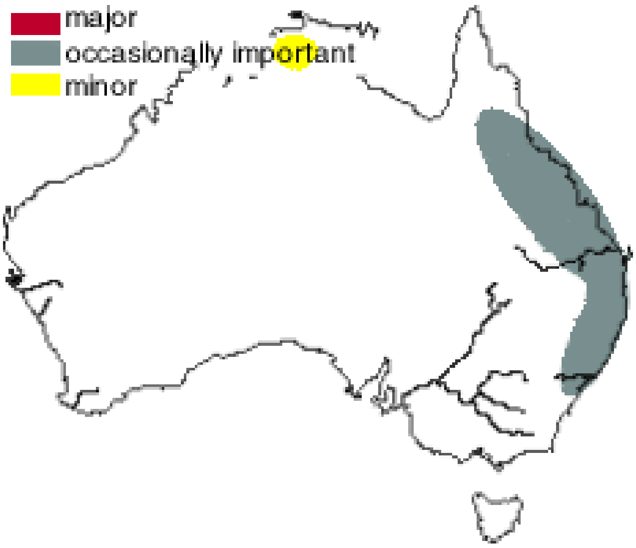


Figure 1. Importance and distribution of Mussel Scale

4.10.5 Monitoring

The pest and its parasites should be monitored from fruit set until harvest. Using x 10 hand lens, check for the presence or absence of scales on 5 randomly selected fruit per tree. On tall trees, take 20% of samples from the tops of trees.

Action levels

Action is required if more than 20% of the fruit are infested with one or more scales.

4.10.6 Chemical control

During dormancy only, 1% petroleum oil spray should be applied as a high-volume spray (PER13933). During fruit set and early fruit development, spray immediately after most crawlers have emerged with a chemical such as methidathion (PER13694).

4.10.7 Biological control

Parasites

The main parasite of mussel scale is the small yellow wasp, *Aphytis lepidosaphes*, which originated in China (Plate 2). It attacks mainly third instar scales, and usually achieves adequate control of the pest.

Plate 2. Mussel scale parasitised by the small parasitic wasp *Aphytis lepidosaphes*. Note the emergence holes and, in overturned scale covers, a pupa (left), and adult about to emerge (right).

Predators

Predatory ladybirds, such as the steel-blue ladybird (*Halmus chalybeus*), feed on Mussel scale.

Pathogens

The red-headed fungus (*Fusarium coccophilum*) and other unidentified pathogens attack Mussel scale.

4.10.8 Orchard management strategies

- Minimise the use of disruptive pesticides, particularly carbamates and synthetic pyrethroids.

- If scales are attended by large populations of ants, the ants should be controlled with a suitable treatment, e.g. basal trunk spray, or sticky bands around the trunk.

- Also see section on orchard management strategies for control of mealybug and ants. (See Sections 4.1.8 and 4.2).

4.11 FRUIT FLY

4.11.1 Damage

It is virtually impossible to detect symptoms of fruit fly in unripe fruit. In near-ripe fruit, fruit soften around the egg-laying sites, sometimes with associated yellowing and exudate. On the mature persimmon fruit, stings appear as black spots with a sunken centre (Plate 1).

Plate 1. Black sunken and grey spots and exudates as a result of a fruit fly sting.

4.11.2 Species and description

Two main species of fruit fly which attack persimmon in Australia (Plate 2). These are:

- Queensland fruit fly (*Bactrocera tryoni*)
- Mediterranean fruit fly (*Ceratitus capitata*)

Queensland Fruit Fly *Bactrocera tryoni*. The adult fruit fly is wasp-like, with an 8 mm long body that is red-brown with yellow marks. The white eggs are 1 mm long and banana-shaped. They are laid in batches of about a dozen just beneath the skin, particularly around the stem of the fruit. The larvae grow into white maggots 7 mm long. These later leave the fruit and pupate in the soil (Plate 3).

Plate 2. Left: Queensland Fruit Fly. Right: Mediterranean Fruit Fly (Photo: Department of Agriculture and Food Western Australia).

Plate 3. Left: Larvae (maggots) of Queensland fruit fly in the tissue of the fruit. Right: pupa found in the soil.

4.11.3 Life cycle

Queensland fruit fly

In coastal regions of Queensland and northern NSW, there are between 6-10 generations of Queensland Fruit Fly per year (Jessup, 2007). Females lay 200-300 eggs in a lifetime. In summer, the life cycle takes about 17-21 days but may be as long as 2 months during the winter (Figure 1). Commencing with the female fly 'stinging' the fruit with her ovipositor, she deposits from 1 to 16 eggs in the fruit and in two days these parcels of eggs will hatch into maggots (larvae). In 4-7 days, these will go through two moults (1st, 2nd and 3rd instars), the last of which burrows to the outside of the fruit and drops to the ground where it changes to the pupal (chrysalis) or resting stage in the litter under the fruit tree. Depending on climatic conditions, it will stay there between 6-14+ days and will then hatch as an immature fly, thereby completing the life cycle.

Fruit flies like humid moist conditions for survival. Three to four heavy frosts of -3°C and drought can kill flies. Queensland Fruit Fly can fly up to 1 km, but they can also be blown by strong winds. It takes about 7-10 days of feeding on protein before an emerging fly becomes sexually mature so it can mate and start laying eggs (Bull, 2009).

Juvenile flies normally obtain the protein required to mature by licking the surface of fruit and leaves where specific bacteria and fungi occur. These bacteria and fungi are re-cycled from the gut of fruit flies so when the eggs are laid in the fruit, the ovipositor is actually contaminated with these organisms. These bacteria initiate rot around the eggs in the fruit and it is in this rotting tissue that the maggots derive their nutrients to grow, but retain the organisms in their gut through their entire life cycle.

Flies defecate on the surface of fruit and leaves and the newly emerged adult flies then feed on this bacterial culture to provide protein for the maturation of their ovaries and testes. If they don't get protein, they will never lay an egg so their craving for protein is where protein bait sprays play such an important role in controlling fruit flies.

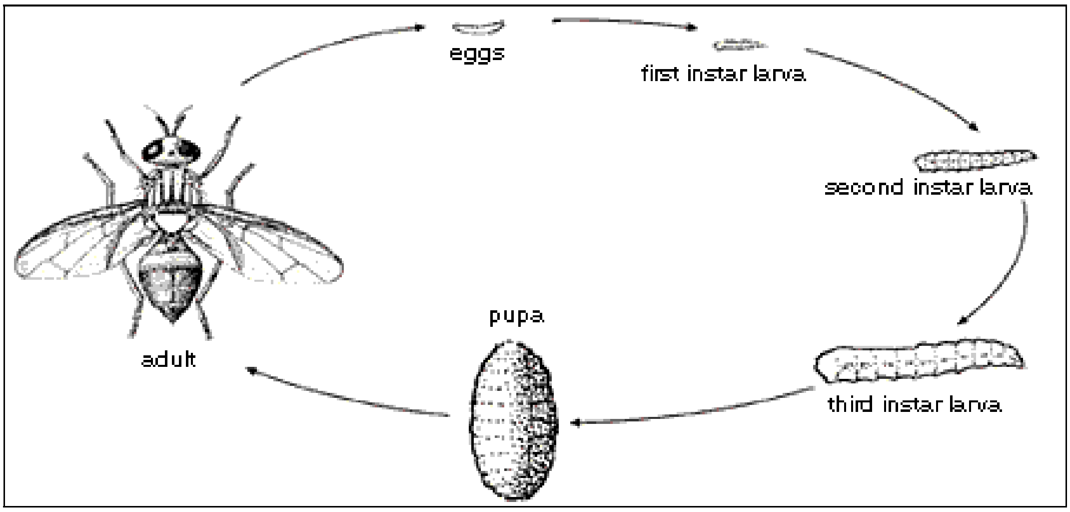


Figure 1. Life cycle of Queensland fruit fly.

Mediterranean fruit fly

The life cycle of Medfly is similar to Queensland Fruit Fly except that some stages of the life cycle are more protracted. This may be due to the cooler subtropical conditions in Western Australia. Medfly are most active from October to May. Some activity will continue in warmer periods during the winter months. Medfly overwinters as adult flies in sheltered locations. Medfly overwinters as eggs or larvae in fruit, or pupae in the soil.

Adults of Medfly become active again in spring and begin laying eggs in mature fruit. A Medfly may lay up to 1 000 eggs during her life. The pupal stage lasts two to seven weeks. Life cycle of Mediterranean fruit fly is presented in Figure 2.

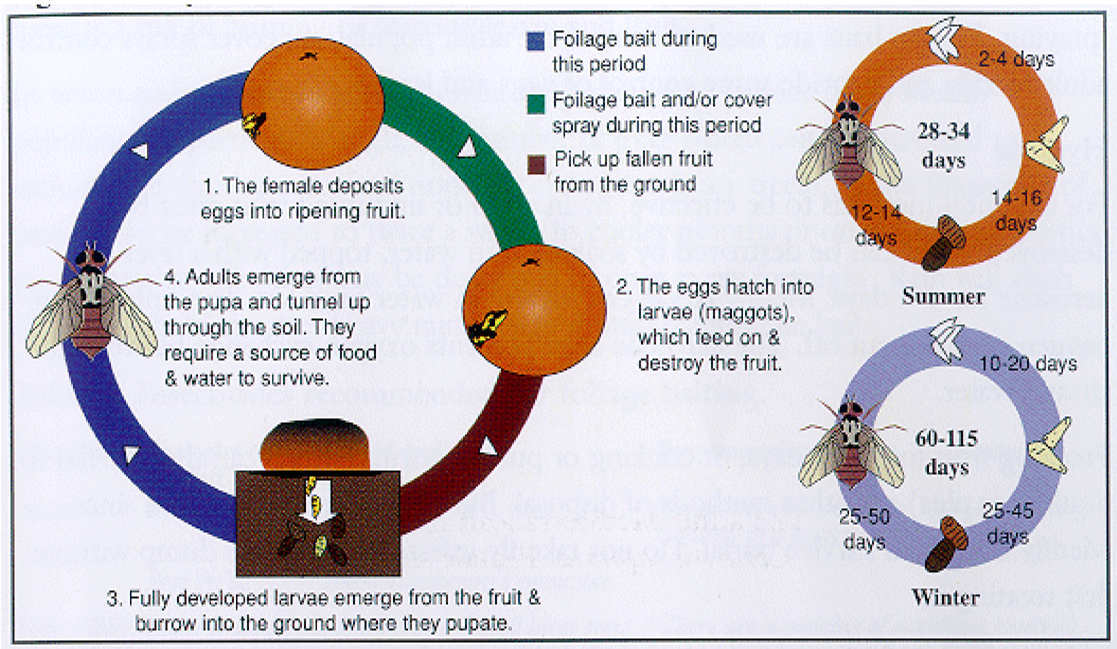


Figure 2. Life cycle of Mediterranean fruit fly. (Department of Agriculture and Food Western Australia).

4.11.4 Importance and distribution

There are about 100 species of fruit fly in Australia but only a couple are economic pests of eastern Australia (Mediterranean fruit fly is present in West Australia) (Bull, 2009). The main one in Queensland is the Queensland Fruit Fly, *Bactrocera tryoni* and it occurs with a smaller population of the Lesser Queensland Fruit Fly (*B. neohumeralis*) which looks very similar but is darker in colour and lacks the distinctive yellow shoulder spot of the former. They are equally destructive to fruit. Both species are strongly attracted by Cue-lure and several others are too, but the latter are either non-damaging or very minor pests. One other pest is the Cucumber fruit fly (*B. cucumis*) but is not attracted to Cue-lure. Although Queensland Fruit Fly and Lesser Queensland Fruit Fly occur together they do not hybridise, probably as they have different mating times. The Queensland fruit fly mates at dusk and the Lesser Queensland fruit fly mates in the morning.

Almost all commercial fruits and many native fruits and berries are hosts to Queensland fruit fly which infests up to 100% of susceptible fruit if not protected by an effective management/control program. Fruit species have variable attraction to fruit fly while varieties within the species also vary; for example: grapes low, kiwifruit low to high, carambola high, guava very high. Within citrus varieties Meyer lemon, Marsh and Red grapefruit and Lemonade are highly susceptible, Washington Navel, most mandarin varieties, Valencia orange and pummelo moderately susceptible, and Lisbon and Eureka lemons and Joppa orange of low susceptibility (Bull, 2009). Tahitian lime and bush lemons are seldom stung.

With persimmon, 'Izu' is more susceptible to attack than other varieties. Queensland fruit fly mainly infests fruit maturing from March to May. The fly's larvae feed inside the fruit, causing breakdown and rendering it inedible. Some interstate and export markets have strict quarantine restrictions on the presence of this pest in fruit. One infested fruit can result in the whole consignment being rejected. Distribution of Queensland Fruit Fly and Mediterranean Fruit Fly in Australia are presented in Figure 3.

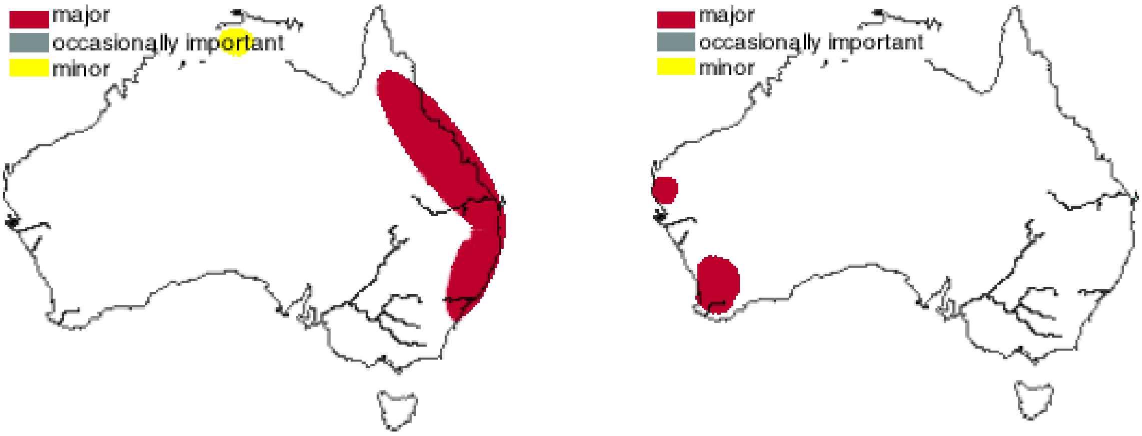


Figure 3. Distribution patterns. Left: Queensland fruit fly. Right: Mediterranean fruit fly.

Fruit fly Exclusions Zones

Movement of fruit fly throughout Australia has been limited through quarantine restrictions. The Commonwealth Government has legislated that selected regions of of NSW, Victoria and SA to be designated as 'fruit fly exclusion zones' (FFEZ) for the purpose of maintaining access to important export markets that are sensitive to fruit flies (Figure 4). The grower's approach to managing fruit fly depends on whether they are within or outside the FFEZ. Within the FFEZ, State agriculture departments apply quarantine restrictions, operate an intensive fruit fly monitoring program, and when necessary run eradication programs, to maintain the fruit-fly-free status of the zone. Landholders within the FFEZ must not use sprays or traps for fruit fly unless authorised by a state agriculture department, as they may compromise the effectiveness of the official monitoring program. Movement of fruit and other hosts for fruit fly are also restricted by both State and Commonwealth Government laws (See later sections on ICA protocols).

Figure 4. Map of fruit fly exclusion zone (DPI Vic)

4.11.5 Monitoring

Types of lure traps

Fruit Fly larvae are virtually impossible to detect in unripe fruit. Fly activity is monitored by lure traps (Plates 4 and 5). Lure traps attract male flies only. These traps are more effective than 'wet' traps that attract female flies. The trap contains a replaceable cotton wick impregnated with a sex attractant (lure) and a toxicant. The lures vary with species:

- Capilure (Cap) for Mediterranean fruit fly
- Trimedlure for Mediterranean fruit fly
- Cuelure (Cue) for Queensland fruit fly

Male fruit flies are attracted from up to 400 metres and are killed upon entering the trap. The wick is replaced about every three months. For optimal control of fruit flies, lure traps must be used in conjunction with weekly insecticide protein sprays, or other control methods such as cover sprays (see section 4.11.6 on chemical control).

Commence placement of traps in the field 12-16 weeks prior to the stage of maturity at which the crop becomes susceptible to fruit fly attack. Early setting up of traps in small orchards is critical to successful control. Four traps per hectare will give a good indication of fly activity but placing additional traps, up to 16 per hectare, will give some control.

We recommend that you monitor fruit fly activity weekly using traps starting in November–December. The objective is to monitor fruit fly populations and reduce their number before the fruit starts to mature, when the fruit is highly susceptible. Where fruit fly populations indicate low pressure, use bait sprays for control (see next section). In most cases, this will be sufficient. Where pressure is high, cover spraying with an insecticide will also be necessary.


Plate 4. Left: Lure traps, which attract male flies of Queensland Fruit Fly, consist of a synthetic attractant called 'cue lure' and an insecticide impregnated in a cotton wick. Right: trap filled with fruit fly. Photos from Bugs for Bugs.

By monitoring fruit fly populations with multiple traps, it can seen from which direction the fruit fly is coming from and accordingly go out into the neighbouring properties, in that direction, and hang up more Cue lure traps (Bull, 2009). This effectively reduces the trap counts soon after. In Queensland, all Cue lure traps in the orchard should be replaced at the beginning of January so they are at full strength as the fruit mature for picking beginning the end of March in south-east Queensland. In cooler and drier regions such as northern NSW, replacement should be delayed by about 1 to 2 months.

Amulet™ Cue-Lure Stations

Amulet™ Cue-Lure Stations (Plate 5) are produced by BASF and marketed in Australia by Crop Care Pty Ltd. They are an 'attract and kill' device impregnated with an attractant and a low dose of an insecticide, fipronil. They attract only male flies. Amulet™ Cue-Lure Stations come in two pack sizes, large (100 units and 20 stations) and small (16 units and 8 eight stations). Amulet™ Cue Lures are particularly soft on the environment because of the low fipronil dose (20 mg/station) and water insolubility of the active ingredients.

With the Amulet™ Cue-Lure Stations, traps should be tied on a twig out of direct sunlight in dense, shaded foliage of any fruit fly host tree or plant, away from fruit where rain could cause drip from the bait station onto fruit. The traps should be spaced on a 25 m grid to treat the entire orchard. In areas of high fruit fly pressure, place traps outside the orchard (32 m from orchard) in non-crop vegetation to intercept immigrant flies (Figure 5). Traps have a field life of 3-5 months if hung in permanent shade.

Plate 5. Amulet™ cue-lure (active constituents: insecticide 3.4 g/kg fipronil, attractant 94 g/kg 4-(p-acetoxyphenyl)-2-butanone). The lure attracts and kills male Queensland fruit fly only. For monitoring populations use Amulet cue lure placed in Steiner trap (see Plate 6).

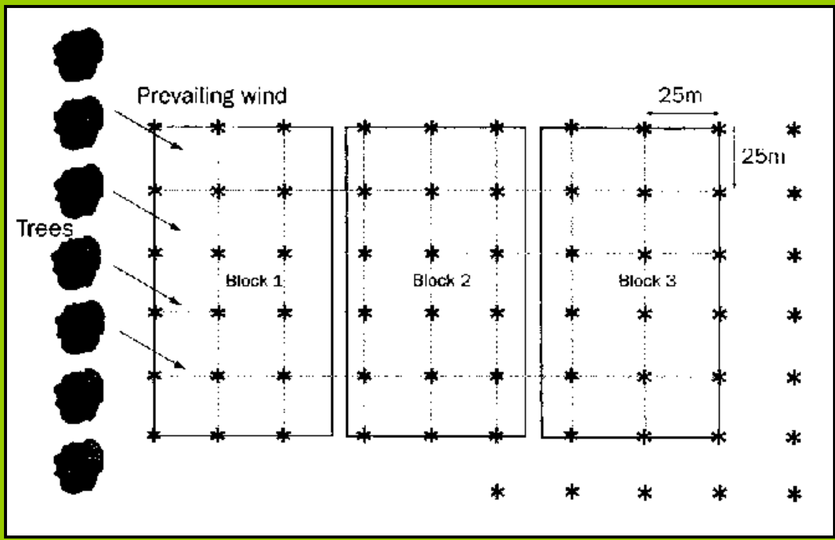


Figure 5. Layout of Amulet™ Cue-Lure Stations in an orchard. Note that stations have also being placed outside the orchard block in surrounding bush. Bull (2007).

In studies on custard apple, Bull (2009) showed that Amulet™ Cue-Lure Stations have slow kill, enabling males to transfer lethal doses of fipronil to female fruit flies several hours later during mating activities, killing both males and unmated females. In contrast, malathion Cue lure blocks kill males within minutes of contact so no transfer of toxicant to females is possible.

Modified Steiner traps

The most efficient monitoring traps are those of the Steiner design (Plate 6). These have two inverted funnel entrances and the DPI modification was the first improvement after Steiner's original design. As they were not available commercially, Richard Bull, a private consultant, decided growers needed a Steiner-type trap for on-farm monitoring and designed a further modification that performs equally, which he now manufactures. A range of traps have been developed but few are available commercially.

Plate 6. Steiner type fruit fly trap baited with Amulet Cue lure. The lure attracts male flies only. Used for monitoring Queensland fruit fly populations.

Action levels

Queensland fruit fly

The relationship between the numbers of male Queensland fruit flies caught in traps, and the numbers of females in an orchard is not clear. However, assume that less than 15 male flies per trap per week usually indicate low activity, while a surge to 30 flies per week would require action to protect susceptible fruit. Take action if even one female fly is seen stinging fruit within the orchard.

Apply a bait spray when trap catches of more than 15 flies per week are recorded or where fruit flies are observed on fruit. If more than 30 flies are caught in the cue lure traps then apply cover sprays of an insecticide.

Mediterranean fruit fly

No action levels have been developed for medfly in fruit crops in Western Australia. Growers begin regular baiting either when fruit is half-grown, or at least 6-8 weeks before harvest, or when fruit begins to colour.

4.11.6 Chemical control

Male annihilation technique (MAT)

Male annihilation technique (MAT) is used for male fruit fly population depletion. The method uses attract-and-kill devices; comprising impregnated blocks containing lure attractant and an insecticide e.g. Amulet®, distributed throughout the area (see previous section for types of traps). Male fruit flies are attracted (300-400 m) to the blocks and killed after they contact them. Commence placement of traps in the field 12-16 weeks prior to the stage of maturity at which the crop becomes susceptible to fruit fly attack. Early setting up of traps in small orchards is critical to successful control. We suggest that in Queensland this will be around November and in northern NSW about December. MATs are always used in conjunction with the protein bait spray which targets the female fruit fly.

MATs for male fruit fly population depletion should be extended as a barrier as far as possible out from the orchard to create a fruit fly free zone. Orchards in a fruit growing district need to act together to achieve extensive area-wide coverage with MATs and back yard orchardists benefit from better results achieved by getting neighbours to cooperate similarly. When the system is well organized, the need for toxic cover sprays may cease or reduced significantly.

If used correctly, MATs and bait sprays significantly reduce reliance on systemic cover sprays or even eliminate their use and there are no fruit residue issues with them but it's not quite organic! (Bull, 2009). The only way you can use Amulet in an organic orchard is to put them outside the boundary fence as a protective barrier treatment.

Standard bait sprays

Apply bait sprays from October - May right up to and through harvest. As a guide spray with a bait spray when trap catches of more than 15 flies per week are recorded or where fruit flies are observed on fruit. Under high pressure conditions, bait sprays may need to be applied 2 to 3 times a week.

The bait spray consists of a feeding attractant, yeast autolysate, and an insecticide either:

- malathion (e.g. Maldison®)
- or chlorpyrifos (e.g. Lorsban®)
- or trichlorfon (e.g. Dipterex®)

One example of a prepared mixture is HyMal Fruit Fly bait spray which is prepared by diluting 30 ml protein autolysate per L water and adding HyMal 1150g/L maldison @ 4.35ml per litre of bait liquid. The flies are attracted to bacteria growing on the yeast bait and absorb the insecticide. Spray about 50 to 100 mL of the mixture on about a square metre area of foliage per tree, low on the skirt of the tree.

The yeast autolysate bait is available from various distributors in Australia. The most commonly used one is Pinnacle Protein Insect Lure™ manufactured by Mauri Foods Ltd in Toowoomba. Bugs for Bugs re-packs it in small containers as Bugs for Bugs Fruit Fly Lure, but it has to be mixed. You make up a 3% solution and mix it with an appropriate insecticide.

Chlorpyifos is like Spinosad® and UV degraded on foliage breaking fairly fast, so in sunshine it may not last a full week (Bull, 2009). Diperex® is reasonably good but for some reason is not popular. Most popular insecticide used in the baits is malathion although some persimmon growers suggest that trichlorfon (Dipterex®) does a better job than maldison as the kill insecticide.

The other alternative is Naturalure® and Eco Naturalure (both the same product) which is Spinosad-based and has organic approval (see next section).

These baits only work if you incorporate them into a whole program - you can't start using them the week before the fruit gets ripe – it must be 8 - 12 weeks before the fruit is susceptible to get gravid females out of the system.

During periods of high fly activity, bait spraying may be required twice per week. In this case, check the traps twice a week and apply an extra bait spray if required. In large commercial orchards (>1 000 trees), when fruit fly pressure is low, apply spray bait on every second tree in every second row (Figure 6). For smaller orchards, apply baits to every tree. When pressure is high, every tree will need to be sprayed with bait.

For each tree, growers should apply about 3 x 5 mL squirts with a hand sprayer on the lower leaves in a shady spot, or a drive-by fine spray of about 75 cm width at a rate of 10-15L/ha.

We suggest that if more than 30 flies are caught in the cue lure traps, then cover sprays of an insecticide are advisable (see next section). When bait spray is applied to only a small area of the tree there is little adverse effect on the natural enemies of other pests.

Newer bait sprays

DPI researchers led a national project to evaluate new generation bait products based on "soft" insecticides which are used in much lower concentrations and have much lower mammalian toxicity than the organophosphate insecticides currently registered for use in baits in Australia. Two new commercial baits include attractant protein sources mixed with either spinosad (Dow AgroSciences) or fipronil (BASF) as insect toxicants.

In large scale field trials carried out by researchers from Qld DPI and NSW DPI, in a variety of commercial crops (citrus, pome fruit, custard apples, passionfruit, blueberries), these new baits have shown to provide the same level of control for Queensland Fruit Fly as currently used standard bait. The new baits are applied at lower rates, 5-7 L/ha compared to standard baits which are applied at 15-30L/ha, depending on the crop type. Both bait formulations include thickening agents which prolong the effective life of the bait on foliage but current recommendations are that these baits should still be applied on a weekly basis, the same as for the standard bait.

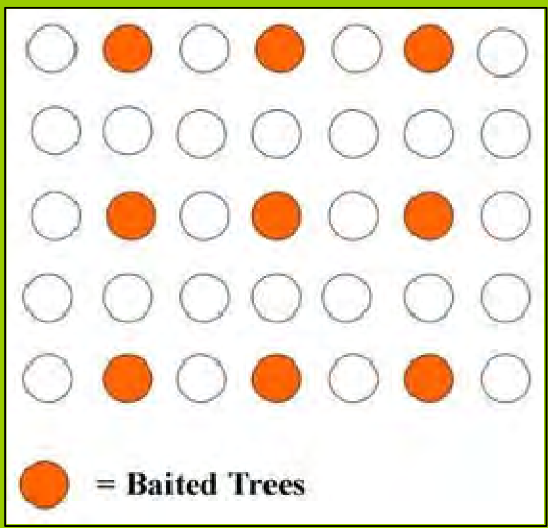


Figure 6. When fruit fly pressure is low, spray bait on every second tree in every second row. When pressure high every tree will need to be sprayed with bait.

Crop Care Pty. Ltd. has registered Amulet Gel which is a one mix powder containing fipronil, protein autolysate attractant and gelling compounds (Bull, 2009). Extensive field trials showed that it exceeded other protein baits for convenience and was highly effective (Bull, 2009). The pre-cursor of Amulet Gel was used in the Nauru Island fruit fly eradication program and in the successful Cook Island fruit fly eradication. The use pattern is for 7 - 10 day application intervals at 3.5 - 5L/ha. Application is approximately 10ml/tree or 250 ml/100 m row with either a 75 cm patch or 75 cm drive-by band. It is viscous and sticks to shiny foliage with rain-fastness. Field observations found it re-hydrates with dew, but is still attractive as dry spots on leaves.

Naturalure Fruit Fly Bait™ (Spinosad)

Naturalure Fruit Fly Bait ™ concentrate is a protein and sugar based bait containing the active ingredient spinosad. Naturalure is approved by Biological Farmers Australia, so it may fit into an organic production system. It has been approved by the Australian Domestic Plant Health Working Group for use in fruit crops. There is no withholding period required when used as directed. It works in much the same way as maldison-yeast autolysate fruit fly bait, and needs to be reapplied in moister conditions. Naturalure™ is highly attractive to fruit flies, including Queensland and Mediterranean Fruit Flies. Female fruit flies can detect the bait from several metres away. The bait mixture may cause fruit burn in some sensitive crops, especially mangoes, grapes and pears. Sensitivity will vary with climatic conditions and varieties. Avoid contact of the mixture with fruit. Test on a small area first if unsure.

Applications should begin as soon as fruit fly traps indicate fruit flies are present and fruit is at a susceptible stage. It is important that baiting begins early in the crop cycle before fruit flies have become established. Applications should be repeated every 7 days, re-applying sooner if rain washes off the mixture. A coarse spray should be applied in a 1 metre band to the skirt of trees or as coarse spots to trees and foliage. Naturalure Fruit Fly Bait Concentrate™ can be diluted with water to produce either a concentrated or a dilute solution. Use of the concentrated solution will maximise bait longevity and improve rainfastness. Baiting for fruit fly control should be supplemented by good orchard management practices such as removal of fallen and/or rotting fruit.

Non-foliar bait application

As with all types of protein baits, both of these new baits should be applied in a manner to minimize the possibility of phytotoxicity in treated crops (e.g. applying to alternate rows and to different sides of the tree each week). Mangoes are particularly sensitive to phytotoxic damage from all protein baits but it is generally not possible in commercial orchards to apply baits to foliage without some contact with fruit. It has been generally accepted in the past that protein baits for fruit fly control will be ineffective if not applied to host tree foliage. However, there is considerable historical evidence from growers that bait applied to other surfaces does provide a level of control. Furthermore, the new thickened baits are likely to be much more effective than standard non-thickened baits on non-foliar surfaces. Hence research is currently being undertaken by DPI to evaluate the efficacy of non-foliar application of bait. This will involve applying bait to tree trunks, to plywood squares, folded hessian bags, or carpet squares hung in and around host trees. This research could lead to an effective off-crop treatment for commodities which are sensitive to bait phytotoxicity, where residues may be a problem, or in organic production situations.

Cover sprays of insecticides

The alternative treatment to bait sprays is to use cover sprays of insecticides; however, this is not as desirable, as it is harmful to the natural enemies of other pests. However, we recommend that covers sprays of an insecticide should be applied if more than 30 fruit flies are caught in the cue lure traps. The insecticide alpha-cypermethrin can be used to control Queensland and Mediterranean fruit fly (APVMA Permit No. 14901).

Disinfestation

Interstate

For Queensland growers to send persimmon to southern states such as Victoria, their fruit must be treated according to interstate certification assurance (ICA). Farmers must be accredited and issued a certificate of accreditation. The operational procedures are audited by externally appointed inspectors appointed under the Plant Protection Act of 1989.

Export markets

Export markets to Thailand and Malaysia will require Australian fruit to free of fruit fly and mealybugs. Dipping with dimethoate will not be accepted. The only options available are cold sterilisation and irradiation. The European Union does allow importations of fresh fruit and vegetables from Australia based on phytosanitary certification and inspection for pests of quarantine significance. Accessing these high-valued markets will therefore require the eradication of fruit flies or treatment of fruit and vegetables in a manner acceptable to the importing countries.

Developing a systems approach to achieve quarantine security for fruit fly host commodities is one of the new directions that is beginning to impact on the bottom line for fruit fly control. Systems approaches involve a number of pest mitigation steps, which cumulatively reduce the risk of fruit fly infestation in the end product to a level that is acceptable to the importing state or country.

4.11.7 Biological control

The main natural enemies of Queensland fruit fly are the braconid wasps *Opius perkinsi*, *Fopius deeralensis*, *Fopius arisanus* and *Diachasmimorpha tryoni*. These wasps are about 8 mm long. Females use their long ovipositor to parasitise fruit fly larvae inside fruit. At times these wasps are quite common, but they do not significantly reduce fruit fly numbers.

4.11.8 Orchard management

Removal of host trees

Fruit trees that are hosts for fruit fly should be removed. For example, ripe guava fruit can greatly attract gravid females from nearby bush.

Eradiaction of neglected orchards

Neglected orchards should be eradicated, and backyard and hobby growers should control fruit flies by applying bait sprays.

Orchard hygiene

Orchard hygiene is also important in keeping fruit fly numbers down. Remove and bury old rotting fruit and avoid, where possible, leaving unsprayed alternative hosts such as guavas and citrus nearby.

Harvesting fruit at the correct stage of maturity

Whilst it is important not to harvest immature fruit, it is equally important not to leave over-mature fruit on the trees as these are more susceptibility to fruit fly attack.

Exclusion netting

Physical barriers which exclude the adult insect and thereby prevent oviposition into fruit provide non-chemical fruit fly control methods. These are highly suitable for both conventional and organic production on a number of different scales. On the smallest scale, applicable to organic home gardeners, various types of bags can be used to completely enclose individual fruit to protect them from fruit fly and other insect pest damage. On a larger scale, small mesh net fabric can be used to fully enclose individual trees when fruit are susceptible to attack. On a commercial scale, DPI researchers have been working with local netting companies for some years to extend existing net technology to become an insect control method. Netting is already widely used in some horticultural crops for protection from hail, birds, bats, wind and sun. In some areas it is seen as a highly preferred option because it provides non-lethal protection from native fauna. A 2 mm mesh net made from long lasting, translucent fibre which minimizes the shading factor has become commercially available (Plate 7). This net excludes fruit flies and a variety of other insect pests such as macadamia nut borer, fruit spotting bug, fruit piercing moth, and yellow peach moth. The net fabric is available in a range of widths and has reinforced edges which allow for gap free seams. Provided this exclusion net is correctly erected and maintained, this technology has the potential to significantly reduce pesticide usage in conventional production, and to provide a practical and appropriate method for organic pest control in a range of crops. Exclusion netting involves a high initial capital cost and it will not be appropriate for all crops, but in some crops where conventional hail/bird/bat netting is already being extensively used (e.g. stonefruit, pomefruit, kiwifruit, persimmons). It will provide new options for both conventional and organic producers at relatively little extra cost.

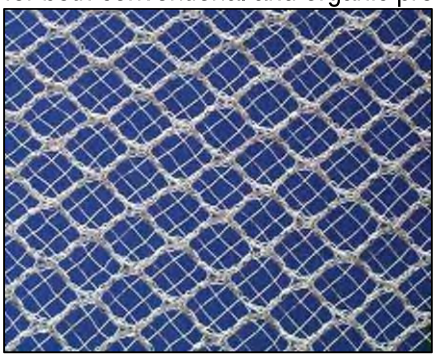



Plate 7. Left: quad netting with cross hairs will exclude some fruit fly. Right: exclusion netting (2 mm mesh) will exclude all fruit flies.

4.12 LIGHT BROWN APPLE MOTH

4.12.1 Damage

Scarring of calyx; fruit drop if the calyx is badly damaged; shallow scarring of older fruit. Young leaves webbed or rolled together. Caterpillars also feed on older fruit at points of contact with leaves and other fruit, causing shallow scarring. During autumn and spring, caterpillars may bore into ripe fruit causing fruit to drop. Some export markets do not tolerate the presence of any lightbrown apple moth in fruit. Detection of the pest in packing sheds may result in the rejection of fruit for export.

4.12.2 Species and description

Epiphyas postvittana. The adult lightbrown apple moth (LBAM) is a small, pale-brown moth, with a wingspan of about 18 mm (Plate 1). When viewed from above, the adult is bell-shaped. The caterpillars form silken feeding shelters under the calyx, in flowers, and between young leaves. They wriggle vigorously backwards when disturbed and may drop off the plant to hang from a silken thread.

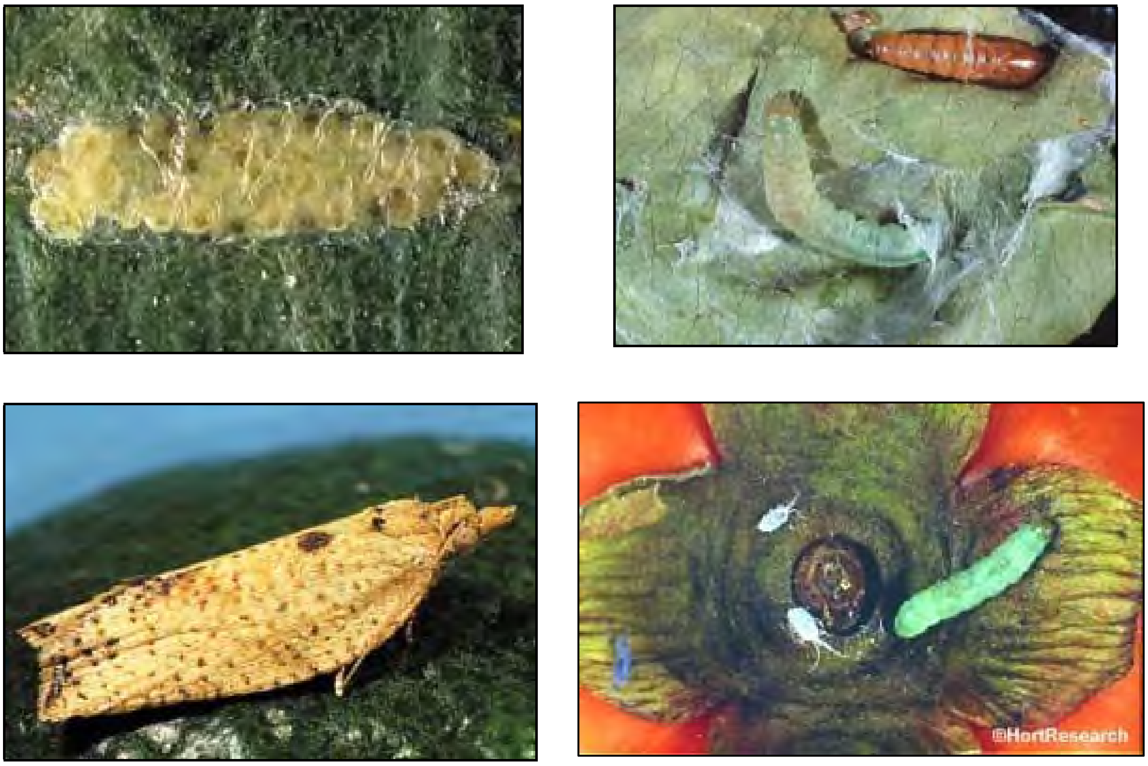


Plate 1. Top left: Flat mass of eggs, overlapping like fish scales (Photo: A Green). Top right: Pupa, larva and fine webbing (Photo: D Ironside). Bottom left: Moth at rest (Photo: C Freebairn). Longtailed mealy bug and lightbrown apple moth larva on persimmon (Photo Peter R. Dentener, Philip J. Lester and Allan B. Woolf - HortResearch, Auckland).

Plate 2. Mature larva of light brown apple moth.

4.12.3 Life cycle

The eggs are pale green and laid in flat overlapping masses that look like fish scales. Eggs are laid on leaves, stems and fruit. After hatching, the caterpillars pass through about six developmental stages, increasing in size from one to 18 mm in length (Plate 2). Young caterpillars are pale yellow-green, while mature caterpillars are pale green with a darker green central stripe and a brown head. The pupa is 10–12 mm long and enclosed in silken webbing. Pupation takes place in a rolled-up leaf or in flower debris. The life cycle is completed in 2–3 months. Moths are about 12 mm long and are pale brown with wings folded over the body when at rest.

4.12.4 Importance and distribution

Lightbrown apple moth is a commonly occurring pest in persimmon orchards in southern States (Figure 1). There are normally 4 generations per year in inland irrigated districts. In cooler districts, there are normally 3 generations per year. The two early generations (September–October and December–January) cause most damage to young and mature fruit. Eggs from the last generation hatch to become the over-wintering caterpillar population. Adults developing from the over-wintering caterpillar population emerge in mid-spring. They lay eggs that hatch into the spring generation of caterpillars. Moths are weak fliers and do not disperse far. However, in early summer they can move into orchards from native plants or weeds. Juvenile stages can be transported in nursery trees. When disturbed, young larvae wriggle backwards or drop on silken threads. In inland districts, hot dry summers reduce populations of lightbrown apple moth. Lightbrown apple moth also infests a wide range of native plants, ornamentals, vegetables, pasture crops and weeds.

Figure 1. Distribution of Light Brown Apple Moth in Australia.

4.12.5 Monitoring

- Lightbrown apple moth attacks all varieties.
- Monitor fortnightly, checking flowers, fruitlets and maturing fruit.
- The most critical times for monitoring are mid-September to mid-February for young fruitlets, and May-June for mature fruit.
- Pheromone traps (Plate 3) and wine lures, both of which attract moths, can assist with monitoring.
- It can also be helpful to collect temperature data, which can be used to predict development times and seasonal activity.
- Fruit for export markets require careful monitoring during March–June.

Plate 3. Pheromone trap used to monitor Light Brown Apple Moth.

Action level

The action level is 5% or more of flowers, fruitlets or fruit infested in spring.

4.12.6 Chemical control

Methidathion

There are several options available to control LBAM. The insecticide methidathion (Supracide®) is currently permitted for controlling LBAM in persimmon (PER13694) but its use is hard on beneficials.

Spinosad

The insecticide spinosad (Entrust Naturalyte®, Success 2®), which is currently registered for controlling Yellow Peach Moth in persimmon, will also control LBAM and is much softer on beneficials. Spinosad is derived through the fermentation of a naturally occurring organism. It uniquely combines the efficacy of synthetic products with the benefits of biological insect pest control products. It is highly active at low use rates and it has less impact on certain predatory beneficial insects.

Methoxyfenozide

The insecticide methoxyfenozide (Prodigy®) is also used to target all lepidopterous caterpillars as soon as they are seen. The APVMA permit allows for a maximum of 2 sprays only but under high pressure situations up to 4 sprays may be needed. To overcome this problem Prodigy® may be alternated with Success 2®. Use Prodigy® early and Success® later based on the number of caterpillars found under the calyx.

Dipel®

Softer chemicals such Dipel® which contains live spores and endotoxins of the naturally occurring bacterium (*Bacillus thuringiensis*) may be effective if sprays are timed to coincide with first-stage caterpillars.

4.12.7 Biological control

Parasites

Tiny Trichogramma wasps parasitise the eggs of light brown apple moth. Parasites of the caterpillars include the wasps *Dolichogenidea arisanus* and *Xanthopimpla* spp., and the parasitic flies *Voriella* spp., *Goniozus* spp. and *Zosteromyia* spp.

Predators

The most important predators of lightbrown apple moth caterpillars are the predatory bug *Oechalia schellembergii*, lacewing larvae *Micromus* spp.) and spiders.

Pathogens

Lightbrown apple moth caterpillars can be affected by a nuclear polyhedrosis virus (NPV), and are susceptible to the bacterial pathogen *Bacillus thuringiensis*.

4.12.8 Orchard management strategies

- Fallen fruit and broadleaf weeds may also harbour LBAM. Removing these from the orchard will help reduce LBAM populations.
- Leaves adhering to the fruit are excellent sites for caterpillars e.g. light brown apple moth, mites and thrips.
- Thinning fruit also helps control of LBAM by reducing potential feeding sites and leaf-to-fruit and fruit-to-fruit contact.
- Since LBAM larvae prefer young foliage, practices that reduce the amount of autumn flush on trees are also beneficial.

4.13 YELLOW PEACH MOTH

4.13.1 Damage

Typical appearance of infestation is the webbed insect frass (droppings) around the entry hole into the fruit (Plate 1).

4.13.2 Species and identification

Conogethes punctiferalis. The pale green scale-like eggs are small and are laid on the developing fruit or near the growing point. The entire larval stage is passed in the plant tissue. Larvae often live under the calyx. After about three weeks from the commencement of summer, larvae are mature, 2.5 cm long, greyish-green and tinged pink. They pupate on the outside of the fruit in shelters of webbed frass. The bright yellow moths have black dots on the wings (Plate 1).

Plate 1. Top left: frass on the shoulders of the fruit. Top right: Adult moth. Wings are orange-yellow with dark markings. The coloured scales are often quickly lost after emergence, and the moths tend to take on a more drab appearance. Bottom left: larva of yellow peach moth inside fruit. Bottom right: Larvae of yellow peach moth.

4.13.3 Life cycle

Egg laying normally starts in early February. After three weeks, the last stage larvae (now up to 2 cm long) pupate in the shelter of the webbed frass. The life cycle takes about 4-6 weeks. There are about six generations per year.

4.13.4 Importance and distribution

In Queensland only, yellow peach moth is a moderate pest of persimmon. The moth attacks the most advanced persimmon fruit (from about 6 cm diameter) from as early as late December - early January, and increases during February - April until the cool weather begins. The pest especially attacks large fruit. Individual growers have suffered up to 50% damage to fruit.

The pest also breeds on sorghum, maize and a wide range of fruit crops including citrus, papaw, custard apple, peach, carambola, macadamia, pomegranate, lychee, mango, cocoa and coconut.

The larvae or grubs, which hatch from the eggs, bore into the fruit, and as they grow produce masses of brown frass, which is matted to form a shelter on the outside of the fruit. Individual fruit can have up to 12 actively feeding larvae present. Unfortunately, they attack larger more valuable fruit. Even one larva makes the fruit unmarketable.

Distribution of Yellow Peach Moth in Australia is shown in Figure 1.

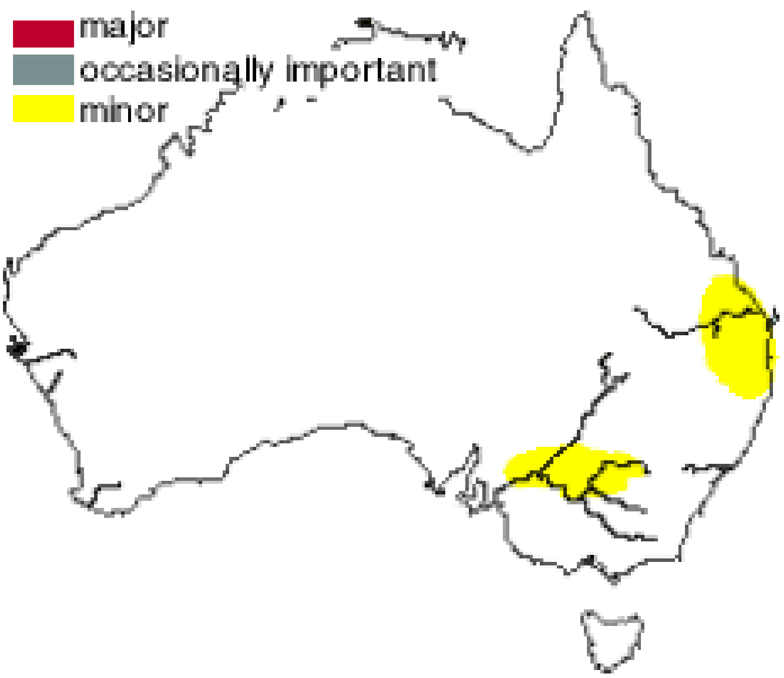


Figure 1. Distribution of Yellow Peach Moth in Australia.

4.13.5 Monitoring

Monitor pest levels regularly during the season so that appropriate sprays can be applied before the problem gets too severe. Regularly collect infested fruit from the orchard and around the packing shed and bury it deeply or preferably place under water in a drum.

Action level

At least 2% of sampled fruit need to be infested to make it worth spraying. Determine percentage fruit loss by examining fruit after picking. For trees, examine 5 adjacent trees at 6 widely spaced locations throughout each 0.5 ha of crop. Where required, spray with an appropriate chemical (see below).

4.13.6 Chemical control

Methidathion

There are several options available to control Yellow Peach Moth. The insecticide methidathion (Supracide®) is currently registered for controlling Yellow Peach Moth in persimmon (PER13694) but its use is hard on beneficials.

Spinosad

The insecticide spinosad (Entrust Naturalyte®, Success 2®) is currently registered for controlling Yellow Peach Moth in persimmon and is much softer on beneficials. Spinosad is derived through the fermentation of a naturally occurring organism. It uniquely combines the efficacy of synthetic products with the benefits of biological insect pest control products. It is highly active at low use rates and it has less impact on certain predatory beneficial insects.

Methoxyfenozide

The insecticide methoxyfenozide (Prodigy®) is also used to target all lepidopterous caterpillars as soon as they are seen. The APVMA permit allows for a maximum of 2 sprays only but under high pressure situations up to 4 sprays may be needed. To overcome this problem Prodigy® may be alternated with Success 2®. Use Prodigy® early and Success® later based on the number of caterpillars under the calyx.

Dipel®

Softer chemicals such Dipel® which contains live spores and endotoxins of the naturally occurring bacterium (*Bacillus thuringiensis*) may be effective if sprays are timed to coincide with first-stage caterpillars.

Tebufenozide (Not registered for persimmon)

Tebufenozide (Mimic®) is a growth regulator and has minimal impact on beneficial insects. It is best used to target young larvae. Larger caterpillars in sheltered feeding sites are difficult to control.

4.13.7 Biological control

The Yellow Peach Moth caterpillar has a significant natural enemy, the parasitic tachinid fly (*Argyrophylax proclinata*), which is similar in appearance to the common house fly. However, this parasite can fail in some seasons (Plate 2).

It lays its eggs in the Yellow Peach Moth larva. The parasite's eggs hatch and develop as the host pupates. The dark brown cylindrical fly pupa (about 8mm long) is found beside the remnants of the Yellow Peach Moth pupa. Parasitism levels of 30% or higher occurs where pesticide use is not excessive. At this level of parasitism, fruit infestation should not exceed 5%.

This parasite may not stop the pest becoming a problem in certain areas, but it is vital i.e. without the parasite, the severity of infestation of Yellow Peach Moth would treble.

Plate 2. Pupa of a Yellow Peach Moth (large brown case) with a pupa and adult of the main parasite, a tachinid fly (*Argyrophylax proclinata*).

4.13.8 Orchard management strategies

- Fallen fruit and broadleaf weeds may also harbour Yellow Peach Moth. Removing these from the orchard will help reduce populations.
- Leaves adhering to the fruit are excellent sites for caterpillars e.g. yellow peach moth, mites and thrips.
- Thinning fruit also helps control by reducing potential feeding sites and leaf-to-fruit and fruit-to-fruit contact.
- Since larvae prefer young foliage, practices that reduce the amount of autumn flush on trees are also beneficial.

4.14 FRUIT SPOTTING BUGS

4.14.1 Damage

While feeding, fruit spotting bugs secrete an enzyme which causes extensive breakdown of cells. Damage is small, round sunken black spots (2 to 10 mm in diameter) on the shoulders of young fruit (Plate 1). Damage penetrates about 1 cm into the fruit. Small twigs and shoots can also be damaged (Plate 2). Adults and nymphs pierce fruit repeatedly and young fruit usually drop off within 5-10 days. Older fruit may not drop off but fruit quality is impaired and diseases, such as anthracnose, and infestation by fruit fly, are more likely. Spotting bug damage can be confused with fruit fly stings.

Plate 1. Fruit spotting damage on persimmon.

Plate 2. Fruit spotting bugs also causes spots on twigs and death of terminal shoots.

4.14.2 Species and description

Banana spotting bug (*Amblypelta lutescens lutescens*) (Plate 3 and 4) and the fruit spotting bug (*Amblypelta nitida*) (Plate 5). Adult bugs are yellow/green and about 15 mm long. They can be difficult to find because, when disturbed, they either fly away or quickly hide. Females lay only a few eggs per day, but more than 100 in their lifetime. The eggs are pale green, oval-shaped and about 2 mm long (Plate 6). They are laid singly on fruit or leaves and hatch in 6-7 days in summer. There are five immature stages (nymphs) before the adult is formed. The nymphs are ant-like, pink to red/brown, with prominent antennae and button-like scent glands on the upper side of the abdomen.

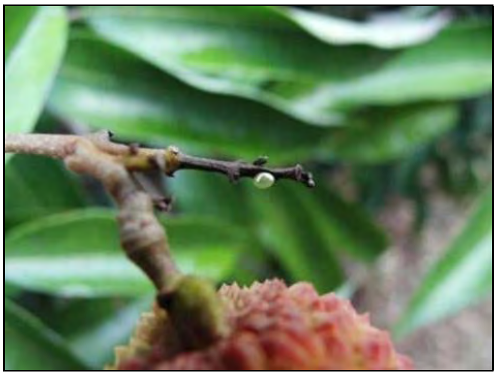


Plate 3. Left: A banana spotting bug egg. Right: Early instar banana spotting bug.

Plate 4. Left: Late instar nymph of banana spotting bug. Right: adult banana spotting bug.

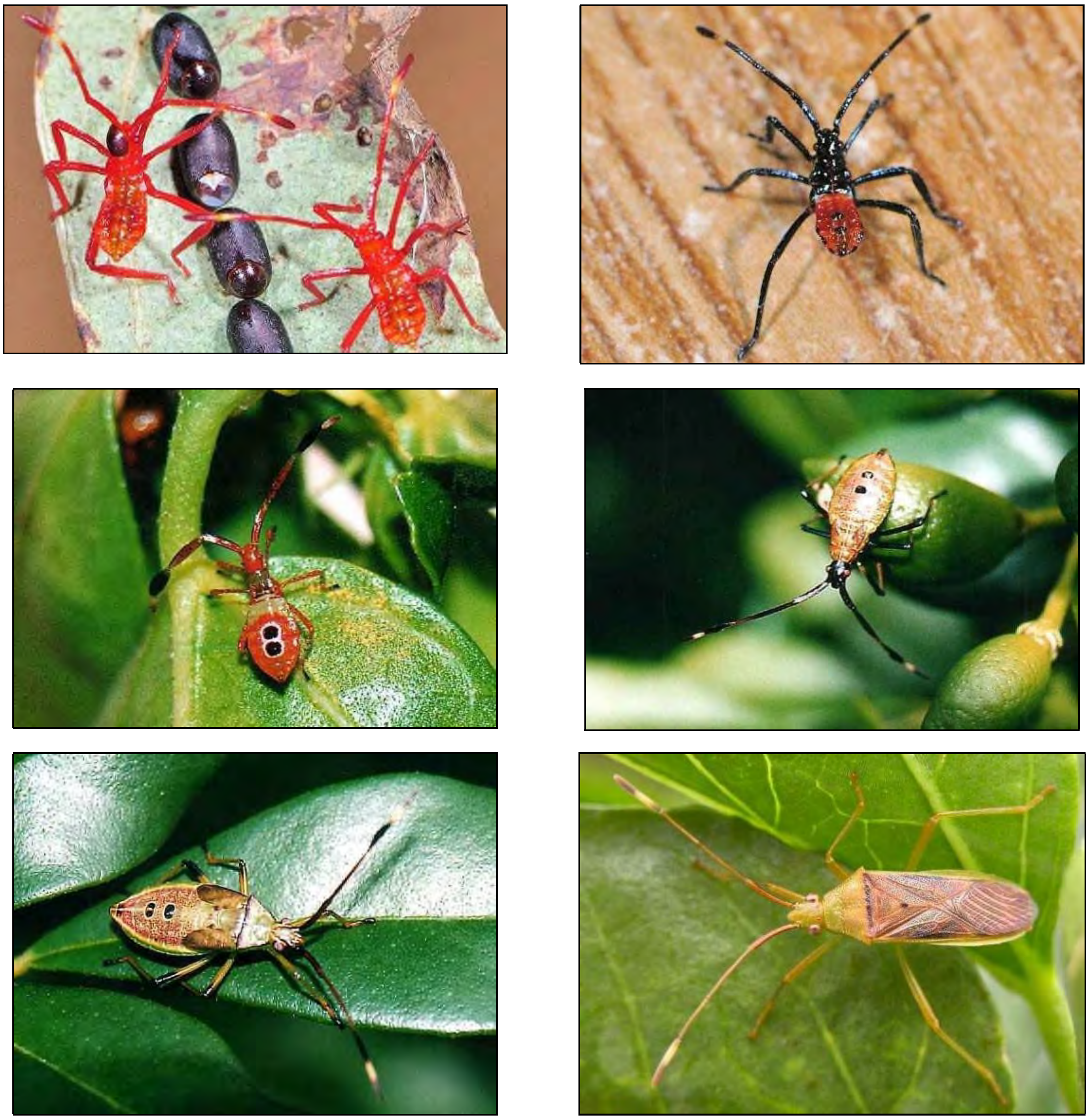


Plate 5. Top left: 1st Instar fruit spotting bug *A. nitida*. Top right: 2nd^{t} Instar. Middle left: 3rd instar. Middle right: 4th instar. Bottom left: 5th Instar. Bottom right: Adult fruit spotting bug. Photos courtesy of Peter Chew, Brisbane Insects.

Plate 6. Eggs of fruit spotting bug. Photo courtesy of R. Llewellyn, Bioresources.

The insects with which fruit spotting bugs are most often confused are assassin bugs (Plate 7 and 8).

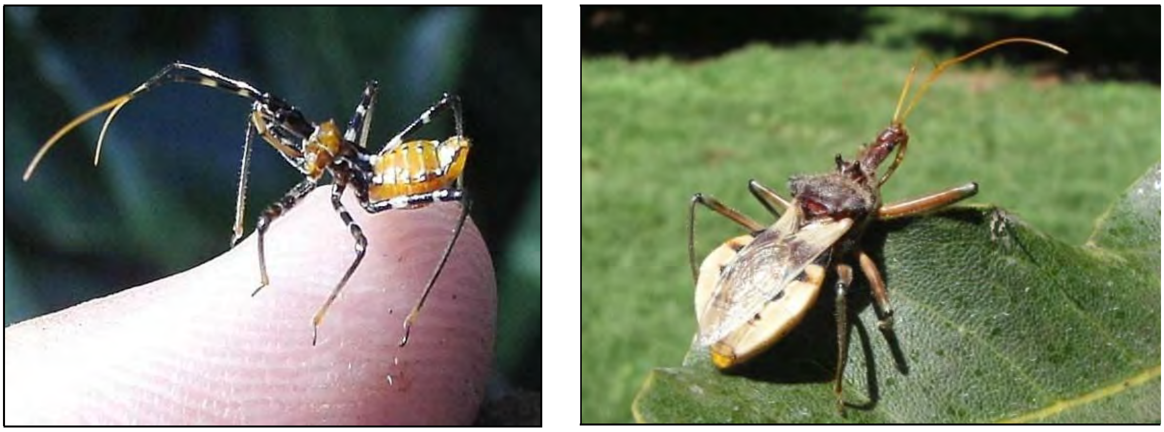


Plate 7. Left: Assassin bug nymph. Right: Assassin bug adult. These are natural enemies of caterpillars.

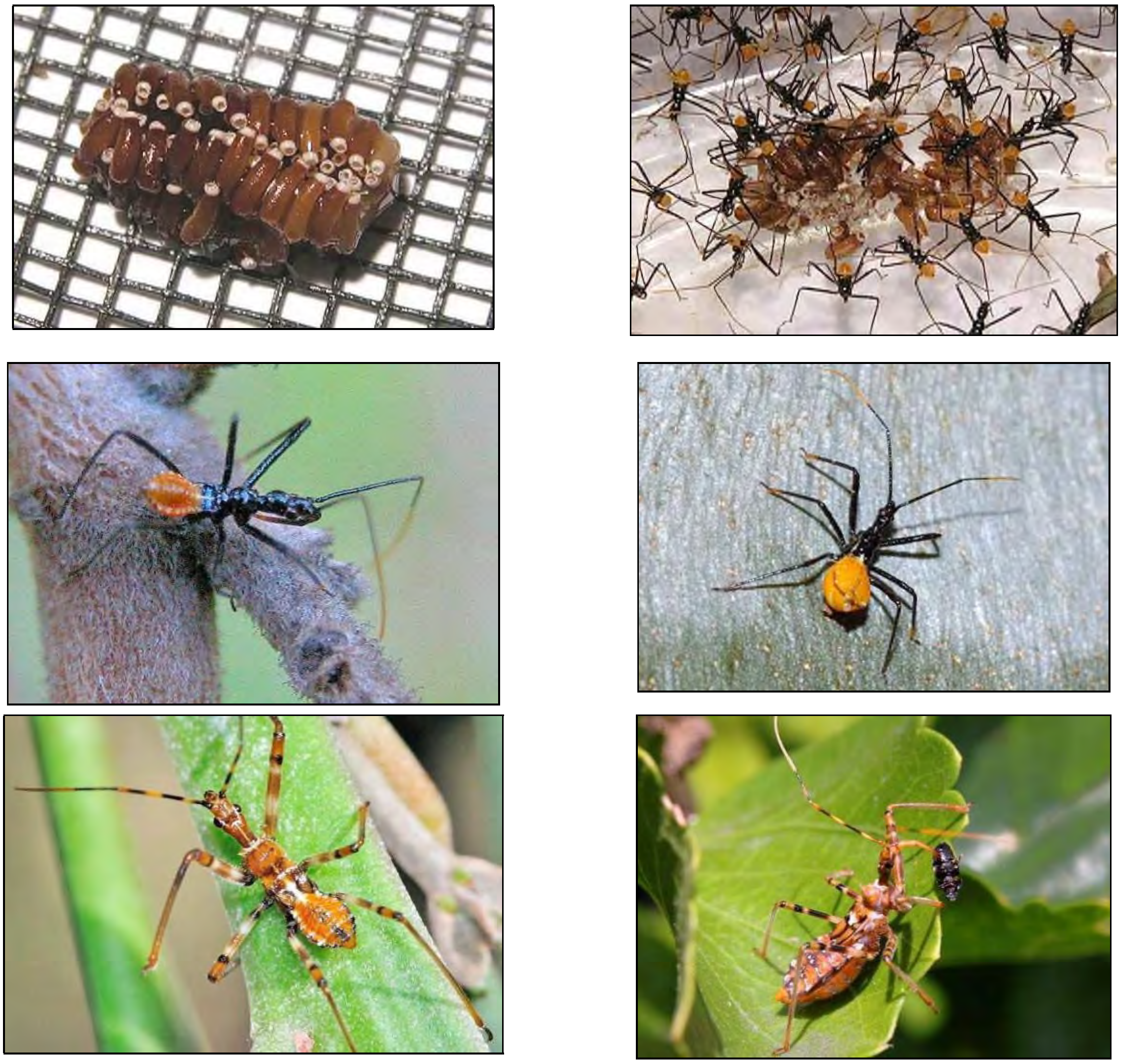


Plate 8. Top left: Eggs of assassin bug. Top right: 1st Instar. Middle left: 2nd instar. Middle right: third instar. Bottom left: 5th Instar. Bottom right: Adult assassin bug. Photos courtesy of Peter Chew, Brisbane Insects.

Some species of assassin bug actually mimic fruit spotting bug, with the nymphs having two distinct dots on their abdomen. They differ in having a more massive proboscis and antennae with a distinct “elbow” in the middle. Mis-identification of assassin bugs as fruit spotting bug can result in unnecessary sprays. Assassin bugs are useful natural enemies of caterpillars and grubs that attack persimmon.

More photos identifying various species of fruit spotting bug can be found at the following sites:

- Richard Llewellyn, Bioresources Pty Ltd provides excellent photos of fruit spotting buds and its natural enemies at his Bioresources Pty Ltd. web site: http://www.bioresources.com.au/FSBbiocontrol/Home.html
- Peter Chew also provides excellent photos of insects such as fruit spotting bug at his web site www.BrisbaneInsects.com

4.14.3 Life cycle

During summer, the spotting bug life cycle takes five to six weeks. There appear to be three overlapping generations - spring, summer and autumn with peaks in numbers about December-February (Figure 1). The adults from the autumn generation persist over winter. Build up of fruit spotting bug occurs earlier under warmer conditions at Mareeba (September) compared with cooler conditions at Alstonville (December).

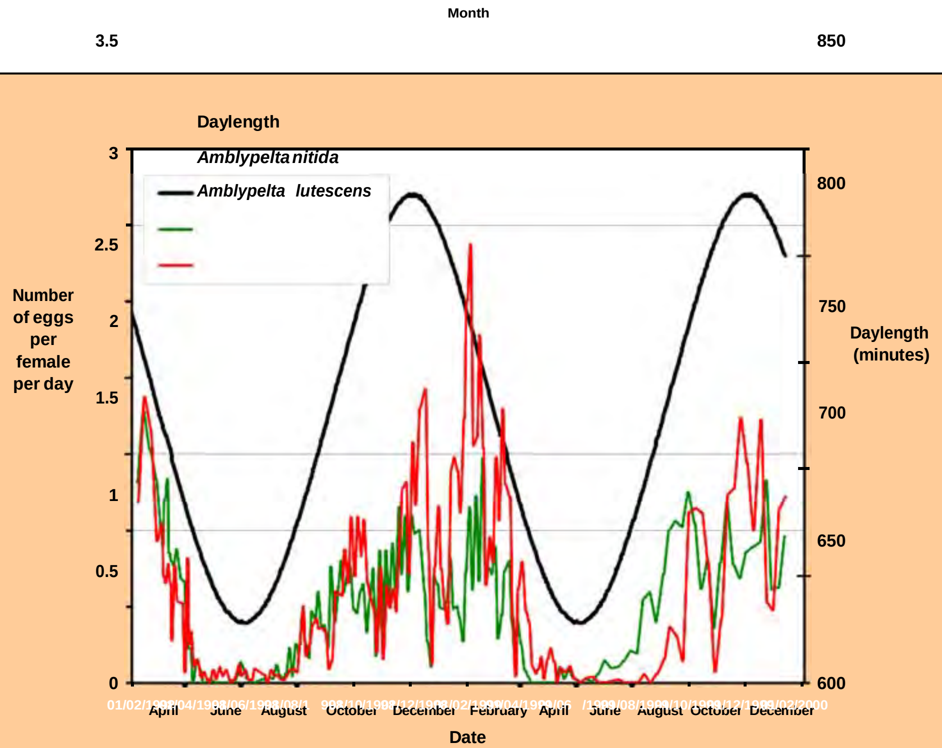


Figure 1. Day-length and the average number of eggs laid per female per day under ambient conditions at Nambour between February 1998 and February 2000 (Waite *et al*., 2001).

4.14.4 Importance and distribution

Both the banana spotting bug (*Amblypelta lutescens lutescens*) and the fruit spotting bug

(*Amblypelta nitida*) are problems on persimmon in south-east Queensland and northern NSW but the banana spotting bug is the only pest in north Queensland.

Fruit spotting bugs are capable of causing considerable damage to persimmon fruit and the damage can often be insidious. Damaged fruit is difficult to see at the tops of trees and it accumulates quickly if you don't intervene with a spray.

The bugs are very mobile so in addition, if you do manage to stop a particular cohort of bugs in its tracks by spraying, the species' migration behaviour ensures that more bugs continuously move into the orchard for as long as the fruit remains susceptible.

One fruit spotting bug can damage over fifty pieces of fruit per tree. Unlike mealy bug/sooty mould damage that may be cleaned off, fruit spotting bug damage makes the fruit unmarketable. Adults and nymphs pierce fruit repeatedly and young fruit usually drop off within 5-10 days. Nymphs do not travel far from their feeding site (they can't fly) and damage is consequently often concentrated in individual trees or parts of trees. Adult damage can appear rapidly over a larger area.

Fruit spotting bugs seem to have become a more severe problem in all susceptible fruit crops over the last 20 years. The reason for this is not known, but increasing urbanisation and its attendant modification of the vegetation spectrum may have created better breeding opportunities for the bugs.

4.14.5 Monitoring

At this stage there is no efficient and reliable monitoring tool for fruit spotting bug. Growers and pest consultants rely on monitoring the damage.

Weather conditions and migration

Many of you will have never seen a bug in your orchard, only the damage they leave. The bugs are very well camouflaged, are active and flighty, and seem to be able to sense your presence, moving quickly out of sight or flying off when you approach. For this reason it is not possible to make sound spray decisions based on the number of bugs sighted, unless there are so many that you can't fail to see them.

Fruit spotting bugs move into the crop if conditions inside the orchard are better than those outside and the weather conditions are suitable. If there is no attractive food source in the crop, they are unlikely to migrate in, unless they are en-route to somewhere else. However, remember that new growth and flowers may attract fruit spotting bug before fruit are apparent.

As unsatisfactory as it is, monitoring for fresh damage is usually the best we can do other than adopting a schedule spray system i.e. spraying by the calendar. In reality, when infestations are constant and severe, weekly or fortnightly spraying may be needed.

Most fruit spotting bug damage occurs between September and February i.e. in the hottest months. Build up of fruit spotting bug occurs earlier under warmer conditions at Mareeba (September) compared with cooler conditions at Alstonville (December). Risk falls significantly after April each season, but a few growers in most areas believe that damage could occur all year. In cool conditions, fruit spotting bugs will be less active and move shorter distances. They are generally poor fliers. This is probably one reason for the strong "edge-effect" in some orchards, where crop along the edge of alternate habitat is more heavily attacked. However, in hot conditions (>32^{o}C) they become highly active and will fly longer distances. This is probably the reason for sudden "outbreaks" through an entire block. Hot and windy weather is the worst case scenario for an "outbreak".

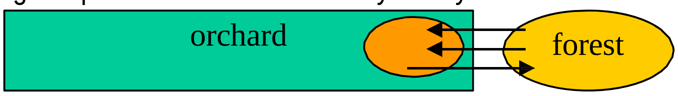
Hot spots

After they enter an orchard, fruit spotting bugs often tend to remain for perhaps several days within a relatively small area of a few trees (Figures 2 and 3). Damage tends to accumulate here, and these areas can be termed 'hotspots'. If the infestation is detected sooner rather than later and an effective spray applied, most damage will be restricted to that area. However, if no spray is applied, as time goes by, individual bugs will start to disperse, damaging fruit throughout the block.

How do hot spots develop?

- Bugs breed in natural forest areas and fly into and out of orchards as found in mark-recapture studies, often alighting first in trees in outside rows.

- Damage accumulates in trees closest to these areas because they are the first encountered, and bugs disperse into the orchard only slowly.



- Sprays kill bugs that are present at the time and prevent their spread through the orchard. After several days immigrant bugs survive due to loss of residual activity of the spray, damage continues in the same area and may spread slightly depending on numbers and spray interval, but the next spray will again limit the area of activity.

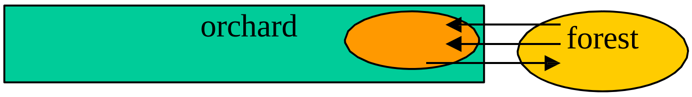


Figure 2: Development of hot spots in orchards

Host plants

Fruit spotting bugs invariably attack only green immature fruit or lush new growth. They have been recorded feeding on the new flush growth of papaw, poinsettia, avocado, mango, custard apple and sweet potato and on the fruit of avocados, bananas, citrus, custard apples, longans, lychees, macadamias, mangoes and persimmons.

Outside the orchard, they appear to favour forest or scrub regrowth containing small trees that bear fruits, such as *Alphitonia* (soap tree and Red ash), *Glochidion* (cheese tree), *Elaeocarpus* (quandong), *Ficus* (sandpaper fig), *Neolitsea* (white bolly gum), *Melia* (white cedar), *Archontophoenix* (bangalow palm) and *Cryptocarya* spp. They have not been confirmed from black wattle and lantana, but both thrive along disturbed scrub boundaries from which fruit spotting bug emerge.

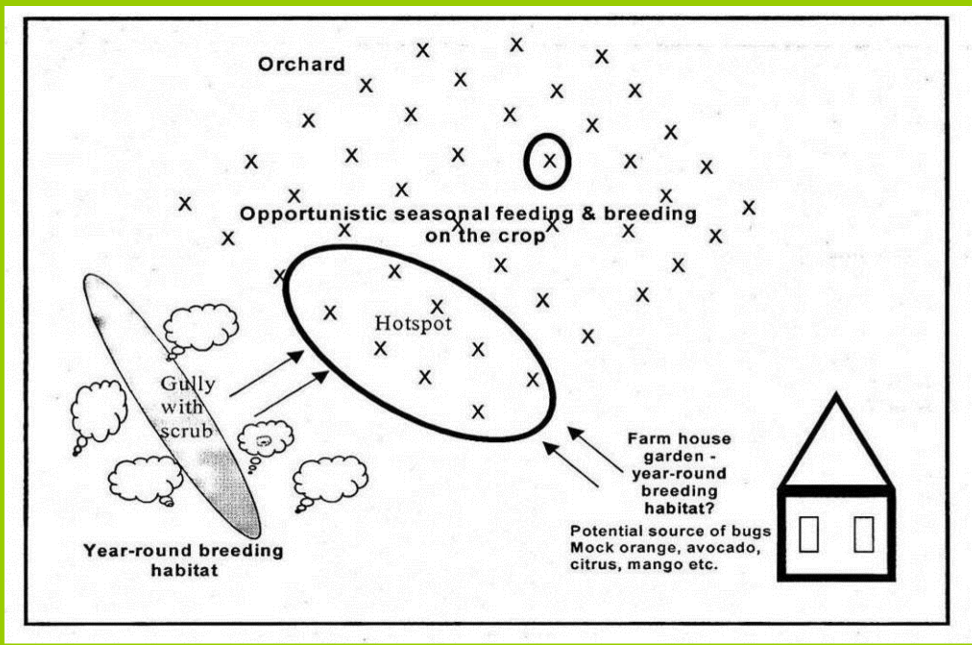


Figure 3. Schematic illustration of where hot spots normally occur.

Most hotspots develop in outside rows adjacent to natural breeding areas i.e. rainforest or scrub, or sometimes urban areas containing suitable host plants that may be unsprayed backyard fruit trees, or any of numerous ornamental hosts such as *Murraya paniculata*, *Calliandra* spp., and *Bauhinia galpinii*. However, individual orchard trees some distance from the outside rows may also become ‘hot trees’. As you accumulate damage data on a tree by tree basis, and build up your specific orchard history, you may be able to identify areas that could be regarded as hot spots. However, be aware that if individual blocks of trees are very small (less than 1 ha), the whole planting may quickly become one big hot spot.

Hot spot spraying

Once hot spots are identified they can be used to advantage to facilitate monitoring and control i.e. you can concentrate your time and effort on these areas, even perhaps spraying them more frequently to ensure that the bugs don’t have a chance to disperse through the rest of the orchard. The position of hot spots can change over seasons, but the ‘hottest’ hotspots are likely to be downwind from rich alternate habitat. In south-east Queensland where the winds are generally northerly or north-westerly, the hottest spot will likely be where there is rich alternate habitat on the north side.

The advantage of controlling fruit spotting bugs in hot spots is that it will be cheaper (less pesticide, fuel and labour), and there is no disruption of parasitoids and predators in the rest of the orchard. It also retains a reservoir of natural enemies that can recolonise the sprayed hot spot area. If you do adopt the hotspot strategy, a quick check of the rest of the orchard is still advisable until you are absolutely confident that this approach will work for your situation.

Orchard monitoring

Systematic monitoring involves looking for live insects or damage to fruit on a regular basis. It helps you avoid surprises. The 'avocado hot spot' project showed over two seasons that systematic monitoring could significantly reduce the number of fruit spotting bug sprays without resulting in increased damage compared with calendar sprays (Waite, 2004).

Detecting the movement of fruit spotting bugs relies on detecting their presence in the crop or on a managed alternate host. To do this requires the accurate identification of:

- Fruit spotting bug eggs
- Fruit spotting bug nymphs and adults
- Similar beneficial insects
- Fruit spotting bug damage

Monitoring for fruit spotting bug eggs is almost a complete waste of time as a professional pest scout monitoring 30-40 farms every week is likely to find only two to three fruit spotting bug eggs per year. Systematic monitoring is not the norm in avocados or persimmon, but is standard practice for fruit spotting bugs in the macadamia industry. There are two main reasons for this:

1. Monitoring in persimmon is more difficult and time consuming. Currently monitoring relies on a trained person inspecting high numbers of trees and fruit. If a pheromone product or host volatile product is developed it may be more cost-effective in future to monitor using a trapping system.
2. Most growers are applying calendar sprays to reduce the risk of diseases. This is despite the fact that neither the effective frequency nor dose of insecticide required to give effective control are known in different varieties or areas.

A systematic monitoring system can then be implemented to assess the levels of bugs, damage and beneficials. Monitor for the pest at fortnightly intervals from late November to late March. It is generally better to assess a high proportion of the trees at a more superficial level than a few trees at high level. A monitoring system developed by Drew (2007) is presented below:

- *Aim to assess 100% of the trees at least every 2 weeks. Assessing 50% of the trees (every tree in alternate rows) every week is the minimum.*
- *Assessment consists of slowly walking past one side of the tree, scanning visible fruit for live bugs and stings. Any suspicious fruit should be removed and inspected. About 300-350 trees can be checked per hour in this manner.*
- *Always cut through suspicious marks in thin slices. Fruit fly damage rarely penetrates more than 2-3 mm, while fruit spotting bug can penetrate up to 10 mm.*
- *If the sting is already woody it is old damage (2-3 weeks at least). If there is a sticky exudate around the sting it is recent damage (1 week).*
- *If a tree is found to have fruit spotting bugs or damage, thoroughly check the whole tree, mark the tree with coloured tape and remove all damaged fruit. The next time this tree is visited it should again be checked thoroughly.*

- *Record how many trees had live fruit spotting bugs or fresh damage and the total number of stung fruit. The total number of stung fruit will include fresh damage plus old damage from the side of the tree not checked the previous week.*
- *This system allows for the whole block to be assessed but with a focus on known high risk trees that may be particularly attractive due to their physiology, variety or location.*

Action levels

Once monitoring has been carried out it is time for decision-making. There are two possible outcomes – no action required, or action required. No action may be necessary if fruit spotting bugs are absent, only at very low level or likely to be controlled by natural enemies. Below are two examples with proposed action levels for spraying fruit spotting bugs in tree fruits (Tables 1 and 2).

TABLE 1.

Example 1. Data from an orchard and the decision to spray or not based on threshold levels (adapted from Drew, 2007).

Number of trees Checked	254	Actual % of trees or fruit affected	Spray Threshold	Spray Decision?
No. trees with live bugs	3	1.2%	0.5%	Yes
No. trees with freshly stung fruit	9	3.5%	2.5%	Yes
Total no. stung fruit	16	0.06 fruit/tree	0.10	No

*The results indicate that bugs are just moving in but little damage has occurred – a good time to spray.

TABLE 2.

Example 2. Data from an orchard and the decision to spray or not based on threshold levels (adapted from Drew, 2007).

Number of trees Checked	254	Actual % of trees or fruit affected	Spray Threshold	Spray Decision?
No. trees with live bugs	0	0	0.5%	No
No. trees with freshly stung fruit	6	2.4%	2.5%	No
Total no. stung fruit	18	0.06 fruit/tree	0.10	No

*The results indicate that bugs are at low levels and little damage has occurred – no need to spray.

4.14.6 Chemical control

Hot spot spraying

A combination of management tools (e.g. trap crops, varieties, biological control etc) may be necessary to reduce fruit spotting bug numbers back to controllable levels with "minimal spraying "(e.g. restricting spraying, one spray or spot spraying) (Llewlyn, 2011). If growers can identify ‘hot spots’, and before large scale infestation, these trees should be sprayed first. Spraying “hot spots” instead of the whole orchard means better survival of beneficial predators.

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Methidathion

Methidathion (e.g. Supracide® PER13694) provides adequate control of the pest but tends to disrupt natural enemies and induce outbreaks of other pests such as two-spotted mite. Two or more sprays of methidathion (e.g.Supracide ®) should be made prior to the release of the predators. In warmer areas spraying will have to commence earlier (November) compared with cooler regions e.g. December. Under high pressure situations, sprays may need to be applied every two to three weeks for several months.

Spray volumes

For large trees, growers may need to spray between 1500 -2000 litres per hectare because at lower rates (<1000 litres) fruit spotting bugs simply move to parts of the tree not sprayed effectively.

4.14.7 Biological control

Predators

Llewlyn (Bioresources, 2011) has indicated that natural predators of fruit spotting bugs include:

- ants (found in good numbers in macadamia farms)
- spiders (a significant predator in avocados) (Plate 9)
- green lacewings (late instar green lacewings have been observed predating on FSB nymphs)
- birds and micro bats
- assassin bugs feed on spotting bug nymphs

Llewlyn (Bioresources, 2011) considers that assassin bugs may be a potential mass rearing candidate. They were once commercially reared but not now. They were reared mainly to target heliothis in cotton and field crops but the cost of production and quantities required were a major limitation. Positioned in an IPM program and with other mass reared natural enemies of spotting bugs, they are likely to make a useful contribution and may be commercially viable under a different pricing structure. They could be released at 3rd instar stage into crop headlands, trap crops and boundary rows. They take about another 6 weeks to develop to adults so cannot fly away until then.

Plate 9. Garden wolf spider, *Lycosa godeffroyi*. Spiders are predators of spotting bugs. Photo: David McClenaghan, CSIRO.

Parasitoids

Parasitoids are typically wasps or flies. They lay their eggs into or on the host. The eggs hatch and the larvae consume the host and kill it in the process. They develop to adulthood inside or adjacent to the host. Parasitoids generally have a narrower host range than predators and some are narrower than others.

A number of egg parasitoids have been found in the past (Huwer, 2009; Fay *et al*., 2009; Llewellyn, 2011)). The egg parasitoids are difficult to rear. These egg parasitoids include:

- *Anastatus* spp. (Plate 10)
- *Ooencyrtus caurus*
- *Gryon* spp.
- *Centrodora darwini*

Plate 10. The wasp Anastatus parasitising and egg of fruit spotting bug. Photo courtesy of Richard Llewlyn, Bioresources Pty Ltd.

Gryon spp. and *Centrodora darwini* commonly occur in orchards at Altonville, NSW.

The parasitic fly *Trichopoda giacomellii* has been released in Australia to control the green vegetable bug *Nezara viridula*. This paraitic fly attacks the late instar nymphys and adults and would thereore be much more effective in reducing bug populations and could be useful for the the biological control of fruit spotting bug (Huwer, 2009). A closely related species *Trichopoda pennipes* has been recorded as a biological control agent for *Amblypeta cocophaga* (closely related to fruit spotting bug). It would also be worth testing.

At present, the natural enemies that are most likely to exert short-term control of fruit spotting bug, in an outbreak or migration phase, are birds and spiders that are already in the orchard. Little is known about the effects of birds. While wolf spiders are commonly seen lurking on fruit, whether they can catch fruit spotting bug, is another matter. However, anecdotal evidence suggests that high numbers of wolf spiders and web-making spiders do keep fruit spotting bug at bay. In one avocado orchard, in a high risk area, piles of chicken manure were left to breed up flies, to boost the food supply and spider population. These resident spiders then caught the fruit spotting bugs flying in.

The presence of high numbers of spiders is a good indication of an active predator-prey system in the orchard. Thus, if weekly monitoring indicates that spider numbers are high and fresh fruit spotting bug are low, and temperatures are below 30^{o} C, then give the spiders the benefit of the doubt. If temperatures are high it is likely that they will be overwhelmed and a spray may be warranted.

If natural enemies are unlikely to exert sufficient control there are chemical options available. These are generally cheap and effective but may disrupt other ecological balances or cause unacceptable outcomes. If used incorrectly they can also be expensive and ineffective, so it is well worth ensuring that the application methods and chemical dose are reviewed regularly.

Alternate habitats

Natural enemies can exert an effect either in the orchard or in the nearby alternate habitat. To maintain natural enemies in the orchard requires a constant food source. Natural enemies appear to be relatively unimportant in controlling fruit spotting bugs in orchards. This is because fruit spotting bugs are "stink bugs" and are well adapted to protecting themselves by releasing noxious allomones to deter natural enemies. Additionally any effective spray program for fruit spotting bug is likely to eliminate any insect predators and parasites.

Natural enemies in the alternate habitat, unaffected by sprays, will be exerting a general depressive effect on fruit spotting bug populations. However, once the fruit spotting bug population enters an outbreak phase, generally stimulated by higher temperatures in late spring and summer, it is unlikely that these natural enemies will follow them quickly into the orchard and exert short-term control. There will be a critical catch-up phase, during which significant damage may occur.

Local area management

Local area wide management programs would be desirable involving collaboration between nearby farmers (Llewlyn, Bioresources, 2011). What is envisage (assuming it possible to mass rear a good parasitoid) is to release parasitoids into areas where fruit spotting bug are breeding - hot spots in the crop, along crop boundaries and non-crop hosts nearby.

4.14.8 Orchard management strategies

Reducing fruit spotting bug migration

Migration into the crop can be reduced by four factors, namely:

- Removal of, or increased separation from, alternate favourable habitat
- Making the crop habitat less attractive
- Attracting the fruit spotting bugs to a managed alternate host
- Exclusion netting

Clearing alternate habitat back from your crop can reduce the edge effect which is predominant in cooler weather. About 20 metres would probably help, but to reduce migration during hot weather would probably require 100 metres. Removal of preferred species in the undergrowth (the preferred habitat) may assist.

Tree training system, pruning and tree density

Fruit spotting bug prefer a humid shaded microclimate. Increasing the distance between trees or opening up the canopy makes them less attractive. One commercial persimmon grower has indicated that there is considerably less damage on trellised trees. Trellising also improves spray penetration. However, hot spot studies suggest that orchard location is the most important factor and changes to canopy structure would likely have only a small effect.

Netting

Nets of a suitable mesh size (10-12 mm quad), exclude not only vertebrate pests from fruit crops, but also many insect pests, including fruit spotting bugs. For crops such as persimmon, lychees and persimmons, such nets have protected the crops from a range of pests without having a serious impact on the physiology of the trees through reduced light, increased temperature, and reduced air movement. Commercial netting companies continue to refine net types and structures, and opportunities for excluding fruit spotting bugs need to be examined.

Physical barriers on the fruit and tree

Particle film (Surround®), and oil sprays (Biopest®), have been investigated to determine if a film of these products sprayed onto the surface of the leaves and fruit, will deter fruit spotting bugs from feeding.

Surround®, seems to provide some protection from the bugs, and provides protection for those fruit that might suffer from sunburn.

Decoy and trap trees

Current research is investigating the possibility of using attractive host trees for monitoring fruit spotting bug and targeted control. The bugs invade orchards from external breeding areas. In many situations, mainly in larger orchards, hotspots can be identified, and the planting of attractive alternative hosts as decoys or trap trees is an option.

Apart from many crop species, numerous ornamental and native plants are hosts of fruit spotting bugs. Mock orange, *Murraya paniculata*, (Plate 11) is a particular favourite of both species of fruit spotting bug, but it is only attractive while it bears fruit. Only the flowering and early fruit set period of some crops would be covered, if *Murraya* were used as a trap tree. It could be of use in persimmon with their short flowering period.

Plate 11. Hedge of Mock orange *Murraya paniculata*

On the other hand, ‘Fuerte’ avocados are attractive from fruit set in September through to the end of the fruit spotting bug season in April, and could be used in an ‘attract and destroy’ strategy for persimmon.

A continuous row of avocado, or a mix of early and late crops such as lychee and longan, would need to be planted around the block boundaries. This row could then easily be sprayed on a regular basis, leaving the main portion of the block to be sprayed only as required based on monitoring. This is likely to be more effective than spraying the boundaries of the scrub.

Host plant volatiles and pheromones

Dr Harry Fay and his team from DAF have produced an artificial attractant based on the fruit spotting bugs natural pheromones. In work with the U.S. Department of Agriculture, the scientists have found a way to synthesise a sexual attractant produced by male fruitspotting bugs. The fake male pheromone has now been successfully trialled to trap female bugs. Dr Fay says finding the bugs as soon as they arrive in a crop can tell a grower when to spray to prevent damage. It may be up to two years before a trap is commercially available

It may also be feasible to produce host plant volatiles using some new technology that allows efficient sampling of the headspace of fruit and plants. The theory is that the bugs recognise specific chemicals produced by host plants or the fruit on which they feed, and these lead them to the plant to feed.

4.15 THRIPS

4.15.1 Damage

Damage consists of uneven, silvery-grey scarring of the fruit surface (Plate 1). The thrips are often found beneath the petals that adhere to the bottom of fruit. Consequently, thrips are not noticed but damage shows up as fruit near maturity. Larval and adult greenhouse thrips cause feeding injury by piercing and sucking out the contents of cells, causing collapse of the cell wall and discolouration of the surface of the fruit or leaf.

Plate 1. Thrip damage on persimmon.

4.15.2 Species and description

There are several species (Plates 2 and 3) which attack persimmon including:

- Greenhouse thrips *(Heliothrips haemorrhoidalis)*
- Western Flower Thrip *(Frankliniella occidentalis)*
- Plague thrip *(Thrips imagines)*

Plate 2. Left: Western Flower Thrip (Photo SARDI). Right: Plague thrip.

4.15.3 Life cycle

Thrips belong to the insect order Thysanoptera. They are small, slender insects, mostly 0.5 to 2 mm in length. The adults of most species have band-like wings with a wide marginal hair fringe. There are over 5 000 known species of thrips and they occupy diverse habitats in all climatic zones. Most species feed on fungi or plants. Those that feed on plants use their piercing and sucking mouthparts to pierce plant cells and then suck out the cell contents. The life cycle of plant feeding thrips is illustrated in Figure 1. Adult female thrips lay eggs into leaves or flowers.

The eggs hatch into an active, feeding juvenile or larval stage. There are two larval stages, which look like small, wingless adults, followed by two inactive, non-feeding pupal stages found on the ground or on plants. Winged adults then emerge and can live from 28 to 90 days. The length of the life cycle depends on temperature and the quality of the food source. For example, at 30°C the life cycle of western flower thrips will typically be completed in approximately 12 days while at 20°C the cycle extends to about 19 days.

Plate 3. Adult and larval stages of thrip.

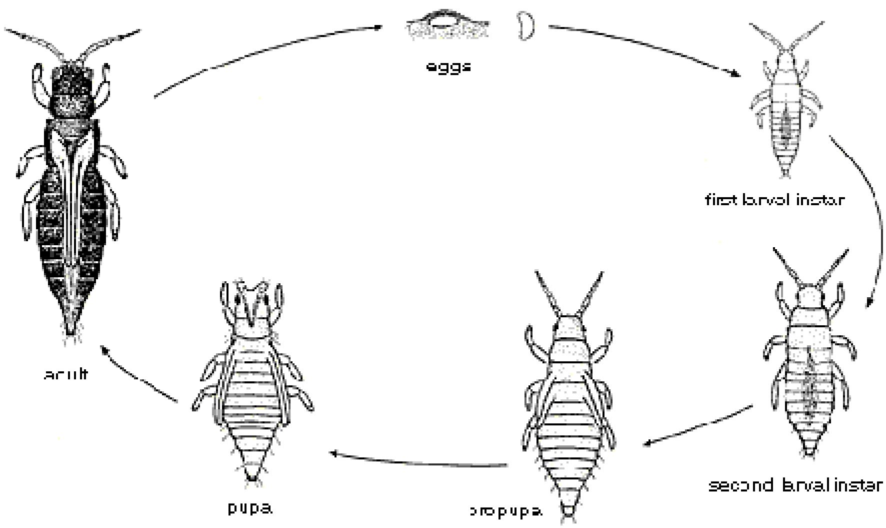

Figure 1. Life cycle of thrip

4.15.4 Importance and distribution

More than 40 types of plants are hosts for thrips and feeding damage is often described as ‘silvering’. The thrips are often found beneath the petals that adhere to the bottom of fruit. Consequently, thrips are not noticed but damage shows up as fruit near maturity. While minor thrips damage can be tolerated, any damage covering an area of more than 2 cm^2 will result in the fruit being unacceptable for premium export grade. The variety ‘Izu’ appears to be more affected because of its thinner skin. In the past, thrips were controlled through sprays of endosulfan which was sprayed to control fruit spotting bugs. Since endosulfan has been deregistered, and no longer sprayed by growers, thrips have become more of a problem in some regions.

4.15.5 Monitoring

Monitor thrips adults and larvae by branch beating or shaking foliage or flowers onto a sheet of paper. Adult thrips can also be monitored using bright yellow sticky traps. Blue sticky traps are most effective for capturing western flower thrips, but thrips are harder to discern on this darker background. Do a weekly count of thrips on each trap. Remember that the presence of thrips does not mean that damage will result from their feeding. Even large numbers of thrips in traps or adults at flowers feeding on pollen do not necessarily indicate that control action is needed.

Action levels

Currently there is no spray thresholds and no counts on the number of thrips which could be tolerated before economic damage occurred. Check thrips numbers in flowers 1-2 days after spraying to check efficacy.

4.15.6 Chemical control

Thrips are currently controlled using a calendar spray programme based on broad-spectrum insecticides. Most greenhouse thrips damage persimmon just after fruit set (October-November) or when the fruit reach full maturity. The timing of insecticide applications necessary to prevent greenhouse thrips damage to new season's fruit potentially falls into the period during flowering and soon after fruit set.

If, after predators are released, the thrips population increases to damaging levels (or above a predetermined spray threshold), a compatible insecticide can be applied to reduce thrips numbers, allowing the predators to catch up and eliminate the remaining thrips. Spot spraying is preferable to blanket spraying.

Spinosad

The least hazardous thripicide currently available for persimmon is spinosad (Entrust Naturalyte®, Success 2®). Timing of application at flowering is critical. Soap and oil sprays, and more toxic sprays such as Lorsban® (chlorpyrifos) can be used with reduced impact on the predators if they are spot sprayed only.

Methomyl

Methomyl (Lannate®) can be used to control all types of thrips (refer to PER14548).

4.15.7 Biological control

Due to their small size and high rate of reproduction, thrips are difficult to control using classical biological control. All predators must be small and slender enough to penetrate the crevices that thrips hide in while feeding, and then prey extensively on eggs and larvae. Releasing purchased natural enemies in most situations is unlikely to provide satisfactory pest control.

Conserving naturally occurring populations of beneficials by controlling dust and avoiding persistent pesticides is the most important way to encourage biological control of pest thrips.

According to the Good Bugs Book (www.goodbugs.org.au) there are number of biological control agents. These include: Cucumeris mite: *Neoseiulus cucumeris*, this predatory mite has been produced commercially for many years in Europe. It is part of a large group of predatory mites called phytoseiids, and feeds on the larval stages of thrips and some mites. This species is currently available in New Zealand but not in Australia.

Other natural enemies of thrips include:

- Soil-dwelling predatory mites *Hypoaspis* spp.
- Native predatory mites
- Minute pirate bug *Orius* spp.
- Parasitic wasps *Thripobius semiluteus* (for greenhouse thrips) and *Ceranisus* spp.
- Entomopathogens *Beauveria*, *Entomophthora*,
- *Verticillium*

4.15.8 Orchard management strategies

- Reflective mulch or mesh confuses and repels certain flying insects searching for plants, apparently because reflected ultraviolet light interferes with the insects' ability to locate plants. Most uses of reflective mulch have been against winged aphids, but infestation of young plants by other pests including leafhoppers, thrips, and whiteflies has also been prevented or delayed.

- Airblast trees with a fungicide to prevent petal adherence just after fruit set. This will help remove the petals which adhere to the base of the fruit; these can become a site for thrips to hide under.

4.16 ERIOPHYID MITES

4.16.1 Damage

Rust damage caused by Eriophyid mite (*Aceria. diospyri*) initially appears, in mid-summer, as black marks from the calyx. The damaged fruit surface cracks due to fruit enlargement and a dark brown rust symptom (Plate 1) appears during the late enlargement stage to the harvest stage.

Plate 1. Eriophyid mite damage near calyx of fruit. (Photos: Ashihara, Japan Agricultural Research Centre).

4.16.2 Species and description

Family: Eriophyidae, possibly spp. Aceria *diospyri.* The presence of this pest in Australia is undecided but damage similar to that shown in Plate 1 has been observed in Australia.

4.16.3 Life cycle

Eriophyid mites over winter as specialized winter hardy females which crawl into bark crevices or buds (depending on the mite species) (Figure 1). Females emerge in the spring and travel to the flowers or leaves. The males deposit packets of sperm on the leaves, the females find the packets and fertilize themselves. The female then lays eggs, which hatch and go through two larval stages. The typical life cycle of eriophyid mites includes an egg, two nymphal instars, and an adult stage. Mites can develop from eggs to adults in only 1 week under favourable conditions.

4.16.4 Importance and distribution

Eriophyid mite appears to be a minor pest in Australia. Cultivar Jiro is more susceptible than 'Fuyu'. The mites can be distributed to other trees by wind, insects, and birds. The adults live for approximately one month. There are several generations per year. When the leaves start to harden, late in the year, the specialized winter hardy females are produced. These females fertilize themselves and move to winter shelter. *A. diospyri* begins to reproduce in the dormant buds around late winter/early spring. The first mite infestation on the leaves is found in dense trichomes by the midrib on the lower surface of the leaves, and moves towards the upper leaves of the foliation. In mid-summer, the number of *A. diospyri* on the leaves suddenly decreases and the mites begin to migrate into the calyces when the leaves become hard and the flower petals drop. Most of *A. diospyri* inhabit the trichomes inside of the calyces. Some of them infest the surface of the fruits and cause damage.

The highest density of mites on fruits is found between mid- to late-summer and the density decreases later. The leaf infestation is observed again on the secondary-growth-shoots in mid-summer (December). Invasion of *A. diospyri* individuals into newly formed axillary buds starts from early summer (November). The mites in the buds may hibernate without reproduction in the axillary buds because the number of eggs is extremely low. The life cycle is shown in Figure 1.

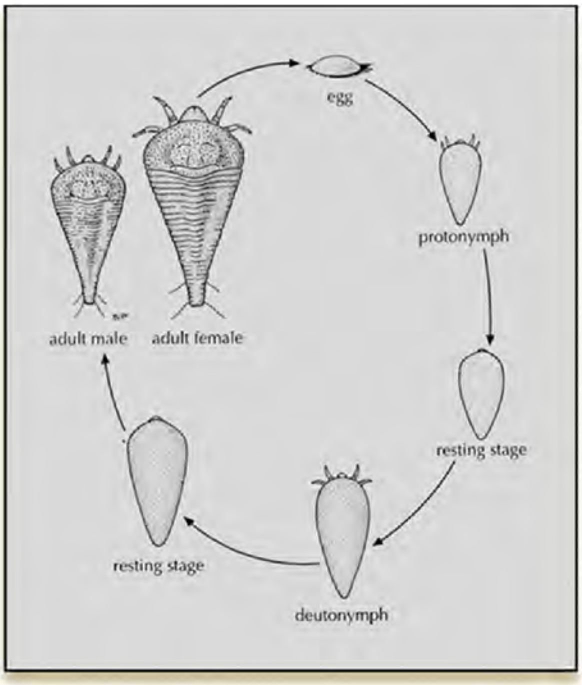

Figure 1. Life cycle of Eriophyid mite.

4.16.5 Monitoring

Check for mites in and around the calyces in early summer.

4.16.6 Chemical control

Currently there are so selective miticides registered for use on persimmon.

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4.16.7 Biological control

Predators

Eriophyid mites are more likely to reach high densities in sprayed orchards where predaceous mites are destroyed. Several species of Phytoseiidae such as *Phytoseius nipponicus*, *P. kishii*, *Typhlodromus vulgaris* and *Amblyseius eharai* are found on persimmon leaves. However, the densities of these phytoseiids are commonly low. Observations that *A. diospyri* population densities were low on fruits where phytoseiids were present may indicate that the predators are effective for control of *A. diospyri* populations.

4.16.8 Orchard management strategies

- Disbudding to create a leaf-to-fruit ratio of about 15 is recommended in order to produce high quality fruits. This process is related to predation of *A. diospyri* by Phytoseiidae which leads to a reduction in rust damage by *A. diospyri*.

- Infestations of mite are commonly the result of misusing broad-spectrum pesticides such as methidathion to control pests such as mealybugs. Such misuse destroys the natural enemies of mite. Avoid using such pesticides, and prevent spray drift.

- Applying fruit fly baits too high in the tree is also disruptive to predators and results in outbreaks of mite. Bait sprays should be applied to the lower parts of the tree.

4.17 TWO SPOTTED MITES

4.17.1 Damage

Two-spotted mites cause leaves of persimmon trees to turn a dull greyish colour and in some cases, leaves become chlorotic and fall (Plate 1).

Plate 1. Spotted mite damage on the back of leaves.

4.17.2 Species and description

Two spotted mite (*Tetranychus urticae*) (Plate 2). The adult female two-spotted mite is 0.5 mm long and greenish-yellow with a dark spot on either side of the body. The males are smaller and narrower than the females. Under stressful conditions, two-spotted mites turn a reddish colour.

Plate 2. Two-spotted mite (right) and Chilean predatory mite (left).

4.17.3 Life cycle

The eggs are spherical and translucent, changing to yellow as they age. They are laid on the leaf or fruit surface within spidery webbing produced by the mites. Each female lays about 70 eggs over a period of a fortnight. Larvae with six legs hatch from the eggs. After moulting to the first of two nymphal stages, they develop eight legs. The life cycle can take as little as 10 days in the summer (Figure 1). There are 10 to 20 generations per year.

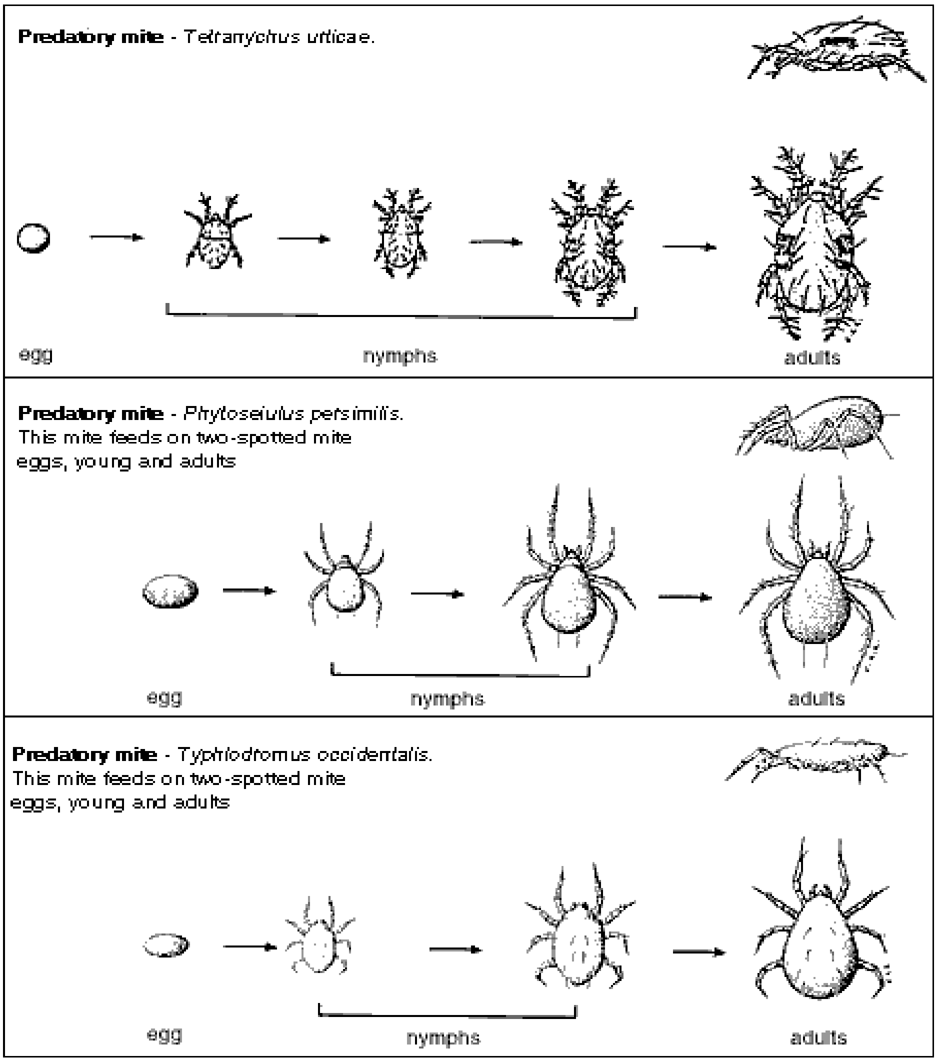

Figure 1. Life cycles of the two-spotted mite, the Chilean predatory mite (*Phytoseiulus persimilis*), and the typhlodromid predatory mite (*Typhlodromus occidentalis*).

4.17.4 Importance and distribution

Although two-spotted mites are widely distributed through all the major persimmon growing regions (Figure 2), they are a minor problem. Their populations can increase during the hot dry months from November to February and during exceptionally dry seasons. They are more likely to be a problem if there is excessive application of broad-spectrum pesticides. They are normally controlled by predatory *Phytoseiid* mites and are also devoured by Stethorus ladybirds, lacewing larvae and predatory thrips.

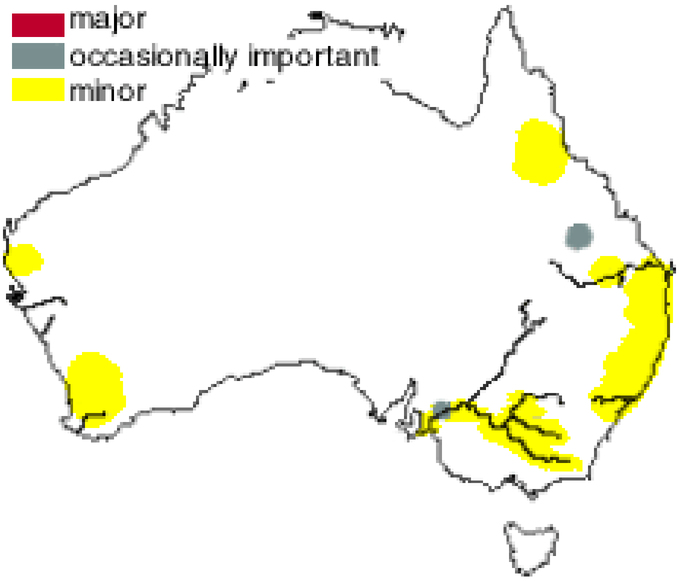

Figure 2. Distribution of two-spotted mite in Australia.

4.17.5 Monitoring

Two-spotted mite occurs on all persimmon varieties. The pest and its predators should be monitored fortnightly, from the beginning of November to May in Queensland and coastal New South Wales, if there is any evidence that the mite is present, or if its presence is suspected. Elsewhere, monitor from January to April. Using a x 10 hand lens, check 5 randomly selected fruit or 5 leaves per tree. Check the upper leaf surfaces and exposed fruit surfaces.

Action level

Action is required when more than 20% of fruit or leaves are infested.

4.17.6 Chemical control

Currently there are so selective miticides registered for use on persimmon.

4.17.7 Biological control

Predators

The major natural enemies of two-spotted mite are predatory thrips (*Scolothrips sexmaculatus*) (Plate 3), stethorus ladybirds (Plate 4), predatory mites (Plate 5) and lacewing larvae.

The Chilean predatory mite (*Phytoseiulus persimilis*) is a voracious predator of two-spotted mite, particularly in coastal areas of Queensland. It is about 0.7 mm long, with a pear-shaped body, and a shiny, orange-red in colour. The adult female lives for about four weeks during which time she lays about 50 eggs. These hatch in 2 to 3 days and develop through two nymphal stages to the adult in about a week.

Plate 3. Six-spotted thrips (*Scolothrips sexmaculatus*), a predator of two-spotted mite.

The Chilean predatory mites multiply twice as fast as the two-spotted mites and each eat about 7 mites per day, so when present they usually completely control the pest within 6 to 8 weeks.

Plate 4. Stethorus ladybird, a predator of two-spotted mite, with some of its prey.

The predatory mite *Typhlodromus occidentalis* is also an important predator in hot, dry areas. Both *Typhlodromus occidentalis* and *Phytoseiulus persimilis* can be purchased from commercial suppliers for release into orchards to control two-spotted mite.

Plate 5. A typhlodromid predatory mite feeding on a two-spotted mite egg.

Native phytoseiid mites, e.g. *Euseius victoriensis* and *Euseius elinae*, also prey on two-spotted mite in Queensland and inland New South Wales.

Lacewing larvae commonly occur on persimmon, where they feed on scales, mealybugs, moth eggs, aphids, thrips and mites. Lacewing eggs are 0.5 to 1.0 mm long, and each one is attached by a long stalk to the laying site, e.g. the surface of a leaf. Groups of several eggs are laid close to each other. The larvae are cream to brown in colour and up to 8 mm long. They move actively amongst the prey, impaling their victims on their large sickle-shaped jaws and sucking out the body contents. The larvae attach the remains of their prey to their backs, probably for camouflage.

Pathogens

Some disease-causing fungi (e.g. *Neozygites* spp., *Hirsutella thompsonii*) may help control two-spotted mite populations, especially in coastal areas.

4.17.8 Orchard management strategies

Infestations of two-spotted mite are commonly the result of misusing broad-spectrum pesticides such as methidathion to control pests such as mealybugs. Such misuse destroys the natural enemies of two-spotted mite. Avoid using such pesticides, and prevent spray drift.

Applying fruit-fly baits too high in the tree is also disruptive to predators and results in outbreaks of two-spotted mite. Bait sprays should be applied to the lower parts of the tree.

4.18 FRUIT PIERCING MOTH

4.18.1 Damage

Moths feed at night by penetrating the skin of the ripe or ripening fruit with their strong proboscis and sucking the juice. Internal injury consists of a bruised dry area beneath the skin (Plate 1). Secondary rots develop at the puncture site. Fermenting fruit are often visited and fed on by secondary-moth feeders taking advantage of the access hole drilled by fruit piercing moths. Early summer to early autumn is the most important period for attack.

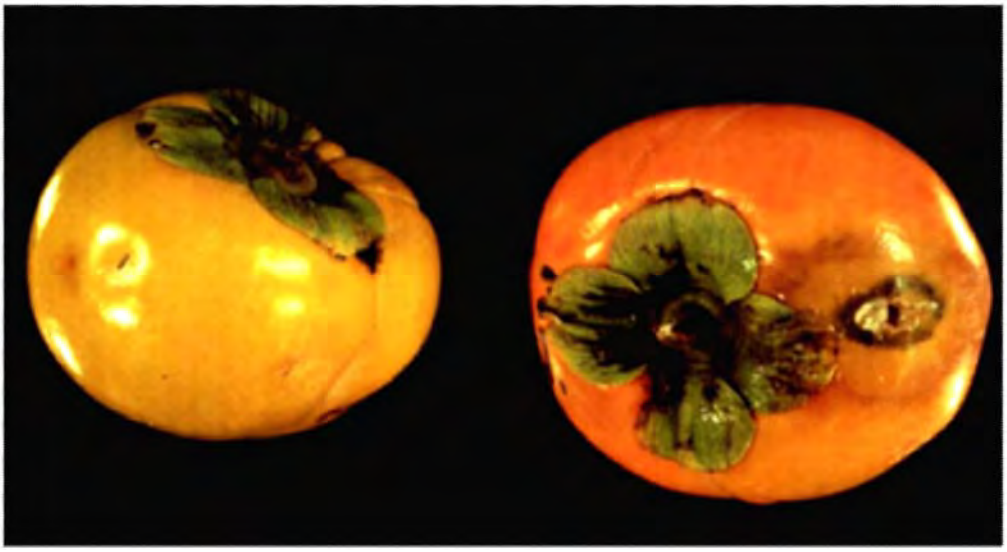

Plate 1. Damage caused by fruit piercing moth.

4.18.2 Species and distribution

Several genera of noctuid moths are fruit piercing but the most damaging are *Eudocima fullonia, E. materna, E. jordani* and *E. salaminia* (Plate 2). The adult moths are large and stout-bodied, with a wingspan of 100 mm. The forewings can be mainly brown, cream or green. Hind wings are yellow orange, with black patches and spots. The larvae of Eudocima spp. have two large spots (mainly white with dark centres) on either side of the body just before the first pair of prolegs.

4.18.3 Life cycle

The larvae feed on native vines for about three weeks, progressing through five or six stages, or instars, before forming dark-brown pupae in a delicate silk cocoon between webbed leaves. After 2-3 weeks adults emerge from the pupa.

4.18.4 Importance and distribution

Fruitpiercing moths are found on the east-coast of Australia, north from the Northern Rivers District of New South Wales (Figure 1). They are a minor pest of persimmon in Queensland and northern NSW. A few species also occur across the north of the continent. Breeding occurs through most of the year in north Queensland, although it is much reduced during the dry season. In drier areas such as Central Queensland outbreaks are more common in wet years that are favourable to continuous growth of the larval-host vines. It is believed that they die out in areas south of Mackay/Rockhampton in cold winters and reinvade the southern areas after winter.

Moths feed on carambola, banana, citrus, fig, guava, kiwifruit, longan lychee, mango, stonefruit, persimmon and ripening papaw. Larval hosts include native vines of the family Menispermaceae (of which there are about 20 species in north Queensland). The preferred species are *Tinospora smilacina* and *Stephania* spp.

Plate 2. Top Left: *Eudocima salaminia* moth resting on a fruit. Top Right: *Eudocima fullonia* with wings pinned out. Photos by David Astridge and Harry Fay, DEEDI. Bottom: Eudocima on persimmon fruit. Photo courtesy of Annette McFarlane.

4.18.5 Monitoring

Nightly inspections with a strong torch are recommended when fruit is nearing maturity. The red eyes of the moths will reflect the light from a torch, aiding detection.

4.18.6 Chemical control

No satisfactory chemical control measure is known. Hand collection of moths and various traps have had limited success.

4.18.7 Biological control

Several native parasitic wasps are known but have limited impact during summer.

Figure 1. Distribution of fruit piercing moth in Australia.

4.18.8 Orchard management strategies

- Netting trees or bagging fruits is very effective. Early harvest, where it doesn't jeopardise maturity standards, will help to reduce losses.

- Flooding orchard trees with light, especially yellow-green light (580 nm), or establishing barriers of outward-shining light around orchards (>2 lumens/m²), have been shown to suppress fruit-piercing moth feeding by 60-90%. Nevertheless, there are still doubts over the effectiveness of the technique when moth populations are extreme. The disadvantages of the technique are the considerable infrastructure costs, the need for an accessible and reliable electricity supply, and the lack of impact on other pests.

- Various types of light traps with fluorescent backlight bulbs have been partially successful in controlling populations of different types of moths. Effectiveness for fruit piercing moth is not known.

4.19 LEAFHOPPERS (JASSIDS)

4.19.1 Damage

Both adults and nymphs feed by puncturing the undersides of leaves and stems and sucking out plant juices, leaving a mottled appearance. Their saliva is toxic causing some plants to react with severe leaf distortions, including warty, crinkled leaves, rolled edges, or stunted growth. Plants may have tipburn and yellowed, curled leaves with white spots on the undersides. As they feed, leafhoppers excrete sticky honeydew.

4.19.2 Species and identification

Leaf hoppers. Various species e.g. Green Mottled Planthopper (*Siphanta acuta)* (Plate 1), vegetable leafhopper *(Austroasca viridigrisea).*

Plate 1. Top: Green Mottled Planthopper (*Siphanta acuta*) is triangular in shape with pink eyes and a pointed head. The forewings cover the body like sloping roof when it rests. This species has the dot patterns on the wings with brown wing edges. Bottom: fourth instar on a persimmon shoot.

4.19.3 Life cycle

Adults over winter, usually on or about wild host plants, and start laying eggs in the spring when leaves begin to emerge on trees (Figure 1). Some species don't survive winter, so they migrate over long distances from warmer Southern areas every summer to the Northern regions. Females lay eggs in rows or clusters usually in the tissue of leaves and stems. The eggs hatch in one to two weeks and nymphs develop for one to four weeks (Plate 2). Most species have two to five generations per year. The first frosts in the autumn usually kill off the nymphs; some leafhoppers will over-winter as eggs. Eggs are laid in slits made in soft plant tissue. During hot weather, a life cycle can be completed in less than two weeks. Dense populations (100 or more per square metre) are frequently encountered on the leaves.

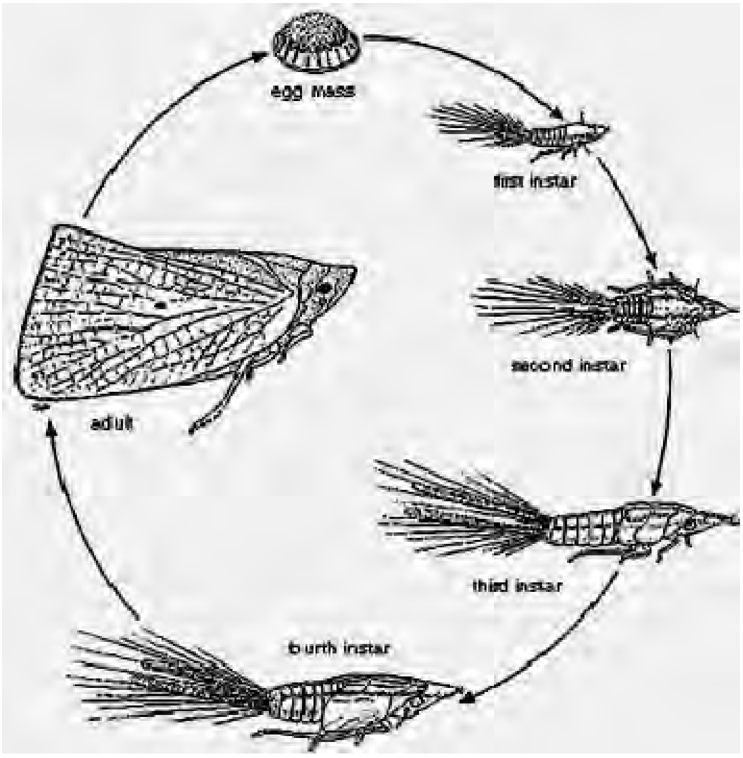

Figure 1. Life cycle of leafhoppers.

 

Plate 2. Left: Mango planthopper egg masses unhatched with newly hatched nymphs. Right; Green planthopper egg mass and newly hatched nymphs.

4.19.4 Importance and distribution

Leafhoppers are a minor pest of persimmon. The species is endemic to Australia - found in all States. Species can be somewhat specific to certain host plants. As a group they feed on most fruits and vegetables, especially apple, bean, cucumber, tomatoes and related plants, eggplant, grape, potato, flowers, weeds and all summer pulses, including peanuts. Many species spread viruses and other disease-causing organisms. Distribution of leafhoppers in Australia is shown in Figure 2.

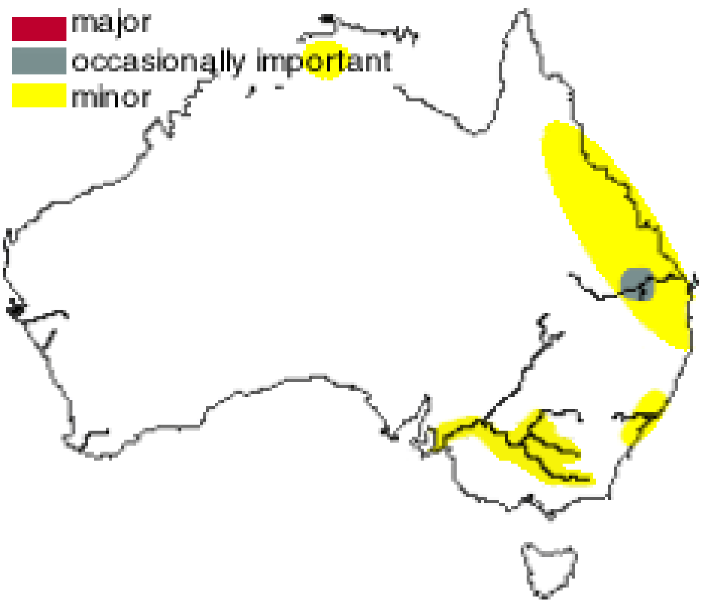

Figure 2. Distribution of Green Planthopper in Australia.

4.19.5 Monitoring

In Queensland, monitor the pest fortnightly from mid-December until March. In South Australia and Victoria, monitor at 3 to 4 weekly intervals from early February to late May. From each tree selected for checking, examine 5 randomly selected green twigs, with fruit attached. Two samples should be taken from the centre of trees. Leafhoppers are most easily sampled with a sweep net. Empty captured jassids into a container with 70% alcohol (or methylated spirits) and express counts as leafhoppers per sweep (one sweep per row).

Action levels

The action level is 20% or more of green twigs infested. If more than half of the sampled egg rafts produce parasites, the planthopper population can be expected to decline.

4.19.6 Chemical control

No chemicals permitted or registered.

4.19.7 Biological control

Attract and conserve natural enemies like damsel bugs, minute pirate bugs, lady beetles, lacewings, parasitic wasps, and spiders. Commercially available beneficial insects, such as ladybugs, lacewing, and minute pirate bugs, are all voracious predators of both the egg and young larval stage.

Parasites

The small wasp *Achalcerinys* sp. parasitises up to 90% of the egg rafts of the citrus and the mango planthopper, and is an important natural enemy of these species. Other wasps which parasitise planthopper eggs include *Ooencyrtus* spp. and *Aphanomerus* spp. Dryinid wasps and strepsiptera parasitise nymphs and adults of all four species (Plate 3). An epipyropid moth parasitises mango planthopper.

Predators

Spiders and assassin bugs prey on planthoppers.

Plate 3. Top Left: Male of the wasp *Achalcerinys* sp. which parasitises mango planthopper eggs. Top Right: Adult dryinid wasp, an ant-mimicking parasite of green planthopper. Bottom: Dryinid wasp larva feeding externally behind the right wing bud of a green planthopper nymph.

4.19.8 Orchard management strategies

Not known.

4.20 ORANGE FRUIT BORER

4.20.1 Damage

Orange fruit borer causes damage to persimmon. The larvae chew and burrow into the fruit generally just below the skin and often near the calyx (Plate 1). Young and mature fruit can be attacked. Larvae can also bore into maturing and ripe fruit causing it to fall. If undetected during packing, it may cause the fruit to decay during marketing. Larvae roll flower buds and young leaves together to form feeding shelters

4.20.2 Species and identification

Species: *Isotenes miserana* (Plate 1).

Plate 1. Larva of the orange fruitborer. Moth of the orange fruitborer (*Isotenes miserana*). Photos David Astridge and Harry Fay, DEEDI.

4.20.3 Life cycle

The adult moths are light grey, speckled with small brown marks, bell-shaped when at rest, with a wingspan of 15 to 25 mm. They fly with a fluttering action mostly at night. The scale-like eggs are laid in clusters under leaves. When fully grown the larvae are about 24 mm long, brown on top and light grey underneath, with a dark brown head capsule and a pair of brown stripes along the body. They pupate within the silken shelter formed while feeding. The pupae are brown or green-brown, approximately 13 mm long and found on the foliage. On hatching the young larva feeds on surface cells and soon constructs a silken webbed shelter. The life cycle takes four to six weeks and successive generations occur throughout the year. There are several generations in a year but activity is less in summer. All stages can be found in winter.

4.20.4 Importance and distribution

This pest occurs widely throughout coastal Queensland. Orange fruit borer feeds on many plants including avocados, citrus, feijoa and macadamia. It is considerd a minor and sporadic pest of persimmon in Queensland only.

4.20.5 Monitoring

Action level

Spray if there is an average of 10 larvae per tree.

4.20.6 Chemical control

Methoxyfenozide

The insecticide methoxyfenozide (Prodigy®), which has a current minor use permit for use on persimmon, is very effective.

Spinosad

The pest is also controlled with Success®.

4.20.7 Biological control

None available

4.20.8 Orchard management strategies

Not known.

4.21 WEEVILS

4.21.1 Damage

The weevil chews pieces of bark around the fruit stalk (Plate 1). Adults of all the weevil species can also scallop leaves. Where damage is severe, fruit may drop. Occasionally the weevil may damage the trunk or crotches of trees (Plate 2). The soil born larval stage feeds on tree roots and may affect tree health, especially young trees.

Plate 1. Top: Weevil and chewing damage. Bottom: Pieces of bark chewed from the fruit stalk.

Plate 2. Weevil damage to base of trunk and major branch.

4.21.2 Species and identification

Various species e.g. Elephant weevil *Orthorhinus cylindrirostris*, Fuller rose weevil (*Asynonychus cervinus).* Adults have a 10-20 mm body length. Size and colour are extremely variable. The weevil body is densely covered with scales that may vary from grey to black. The larva or grub is soft, fleshy, creamy yellow and legless, and reaches a length of about 20 mm. The pupa is soft and white, with light brown wing buds.

4.21.3 Life cycle

Weevils are native species that breed in many native trees, especially Eucalypts. Most weevil species have only one generation per year. Eggs are laid either in the soil or on leaves. The larvae tunnel for about 10 months, the pupal stage lasts for 2 to 3 weeks, and the adults emerge a year after the eggs are laid. Adults emerge in early October and are most abundant in early summer. Numbers decline after this, but some adults may be found through winter. The species is present mainly as larvae through winter.

4.21.4 Importance and distribution

Weevils are widely distributed throughout Australia. They are occasionally a pest of persimmon. Weevils occur on a wide range of hosts including citrus, ornamentals and *Eucalyptus* spp.

4.21.5 Monitoring

- Fortnightly monitoring is necessary from early August to late October, and again from February to late June.
- Trees selected for monitoring must be randomly scattered throughout the block.
- Examine low-hanging fruits near the trunk, looking for egg masses under the calyx.
- Examine low-hanging foliage for signs of feeding damage.
- Digging for larvae near the base of trees will provide an indication of weevil abundance and timing of adults' emergence.
- The abundance of adult weevils can be monitored by beating tree limbs.
- There are no action levels.

4.21.6 Chemical control

The pest is generally not serious enough to warrant treatment. If chemical control is required use a registered insecticide.

4.21.7 Biological control

Various predators have been identified including:

- Wasp (*Fidiobia citri*)
- Braconid wasps
- Assassin bugs
- Praying mantises

- Parasitic nematodes (such as *Heterorhabditis sp.*)

4.21.8 Orchard management strategies

Appropriate actions include

- pruning the skirts of trees at the end of each season,
- controlling weeds
- applying sticky bands around the tree trunk

4.22 LEAF ROLLERS

4.22.1 Damage

The caterpillars of this moth roll and web leaves together and also web leaves to fruit (Plate 1). Inside these shelters the larvae live and feed on the leaf and fruit tissue. Although severe leaf damage may be caused, the damage inflicted on the fruit is more important. Large areas of the skin of fruit may be eaten, sometimes to a depth of four millimetres. Damaged fruit may be infected with anthracnose and drop or the injury may heal, forming scar tissue. Trees in flush are most susceptible since larvae prefer to feed on young growth and cause proportionately more damage on small, unexpanded leaves.

4.22.2 Species and description

Various species including avocado leaf roller (*Homona spargotis)* (Plate 1). Marked differences between the sexes occur in the moth stage of avocado leaf roller. The male is smaller (18 to 20 mm wingspan) than the female (25 to 30 mm wingspan). The forewings in the male are light brown with dark brown banding; in the female the forewings are dark tan to light brown with a darker oblique band and darker wing tip. The female has prominent wingtips and at rest the folded wings give the adult moths a bell shape. The pale, flattened, yellow/orange eggs are laid in masses (sometimes exceeding 400) and overlap like fish scales. They are laid on the upper surface of mature leaves.

The young larvae drop on silken threads to be dispersed by the wind or they crawl a short distance to new shoots. They feed within shelters that they construct by rolling and webbing young foliage (Plate 1).

Plate 1. Left: Two avocado leafroller (*Homona spargotis*) larvae feeding on a leaf. Right: Female moth of avocado leafroller. Photos courtesy of Dr Harry Fay, DEEDI.

4.22.3 Life cycle

Little is known of the life history other than the eggs hatch after six to eight days, and that several generations occur each year.

4.22.4 Importance and distribution

Leafrollers are minor pests of persimmon in Queensland. Hosts include avocado, custard apple, carambola, coffee, tea and other horticultural crops but on these it is a relatively minor pest. The caterpillars of this moth roll and web leaves together and also web leaves to fruit. Inside these shelters the larvae live and feed on the leaf and fruit tissue. Although severe leaf damage may be caused, the damage inflicted on the fruit is more important.

Damaged fruit may be infected with anthracnose and drop or the injury may heal, forming scar tissue. Trees in flush are most susceptible since larvae prefer to feed on young growth and cause proportionately more damage on small, unexpanded leaves.

4.22.5 Monitoring

Action levels are not known.

4.22.6 Chemical control

Spinosad

The insecticide spinosad (Entrust Naturalyte®, Success 2®), which is currently registered for controlling Yellow Peach Moth in persimmon, will also control leafrollers. Spinosad is derived through the fermentation of a naturally occurring organism. It uniquely combines the efficacy of synthetic products with the benefits of biological insect pest control products. It is highly active at low use rates and it has less impact on certain predatory beneficial insects.

Dipel ®

Softer chemicals such Dipel® which contains live spores and endotoxins of the naturally occurring bacterium (*Bacillus thuringiensis*) may be effective if sprays are timed to coincide with first-stage caterpillars.

4.22.7 Biological control

Several natural enemies have been recorded attacking leafrollers. These include several wasp parasitoids, a tachinid fly parasitoid and egg parasitoids. The extent to which these biocontrols operate depends on the level of disruption caused by pesticides applied to control other pests. A baiting system has been developed but is not yet commercially available.

4.22.8 Orchard mangement strategies

Not known.

4.23 CLUSTER CATEPILLAR

4.23.1 Damage

Cluster caterpillar can chew holes in leaves and severely damage the photosynthetic capacity of persimmon trees. Older larvae also attack flowers.

4.23.2 Species and distribution

The species: *Spodoptera litura (*Plates 1 and 2).






Plate 1. Top left: Eggs are laid in a furry cream mass on the underside of leaves. Top right: 1st instar small catepillars eat leaf tissue. Middle left: 2nd instar. Middle right: 3rd instar. Bottom left: 4th instar. Bottom right: Adult moth (Photo J. Wessels).

4.23.3 Life cycle

Eggs are laid in a furry cream mass on the underside of leaves (Plate 1). Young larvae 'cluster' together and are translucent green with a darker thorax. Middle-sized larvae are variable in colour, smooth-skinned with a pattern of red, yellow and green lines, a dark patch on the hump behind the head and dark spots along each side. Large larvae are initially brown with three thin pale lines down the back: one in the middle and one on each side. They have a row of black dots along each side, and a row of conspicuous dark half-moons along the back. Final instar larvae are dark and can exceed 50 mm in length. All larvae have four pairs of ventral prolegs. Young larvae feed on leaves but older larvae may feed on flowers. Larvae pass through six larval stages and take 2-3 weeks to develop, depending on temperature. Larvae pupate in the soil. Moths have brown forewings with criss-cross cream streaks and translucent white hindwings edged with brown (Plate 2). Small to medium larvae (10 mm long) may be confused with helicoverpa larvae, but are distinguished by the 'hump' behind the head, and the row of dark spots on each side.

4.23.4 Importance and distribution

In Australia, *Spodoptera litura* is more common in tropical and coastal regions, but extends as far south as Perth and central New South Wales. For most persimmon growing regions it is a minor pest. The cluster caterpillar feeds on many types of plants including cotton, sunflower, soybean, mungbean, navy bean, lucerne, canola, peanut, chickpea, faba bean, safflower, linseed and adzuki beans.

4.23.5 Monitoring

Inspect trees and leaves weekly from budbreak through to harvest. Look for the distinctive egg masses and clusters of young larvae.

Action level

Control is warranted if defoliation exceeds (or is likely to exceed) 30%.

4.23.6 Chemical control

Cluster caterpillars are controlled by most broad sprectrum pesticides. Spray with either spinosad (Success 2®) or DiPel® (*Bacillus thuringiensis* var. *kurstaki* (Bt)) when applied to very small grubs.

4.23.7 Biological control

Caterpillars are attacked by numerous predators and parasites (e.g. predatory bugs, tachnid flies, braconid wasps and ichneumonid wasps). The use of Bt for control will help preserve beneficial insects and also reduce the risk of subsequent whitefly and mite attack.

4.23.8 Orchard management strategies

- Destroy weeds such as purslane and pigweed. These are host plants for the cluster caterpillar.

- Various types of light traps with fluorescent backlight bulbs have been partially successful in controlling populations of different types of moths.

4.24 LOOPERS

4.24.1 Damage

Ragged holes in leaves, mainly between the veins. Dark green frass. When looper numbers are high, damage may be enough to stunt shoot growth.

4.24.2 Species and distribution

Various species e.g. Cabbage Looper *Trichoplusia ni* (Plate 1). Looper larvae move like inchworms, in a looping motion, because they lack legs in the middle portion of their bodies. Older caterpillars are light green, usually with a white stripe down each side. Younger larvae tend to be paler. Adult moths are grayish brown, but can be recognized by a distinct silvery mark on each forewing shaped like a figure eight. Looper eggs are very pale green to white, and found on the upper surfaces of leaves.

Plate 1. Loopers such as Cabbage Looper attack persimmon leaves and fruit.

4.24.3 Life cycle

Adult cabbage looper moths migrate to northern areas in spring or summer. Moths deposit eggs on host plants, usually singly. The eggs hatch in 2-10 days, dependent on temperature. Early instar larvae feed on the lower surfaces of leaves, while larger caterpillars do more conspicuous damage. Mature larvae pupate on the undersides of foliage or in the soil. The adult emerges in 1-2 weeks. Multiple generations occur during the growing season.

4.24.4 Importance and distribution

Loopers are a minor pest of persimmon. Loopers attack a wide range of crops including: brassicas: cabbage, cauliflower, broccoli, kale, turnips, mustard, tomatoes, peppers, eggplant, potatoes, watermelons, cucumbers, melons, squash, cantaloupe, peas, beans, and others.

4.24.5 Monitoring

Inspect trees and leaves weekly from budbreak through to harvest. Look for the distinctive larvae.

Action level

Control is warranted if defoliation exceeds (or is likely to exceed) 30%.

4.24.6 Chemical control

Loopers are controlled by most broad sprectrum pesticides. Spray with either spinosad (Success 2®) or DiPel® (*Bacillus thuringiensis* var. *kurstaki* (Bt)). Apply Dipel® when larvae are young.

4.24.7 Biological control

Caterpillars are attacked by numerous predators and parasites (e.g. predatory bugs, tachnid flies, braconid wasps and ichneumonid wasps). The use of Bt for control will help preserve beneficial insects and also reduce the risk of subsequent whitefly and mite attack.

4.24.8 Orchard management strategies

Various types of light traps with fluorescent backlight bulbs have been partially successful in controlling populations of different types of moths. Effectiveness for attracting looper moths is not known.

4.25 LEAF AND BARK EATING CATEPILLARS

4.25.1 Damage

Caterpillars of various species chew on the leaves, fruit (Plate 1), calyx and bark of persimmon.

Plate 1. Caterpillar damage beneath calyx. Unknown species.

4.25.2 Species and distribution

Various species and families (Plates 2, 3 and 4).

Plate 2. Caterpillar of *Anthela rubeola* feeding on persimmon leaves. The caterpillars of this species are dark brown with rows of yellow spots and tufts of white hair. These caterpillars have also been found feeding on broad-leaf wattles.

Plate 3. Tussock Moth (unknown species, Family Lymantriidae) caterpillar feeding on bark of persimmon.

Plate 4. Stinging slug Caterpillar

4.25.3 Life cycle

Each species has a different life cycle.

4.25.4 Importance and distribution

Leaf and bark-eating caterpillars are minor pests in persimmon orchards in south-east Queensland.

4.25.5 Monitoring

Check trees and leaves weekly from budbreak to harvest.

4.25.6 Chemical control

N/A.

4.25.7 Biological control

None available.

4.25.8 Orchard management strategies

Not known.

4.26 APHIDS

4.26.1 Damage

Aphids suck on sap and moderate numbers can cause new terminal leaves to furl up (Plate 1). More significant is the production of honeydew that leads to the development of sooty mould. Aphids are commonly found in dense groups on new shoot growth. Their feeding also distorts shoots, and can transmit plant viruses.

Plate 1. Aphids on the undersurface of the leaves of persimmon causing leaves to roll inwards.

4.26.2 Species and distribution

Myzus persicae. Adults are 3 mm long, pale yellow-green (Plate 2), oval-shaped and may have wings. There are small tubercles at the junction of the antennae and head and extended siphunculi (tube-like projections on either side at the rear of the body).

4.26.3 Life cycle

Aphid life cycles are complex. Adults may be winged or wingless, depending on the state of their food supply, and how crowded together they are. Younger stages are all wingless. Some adult females reproduce without mating with a male (i.e. parthenogenetically, or from unfertilised eggs), and others reproduce after mating with a male (i.e. from fertilised eggs).
Populations peak in late winter and early spring; development rates are particularly favoured when daily maximum temperatures reach 20-25°C.

Plate 2. Green aphids on the underside of a persimmon leaf.

4.26.4 Importance and distribution

Aphids are widely distributed throughout Australia. In most regions they are a minor pest.

4.26.5 Monitoring

Sampling should commence during and after the completion of the spring flush. Examine 5 – 10 immature flush leaves on 20 trees in the orchard and check for aphids, honeydew and sooty mould.

Action level

Consider treatment if 25% of vegetative flushes are affected.

4.26.6 Chemical control

N/A

4.26.7 Biological control

A range of predators attack these aphids. They include ladybirds, e.g. the common spotted ladybird (*Harmonia conformis*) (Plate 3), syrphid flies, e.g. the common hoverfly (*Simosyrphus grandicornis*), and lacewing larvae (*Chrysopa* sp.).

Ants can also be associated with aphids protecting them from their natural enemies.

Plate 3. A Ladybird eating an aphid (Photo: Elaine Shallue).

4.26.8 Orchard management strategies

- Early control of weed hosts reduces the reservoir population of aphids.
- Conservation of natural enemies.
- Control ant movement and populations (see Section 4.2)

4.27 RED SHOULDERED LEAF BEETLES

4.27.1 Damage

Adult red shouldered leaf beetles skeletonise foliage, especially new shoot flushes (Plate 1). Swarms can invade the orchard and cause serious damage within 2-3 hours.

Plate 1. Left: Leaf margins chewed by Red Shouldered Leaf Beetle. Right: leaves skeletonised (Photo: J Wessels).

4.27.2 Species and distribution

Monolepta australis. Beetles are about 6 mm long, yellow in colour with red patches over the shoulders and near the distal end of elytra (wing covers) (Plate 2). Small (less than 1 mm) yellowish oval flaccid eggs are laid just below the soil surface near the base of the plant. Larvae are white, slightly dorso-ventrally flattened with sclerotised (hard) brown plates head and tail.

Plate 2. Red Shouldered Leaf Beetle.

4.27.3 Life cycle

Eggs are laid in the soil surface, mainly in pastures, and the larvae, which are about 5 mm long when full-grown, feed on the grass roots and pupate in the soil. The life cycle takes about two months during summer and there are three to four generations annually. Adults usually emerge from the soil after good rains following a dry spell. If larval populations in the soil are high, the multitude of emerging beetles will form an aggregation and swarms may migrate into tree crops at any time of the year.

4.27.4 Importance and distribution

This pest occurs in fruit-growing areas throughout Queensland, northern NSW and the Northern Territory. The damage in persimmon orchards is minor and sporadic throughout Queensland and northern New South Wales. Other chrysomelid beetles, black swarming leaf beetles, cause similar damage in south Queensland. The host range is large and includes avocado, carambola, cotton, corn, Eucalyptus spp., grasses, legumes, longan, lychee, macadamia, mango, strawberry and numerous ornamentals. Larvae feed on plant roots.

4.27.5 Monitoring

Early detection and chemical control is very important in preventing serious damage. The swarms generally start with low numbers on one or two trees on the outer edge of the orchard and within several hours or a few days, numbers increase dramatically to reach swarm proportions. In some cases, complete defoliation can occur on one tree only, leaving neighbouring trees virtually untouched. Examine the whole orchard at regular intervals. Check flowers and new growth for beetles particularly following the first substantial rain after a dry spell.

Control is limited to spraying when beetles are active and damage is evident. Give consideration to the effect on bees if application is required at flowering time.

Action level

Disregard individual beetles or groups fewer than ten if they aggregate on split fruit. Only swarming beetles in a feeding frenzy cause damage.

4.27.6 Chemical control

Developing swarms should be treated immediately by spot-spraying affected trees. Use a registered insecticide.

4.27.7 Biological control

None available

4.27.8 Orchard management strategies

Eucalyptus torelliana as a windbreak is highly attractive to these beetles and is useful for early detection and control. Yellow sticky traps in boundary trees provide an early indication of beetle presence.

4.28 EARWIGS

4.28.1 Damage

Earwigs can damage the calyces of persimmon causing fruit drop. They may also be beneficial in that they have been observed feeding on clearing moth eggs and larvae.

4.28.2 Species and distribution

The European earwig (*Forficula auricularia*) is native to Europe and has spread to several continents including North America, Australia and New Zealand. European earwigs have been in Australia since about 1930. The European earwig's native climate is cool and relatively humid. Although the adults have wings, they seldom fly and are mainly spread by human activity.

Adult European earwigs range from 12 to 24 mm in length. Colour and size variations among European earwigs may occur, however, they all have uniform brown bodies that are smooth and shiny with light brown/yellow legs, pincers (also called forceps) and 'shoulders'. These earwigs have a flattened, elongated body with a reddish brown head and slender, beaded antennae. Male pincers are long and curved and the pincers of the female are straighter (Plate 1). The young earwigs (nymphs) look similar, but are smaller and paler than the adults.

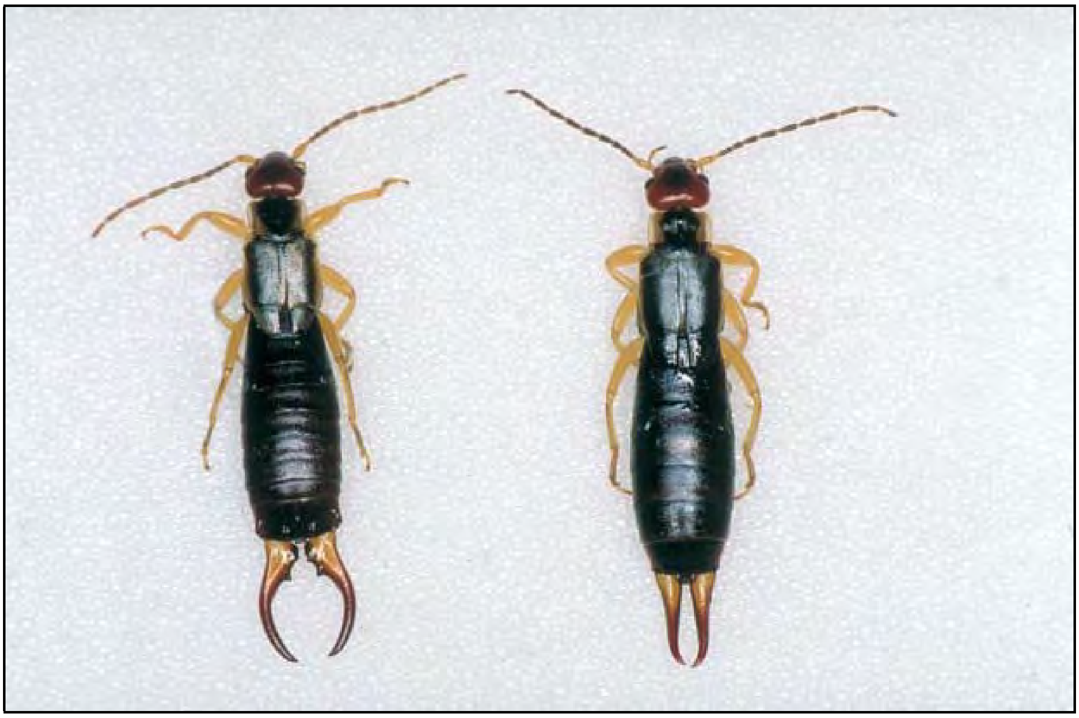

Plate 1. European earwigs: male (left), female (right). Note the light brown legs, pincers and shoulders and the reddish brown heads. (Photo: Marc Widmer, Svetlana Micic and Tony Dore, Department of Agriculture and Food, WA, Farmnote 322).

Native earwigs can be distinguished from European earwigs in several ways. Native earwigs generally have reddish brown foreparts and legs with a darker abdomen and pincers (Plate 2).

Native earwigs are widespread and feed mainly on leaf litter and other organic material and are not known to damage crops. Earwigs tend to be found sheltering under mulch, rocks or logs during the day. European earwigs tend to exist communally and will generally appear more abundant than native earwigs. You will tend to find only a single native earwig in these places but you are more likely to see several European earwigs congregating together.

Plate 2. The native earwig, *Gonolabis michaelseni*: male (left), female (right). Note the reddish brown body. (Photo: Marc Widmer, Svetlana Micic and Tony Dore, Department of Agriculture and Food, WA, Farmnote 322).

4.28.3 Life cycle

The length of the lifecycle depends on temperature. At 25°C, the development from egg to adult takes nine to ten weeks, but at 15°C it takes up to five weeks longer. Adult females lay batches of 20 to 80 white oval eggs in burrows in the topsoil which will hatch in two to three weeks. There are several nymphal instars (stages between moults). Female earwigs display maternal care, remaining in the burrow protecting the eggs and nymphs. Females guard the early instar nymphs initially, but after a couple of moults the young must fend for themselves or risk being cannibalised. Both adults and nymphs are nocturnal and shelter in dark places during the day.

4.28.4 Importance and distribution

Earwigs are more of a pest of persimmon in orchards in South Australia and Western Australia. They can be found eating the calyces causing fruit drop. This adaptable insect is able to survive under a variety of environmental conditions. European earwigs feed on a wide range of food types such as organic matter, fruits, ornamental plants, vegetables, flowers, seeds and live and dead insects, including earwigs, caterpillars.

In persimmon, they have been observed feeding on the the eggs and larvae of clearwing moth and therefore may give some biological control.

4.28.5 Monitoring

Check beneath calyces and in bark crevices and tree crotches where they hide and feed.

4.28.6 Chemical control

Earwig infestations should be treated immediately by spot-spraying affected trees. Use a registered insecticide.

4.28.7 Biological control

Not known.

4.28.8 Orchard management strategies

Earwigs can be easily moved within and between orchards on farm machiney, crates and cartons.

Chapter 5

Monitoring

5.1 ECONOMIC INJURY LEVEL

Monitoring of pest populations and disease is usually carried out to allow accurate timing of pesticide application. It also ensures that pesticides are only applied when necessary to prevent economic loss rather than on a fixed schedule which may only rarely coincide with population fluctuations.

The concept of economic injury level (EIL) for each pest in the crop ecosystem is crucial to IPM since a pest only warrants control when it exceeds the EIL. The EIL set for each pest involves a cost/benefit analyses of the control measures possible. The EIL must be realistic, taking into consideration factors such as market acceptance of pest damaged fruit. The higher the EIL the more flexibility there is in an IPM program.

Diseases are much more difficult to monitor than insect pests. A disease is microscopic and in most cases, is well established and difficult to control by the time symptoms are noticed. We therefore rely on preventive sprays to control most disease problems. Monitoring is still useful for detecting obvious problem areas and for evaluating how well a disease prevention program is working.

Because successful monitoring requires considerable training and skill, we suggest that inexperienced growers use professional pest monitoring services. These consultants will visit your orchard about every 7–10 days during the main part of the season to monitor pest populations. After each visit, the pest consultant will provide a report on pest status and the required sprays. The cost of using a pest consultant varies according to planting density, pest and disease status of the orchard, and other factors. If you wish to do the monitoring yourself, we suggest you first get some training from a pest consultant.

5.2 IMPORTANT MONITORING ISSUES

5.2.1 Correct identification of pests and diseases

Correct identification of both the pests and their natural enemies is essential. There are many situations where incorrect identification can lead to a totally inappropriate response. Both pests and their natural enemies need to be monitored and their levels assessed in order to understand the relationship between them and to make informed decisions about pest control. If assessments are based on pest levels only, decisions tend to be pesticide-oriented.

It generally takes much experience and training before a person is sufficiently familiar with both species to make quick and accurate assessments in the field.

When starting to implement an IPM program and to identify pests and natural enemies, it is important to collect specimens for their identification to be confirmed by an experienced pest scout or entomologist. When in the orchard, carry the following essential items (Plate 1):

- Hand lens (×10), magnifying glass or small microscope
- Notebook, prepared monitoring charts and pen
- Plastic bags, or small bottles, and marking pen for samples
- Sharp pocket knife
- Roll of coloured plastic tape

The hand lens can be worn on a cord around the neck to leave the hands free for examining leaves, fruit and twigs, and for recording the results of sampling. Choose a hand lens with good-quality double lenses that can be separated for cleaning. It is best to have a large field of view (about 180 mm).

Access to a binocular microscope is also desirable, and some growers have chosen to purchase one.

Plate 1. Some tools necessary to monitor pest and disease problems – hand lens, pairing knife, plastic bags and notebook.

5.2.2 Repeatable and accurate results

If possible, the results of monitoring should be accurate and repeatable. It is important to remember that each sample is only one of many for that block for the season. Trends should be considered before taking each new sample.

If the reliability of an assessment is in doubt, another sample should be taken shortly afterwards. Regular, frequent monitoring is generally preferable to infrequent monitoring, even if the latter is more intensive.

While it is necessary to have a monitoring system, this is only one of many tools available to the grower and the pest scout to help them make good pest management decisions. Good decisions are the result of useful monitoring systems tempered with experience, keen observation and common sense. Knowledge of the crop, the particular orchard, and the grower's preferences are other important factors.

5.2.3 Number of trees per sample

Divide your orchard into monitoring blocks, each consisting of trees of the same variety/rootstock, of similar age and planted on a uniform soil type with similar irrigation and nutritional practices. A block of trees can also be considered as an area that is treated (and sprayed) as a unit. Each block should be monitored separately. If your entire orchard consists of trees of the same variety and age, it can be treated as one block.

For most pests, closely examine at least 20 - 30 trees in every hectare of each block. If a block is less than one hectare, check at least 10 - 20 trees in that block. Select the trees for sampling at random. Planting density does not affect the number of trees that must be monitored.

5.2.4 Selecting trees within blocks for the monitoring sample

Sample trees should normally be selected at random from within the block, but the whole block should be covered. However, pest biology and a previous history of infestation may require sampling to be concentrated in certain areas. Consecutive samples should be taken from the four quadrants of each tree (north, south, east and west). Avoid non-representative trees (e.g. unhealthy or smaller trees).

5.2.5 Parts of the tree to be sampled

The parts of trees that are sampled are called 'units'. A unit may be a fruit, a group of leaves, calyces, a shoot etc. In a block where the sample size is 20 trees, 100 individual units of each type may be assessed on each monitoring date, i.e. 5 sample units e.g. fruit are usually taken from each tree.

In large trees, one in five of each unit should be taken by climbing into the top centre of the tree where possible. This is to check for inadequate spray coverage, and for hard to find pest species, such as fruit spotting bug.

It is best to check the type of unit where pests or natural enemies are likely to be most abundant or most damaging. For persimmon, this is most likely to be the fruit.

Highly variable blocks warrant sampling of additional trees. However, early in the season, before fruit are large enough to sample, leaves or branches may be sampled instead.

5.2.6 Frequency of monitoring

The frequency of monitoring will vary depending upon the time of year, the location and the levels of pest activity. It may be as short as 3 - 6 days during high-risk periods, but may stretch to 3 - 6 weeks or more in winter. With persimmon, while monitoring is useful at all times of the year, the critical periods are from October to May. We suggest the following monitoring frequency for persimmon:

- Monitor at weekly intervals throughout the whole year for mealybug, scales, ants and diseases
- Monitor at weekly intervals from October to January for fruit spotting bug

- Monitor fruit fly traps twice weekly. Fruit flies generally become more active in early January. Cue-lure traps are designed to attract male flies of some species only. They will attract male flies from approximately 500 m distance. Place the trap in the middle of each block, not near the edge. Collect and count male flies twice weekly, and look for a sharp increase in numbers (for example a jump from 10 flies per week to more than 30 flies per week).

5.2.7 Time needed for monitoring

As a guide to the time necessary, an average two hectare block will take at least 35 minutes to be properly sampled by an inexperienced person, compared to 25 minutes by an experienced person. A new scout will need several months of full-time monitoring before being able to sample confidently and accurately.

It should be possible to check a sample of 10 trees in 20 - 30 minutes (Table 1). The actual time taken will depend on the time of year and the organisms being sampled.

TABLE 1.

Number of trees in samples for monitoring, and approximate monitoring times, for blocks of different sizes

Number of trees in block	Area (hectares)	Number of trees sampled	Time taken (minutes) to check sample
0-500	<2	10	20–30
501-750	2–3	12	25–35
751-1000	3–4	15	30–45
1001-2000	4–8	20	40–60
2001-4000	8–16	25	50–75
>4000	>16	30	60–90

5.3 DATA RECORDING AND REPORTING

Blank, data recording worksheets (e.g. Microsoft Excel format) should be written so you can use them to record and prepare IPM information.

5.3.1 Sample cards

Sample cards are used for recording the results of monitoring. They should be large enough to write on legibly with sufficient space for additional notes, and small enough to be carried easily in the field. A firm backing board is necessary.

Each column is reserved for data on one species of pest or natural enemy (Plate 2) that may be sampled (Figure 1). The species sampled will vary depending upon the time of year. The names of species sampled routinely may be pre-printed onto the card, but blank columns will allow inclusion of other species when necessary.

If you wish to sample the incidence of diseases as well, columns could also be allowed for particular diseases. Each cell on the sample card is filled in with the number of fruit, leaves or shoots infested with a pest on one tree. The column for each species is totaled and the percentage of the sample units infested is entered in the row at the bottom of the card. For example, inspect 10 fruit selected at random from each of 20 trees per hectare and record the number of fruit damaged or infested. Calculate the % of fruit damaged or infested.

Space is available below the totals row for any comments the scout wishes to make. These may include observations about a species status in the block, signs of damage, hot spots, or anything else in the block that may be worth reporting to the grower, like faulty irrigation equipment.

Each time you monitor, select trees randomly but from different parts of the block. While moving between these selected trees, keep alert and visually scan intervening trees. It is best to do the monitoring on foot, as trees must be inspected thoroughly. Inspect ten fruit selected at random from each of the trees being monitored. Use your hand lens if necessary.

The fruit do not have to be picked unless they are damaged by spotting bug or severely damaged by other pests. Inspect each sampled tree for signs of pest activity and damage to leaves, twigs, branches or fruit. Look for damage to fruit, leaves, bark and wood. If you have collected samples for later examination in the shed or office, place them in a plastic bag inside an esky.

Plate 2. Some of the more common beneficials in persimmon. Top left, assassin bug; Top middle, spiders; Top right, Anastatus wasp; Bottom left, Leptomastix wasp; Bottom middle, Crytolaemus ladybird; Bottom right, Lacewing.

FIGURE 1.
Sample card for recording the results for monitoring one block of trees.

Orchard……………..   Date…………..

Block………………..   Sampler………

Tree no.	Pest or disease									Beneficials				
	FSB	MB	QFF	S	YPM	A				L	C	W		
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
13														
14														
15														
16														
17														
18														
19														
20														
Total														
%														

Notes………………………………………………………………………………………………..

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Key			
Pest or disease	Code	Beneficials	Code
Fruit Spotting Bug	FSB	Leptomastix wasp	L
Mealybugs	MB	Cryptolaemus ladybird	C
Scales	S	Lacewings	W
Ants	A	Assassin bugs	As
Yellow Peach Moth	YPM	Anastatus wasp	An
Queensland Fruit Fly	QFF		

Mark the sample with the block number and date. Monitor fruit fly separately using lure traps. After each monitoring session, transfer the results of your monitoring charts for each block to an orchard record. This will provide a permanent record of trends for each pest and beneficial insect over the season, and will become a valuable source of information as you record data over several years.

5.3.2 Orchard report forms

The results of sampling for each block, as calculated at the bottom of the sample card, are entered onto an orchard report form. Comments or recommendations upon which the grower should act are entered in the column provided. This is an example of how to use an orchard report form.

The columns in the report match those of the sample card exactly to minimise risk of error when transferring the data, (this also applies to computer spreadsheets). The report is completed and presented to the grower as soon as possible after the orchard has been monitored.

5.4 RECORDING PESTICIDE APPLICATIONS AND RELEASE OF NATURAL ENEMIES

Growers must keep accurate records of pesticide application and natural enemy insect releases. This information is essential if scouts and researchers are to improve orchard management. An example of a spray record sheet is presented in Figure 2 and natural enemy release sheet in Figure 3. The information from the spray record sheet is entered onto a wall chart in abbreviated form at the end of each week.

The wall chart provides a summary or overview of the treatments for each block of persimmon at any point in the season and is a useful decision-making tool for the grower and the pest scout.

FIGURE 2.

Example of a spray record sheet

SPRAY RECORD SHEET				
Block name/number		Block size (ha)	Tree height (m)	Variety
Date		Operator	Spray cart	Capacity
Chemicals				Amount/rate
1				
2				
3				
4				
5				
Vat count				Total vats
Tractor gear			RPM	Pressure
Weather/ comments				

FIGURE 3.

Example of a spray and natural enemy release schedule. Section of a block spray record and natural enemy release

Block	Variety	Date					
		12 Nov	19 Nov	26 Nov	3 Dec	10 Dec	17 Dec
A	Jiro			Mancozeb			Release of Cryptolaemus ladybird
B	Fuyu			Mancozeb			Release of Cryptolaemus ladybird
C	Fuyu			Mancozeb			Release of Cryptolaemus ladybird
D	Izu			Mancozeb			Release of Cryptolaemus ladybird

The need for accuracy in keeping these records cannot be over-emphasised. The charts are not only useful for day-to-day decision making, they can also be valuable for research, and provide reliable information on pesticide application, showing how growers are using pesticides responsibly, and also minimising their use.

5.5 COMPUTER SPREADSHEETS AND POPULATION GRAPHS

At a convenient time, data are transferred to a computer spreadsheet. The software used should have a good graphing facility e.g. Excel. Initially, data are entered by date so that all the entries for one visit are located together. Then the data for the entire season can be sorted by block. Data for individual blocks can then be presented as graphs.

Data for application of sprays and release of natural enemies from the wall chart can be added to graphs at this stage, where such information is shown by arrows at the appropriate times. Graphs produced in colour give a good overview of the movement of pest and natural enemy species throughout a season.

The graphs also help to show the effects of various treatments on both pests and natural enemies during a season. For example, certain fungicides are known to harm predatory mites. Graphs can show the extent and duration of suppression of predatory mites by fungicides. When graphs are collated for individual blocks over many seasons, trends can be observed, e.g. a tendency in some species to resistance to or tolerance of certain pesticides.

The graphs also give an insight into the way in which pests and natural enemies interact, and the timeframes within which control of certain pests can be expected. An example of pest and natural enemy graphs is shown in Figure 4.

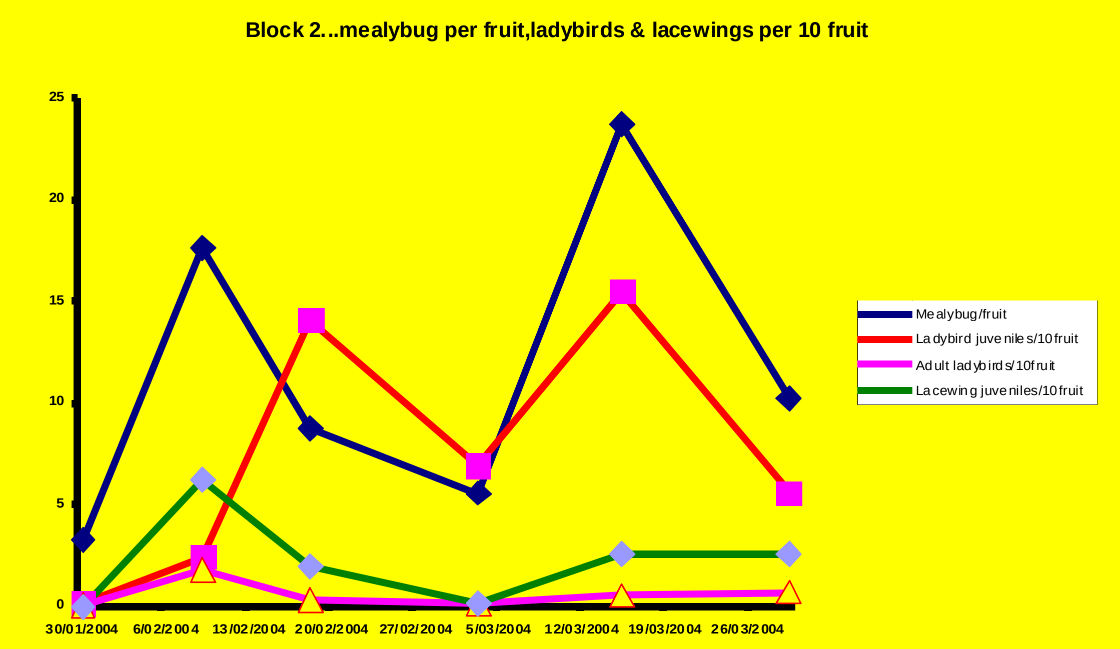

Figure 4. Changes in populations of mealybug on custard apple fruit and natural enemies.

5.6 DECISION MAKING

Every time monitoring is carried out, the pest scout must use the information gained to make appropriate decisions and recommendations, which are discussed with the grower. This is the most difficult part of the job.

Action levels are one decision-making tool available to the pest scout. Other information used by good pest scouts includes their previous experience with pests, knowledge of the block history, estimates of crop volume and market value, as well as knowledge of the grower's preferences. All of these factors need to be weighed up before the scouts discuss recommendations with their clients.

Action levels are helpful in the decision-making process. An action level is the point at which action should be taken to avoid unacceptable damage (i.e. damage that causes economic loss). The action levels given here have been determined by research (see method 1 below) and practical experience (see method 2 below) in the persimmon growing areas of Australia.

5.6.1 Action levels

Method 1

Determine the action level by research, evaluating such parameters as population densities of pests and natural enemies, damage levels, and the economics of crop production, including the costs of spraying and the expected market returns for the crop.

Method 2

It is possible to implement worthwhile IPM programs even if action levels have not been determined for all pests by means of detailed research. Start with a best estimate of the action level. For example, assign an interim action level of 10% of fruit infested with the pest. Pest scouts then use their experience to continually refine the accuracy of the action level.

Interim levels can also take numbers of natural enemies into account. For example, 10% of fruit infested with a pest could be considered the action level if predators are absent. However, if a major predator is active, the action level can be raised according to the counts of predators obtained when monitoring. For example, it could be decided that, if predators are present on more than 40 out of 100 fruit examined, the action level for the pest could be raised to 20% of fruit infested.

Action levels for selected pests of persimmon are presented in Table 2.

5.7 APPROPRIATE ACTION

In most cases, the results of monitoring indicate that no action is required. When the pest scout decides that some action must be taken, several options may be considered. These could include the release of commercially reared natural enemies, some form of cultural control, or the application of a chemical. If the decision is made to use a chemical, choose one that is least likely to harm natural enemies.

5.8 POST-HARVEST ASSESSMENTS

At the end of the growing season, the quality of harvested fruit should be assessed to provide feedback on the success of the IPDM program. Fruit that are downgraded to second grade or processing can be sampled to determine the primary cause of rejection, e.g. wind blemish, sooty mould and so on.

It is also useful if the grower gives feedback based on subjective judgments of the fruit from each block as it passes through the packing shed. This will help the scout get a clearer idea of the grower's perceptions and expectations. Pre-printed forms, ready to fill in, can be supplied to growers at the start of the harvest season.

The information from these assessments can be included with the graph for each block to enable comparison between the results of monitoring and the final quality assessment. A study of this information will help fine-tune action levels.

Plate 3. Checking beneath calyces of individual fruit for mealybugs for export quality fruit in a New Zealand packhouse.

5.9 RESEARCH

Ongoing research is essential to the success of practical IPM, as pests and natural enemies are part of a complex and dynamic biological system. New pests appear from time to time and the status of existing pests may alter with changes in grower practices, varietal selection and so on. Ultimately, the success of practical IPDM depends upon a cooperative relationship between growers, pest scouts, researchers and others in the persimmon industry.

TABLE 2.

Action levels for selected persimmon pests (Also see Chapter 4 for more detail).

Pest	Sample unit	Frequency of monitoring	Action level	Comments
Fruit spotting bug	Assess 100% of the trees if possible. Assessing 50% of the trees (every tree in alternate rows) is the minimum.	Twice weekly from October to February, other periods fortnightly	No. trees with live bugs >0.5% No. trees with freshly stung fruit >2.5% (5 fruit out of the 200 inspected) have fresh bug damage. Total no. stung fruit per tree >0.1	Check for hot spots. Check host pants. Remove damaged fruit.
Scales	Select 20 trees at random per hectare and record the presence or absence of scale on 10 randomly selected laterals per tree.	Weekly throughout the whole year	An infestation of at least 20 live scales on any lateral or more than 5% of new seasons shoots infested.	Check for hot spots. Record the presence of natural enemies on the same fruit. Look for Leptomastix wasps, their cylindrical brown pupae amongst the mealybugs, and their remnants. Also look for Cryptolaemus ladybird larvae and lacewing larvae and eggs. Also check for wasp *Scutellista caerulea* activity. Also monitor ant activity.
Mealybugs and ants	Select 20 trees at random per hectare and record the presence or absence of mealybugs on 10 randomly selected fruit per tree.	Weekly throughout the whole year	The mealybug infestation becomes economically serious when 25% or more of the fruit has one or more adult female mealybugs present. Action is recommended when natural enemies are present on less than 20% of sampled fruit (less than 50% from April to July). Check for ants. Action should be taken to control ants if they are present on >50% of shoots examined for mealybugs or scale.	Check for hot spots. Monitor the presence of natural enemies on the same fruit. Look for Leptomastix wasps, their cylindrical brown pupae amongst the mealybugs, and their remnants. Also look for Cryptolaemus ladybird larvae and lacewing larvae and eggs. Leptomastix is only effective on the Citrus mealybug.

Pest	Sample unit	Frequency of monitoring	Action level	Comments
Clearwing moth	Pheromone traps – minimum of 4 per orchard	Check traps weekly	Monitor clearwing moth throughout the orchard by using pheromone traps. These need to be placed in the orchard in late August. Check traps weekly and record and graph numbers to determine peak activity periods.	
Yellow peach moth	Examine five trees at six widely spaced locations for each 0.5 hectares of crop.	Weekly from late December to April, other periods fortnightly. For trees, examine 5 adjacent trees at 6 widely spaced locations throughout each 0.5 ha of crop.	At least 2% of sampled fruit need to be infested (show signs of frass) to make it worth spraying. Check for the parasitic tachinid fly (*Argyrophylax proclinata*), which is similar in appearance to the common house fly. Parasitism levels should exceed 30% for successful control.	Typical appearance of infestation is the webbed insect frass (droppings) around the entry hole into the fruit.
Queensland fruit fly	Four Cue lure or Amulet traps per hectare will give a good indication of fly activity. Sixteen traps per hectare will give some control.	Twice weekly during peak fly periods from November to April, weekly from April to completion of harvest.	Spray with a bait spray when trap catches of more than 15 flies per week are recorded or where fruit flies are observed on fruit. If more than 30 flies are caught in the cue lure traps then cover sprays of an insecticide may be advisable.	Early detection and reduction of fly populations early in the season is essential for control.
Mediterranean fruit fly	Four Cue lure traps per hectare will give a good indication of fly activity. Sixteen traps per hectare will give some control.	Twice weekly during peak fly periods from November to April, weekly from April to completion of harvest.	Spray with a bait spray when trap catches of more than 15 flies per week are recorded or where fruit flies are observed on fruit. If more than 30 flies are caught in the cue lure traps then cover sprays of an insecticide may be advisable.	Early detection and reduction of fly populations early in the season is essential for control.
Weevils	Examine five trees at six widely spaced locations throughout the crop	Fortnightly	Check trees regularly for damage. There are no action levels.	

Pest	Sample unit	Frequency of monitoring	Action level	Comments
Two-spotted mites	Check 5 randomly selected fruit or 5 leaves per tree.	Fortnightly	Check the upper leaf surfaces and exposed fruit surfaces. Action is required when more than 20% of fruit or leaves are infested.	More prevalent during hot dry weather. Avoid excessive use of insecticides. Avoid applying bait sprays to the tops of the trees.
Aphids	Examine 5 – 10 immature flush leaves on 20 trees in the orchard and check for aphids, honeydew and sooty mould.	Fortnightly, sampling should commence during and after the completion of the spring flush.	Consider treatment if 25% of vegetative flushes are affected.	
Loopers	Look for the distinctive egg masses and clusters of young larvae.	Inspect trees and leaves weekly from budbreak through to harvest.	Control is warranted if defoliation exceeds (or is likely to exceed) 30%.	
Cluster caterpillar	Look for the distinctive egg masses and clusters of young larvae.	Inspect trees and leaves weekly from budbreak through to harvest.	Control is warranted if defoliation exceeds (or is likely to exceed) 30%.	
Fruit piercing moth	Check 20 – 30 trees.	Conduct weekly, nightly inspections with a strong torch are recommended when fruit is nearing maturity. The red eyes of the moths will reflect the light from a torch, aiding detection.	Not determined, but would depend on level of infestation.	DPI has developed a bait to attract and kill fruit piercing moths (*Eudocima* spp.). The bait can be hung from trees.

Pest	Sample unit	Frequency of monitoring	Action level	Comments
Leafhoppers	From each tree selected for checking, examine 5 randomly selected green twigs, with fruit attached. Two samples should be taken from the centre of trees. Leafhoppers are most easily sampled with a sweep net. Empty captured jassids into a container with 70% alcohol (or methylated spirits) and express counts as leafhoppers per sweep (one sweep per row).	In Queensland, monitor fortnightly from mid-December until March. In South Australia and Victoria, monitor at 3 to 4 weekly intervals from early February to late May.	The action level is 20% or more of green twigs infested. If more than half of the sampled egg rafts produce parasites, the leafhopper population can be expected to decline.	
Thrips	Monitor thrips adults and larvae by branch beating or shaking foliage or flowers onto a sheet of paper or a beating tray or sheet.	Do a weekly count of thrips on each trap.	Remember that the presence of thrips does not mean that damage will result from their feeding. Even large numbers of thrips in traps or adults at flowers feeding on pollen do not necessarily indicate that control action is needed. Currently there is no spray threshold and no counts on the number of thrips which could be tolerated before economic damage occurred. Check thrips numbers in flowers 1-2 days after spraying to check efficacy.	Adult thrips can also be monitored using bright yellow sticky traps. Blue sticky traps are most effective for capturing western flower thrips, but thrips are harder to discern on this darker background.

Pest	Sample unit	Frequency of monitoring	Action level	Comments
Light Brown Apple Moth	Monitor fortnightly, checking flowers, fruitlets and maturing fruit.	The most critical times for monitoring are mid-September to mid-February for young fruitlets, and May-June for mature fruit.	Pheromone traps and wine lures, both of which attract moths, can assist with monitoring. The action level is if more than 5% of flowers, fruitlets or fruit are infested.	It can also be helpful to collect temperature data, which can be used to predict development times and seasonal activity.

Chapter 6

Orchard management strategies

6.1 INTRODUCTION

A number of orchard management strategies can be used to reduce pest and disease outbreaks and severity. These can be divided into two categories: those that are implemented pre-planting and those practices that can be employed after trees are planted.

Cultural practices should help to conserve existing natural enemies of pests. In persimmon, these practices include the management of other plants growing in the orchard, tree skirting, trunk banding and good orchard hygiene. Maintaining trees in general good health is also important for both pest and disease control. Healthy trees are usually better able to withstand attack by pests than stressed trees. The microhabitat for beneficials is also of better quality in healthy orchards than in unthrifty orchards.

6.2 PRE-PLANTING CONSIDERATIONS

6.2.1 Disease free planting material

Growers should obtain their trees from nurseries which use good hygiene practices and who produce healthy, disease-free trees. Growers are advised to check the roots of nursery trees for twisting or strangulation of the main tap root, a common cause of tree death within 1-2 years after planting (Plate 1). With other tree fruit crops, if root systems are diseased, the root systems are drenched with a fungicide such as metalaxyl-M (Ridomil Gold®) after planting. However, this chemical is currently not registered for use on persimmon. For soils infected with crown gall, nursery trees should be treated with an inoculant such as NoGall®.

Plate 1. Rootstock of nursery tree showing twisted and strangulated roots.

6.2.2 Varietal selection

In the 2010 clearwing moth survey, George *et al*. (2010) found that cv. Izu was highly susceptible to clearwing moth damage. This variety is also more susceptible to thrip damage because of its thinner skin. Cultivar Izu is not recommended for high pest situations.

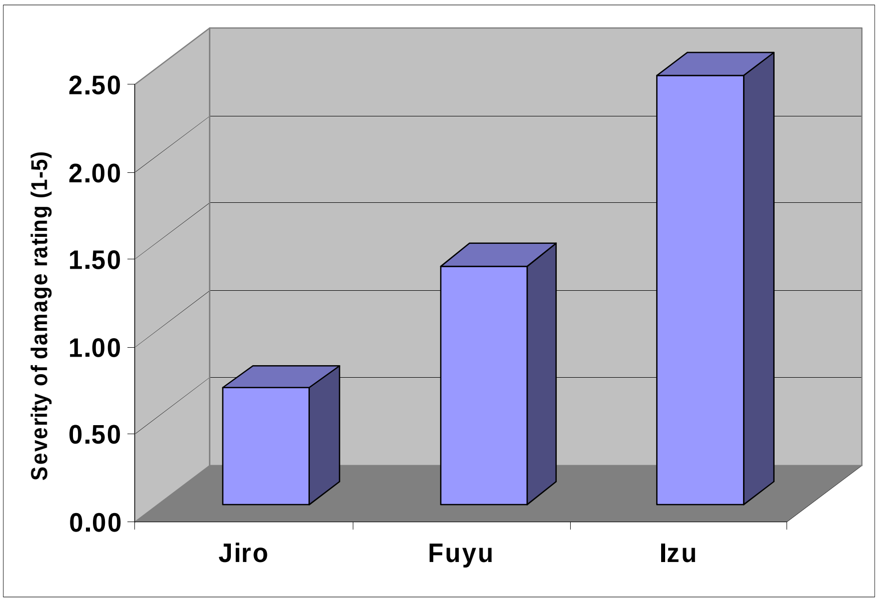

Figure 1. Varietal differences in the severity of damage to clearwing moth (George *et al*, 2010).

6.2.3 Rootstock selection

Low vigour rootstocks may be more susceptible to root diseases if poorly managed or if grown under very cool subtropical conditions. Various selections of *Diospyros kaki* may perform better than other species. Heavy crop loads will increase susceptibility of trees to root rots particularly in the autumn period when fruit are reaching maturity. This is because the crop load restricts root growth and so the root system cannot escape the disease organisms fast enough, leading to wilting and a collapse of the whole tree. In contrast, whilst high root vigour may be of benefit to the tree in escaping root rot diseases, large vigorous trees provide greater shelter for pests and diseases reducing penetration of pesticides sprays.

Rootstock trials are currently under way to evaluate a range of domestic and introduced kaki rootstock races for the flowing traits:

- waterlogging tolerance
- disease resistance
- salinity tolerance

6.2.4 Soil drainage and mounding

Severity of root diseases can be greatly increased due to poor drainage and waterlogging, particularly on shallow, heavy clay soil types. Mounding rows prior to planting and installing sub-surface drains can greatly assist in reducing short-term waterlogging.

Plate 2. Well mounded persimmon rows.

6.2.5 Deep ripping

Deep ripping land that is going to be planted to persimmons can help increase the rate of breakdown of remaining roots. This will lessen the susceptibility of newly-planted persimmon trees to *Armillarea* spp. and other root rot organisms.

6.2.6 Tree training system

Large, densely-foliaged trees will be more susceptible to some diseases such as angular leaf spot (*Cercospora* spp.) and anthracnose. High humidity and free moisture are highly conducive for disease development. Smaller sized trees such as “Jiro” are easier to spray more effectively and have better air circulation and exposure to light.

Whilst most existing orchards are trained to large, open vase systems, new training systems such as the open V trellis have less dense leaf canopies. Some growers are reducing their tree height to less than 3.0 m which will help in improving spray penetration.

Plate 3. Left; Small open trees have less pests and disease pressure and are easier to spray. Right: Large, vigorous trees are more difficult for pesticide sprays to penetrate.

6.2.7 Proximity to neglected orchards

In recent years there has been a three-fold increase in the number of neglected orchards. Some disease organisms such as anthracnose can build up quickly in these orchards. Many fruit crops are a host for anthracnose including: pawpaw, passionfruit, custard apple and mango.

6.2.8 Windbreaks

Windbreaks can have positive and/or negative effects on pest and disease pressure. Large, densely foliaged windbreaks can completely reduce air flow through the orchard. This will slow the rate of leaf drying and may greatly increase the build up of leaf and fruit diseases.

Plate 4. Left: Windbreak of mock orange – a trap host for fruit spotting bugs. Right: a windbreak of poplars used in southern states and NZ.

In contrast, orchards with poorly designed windbreaks or with no windbreaks can have excessive wind-driven rain and rain drop splash which increases the rate of spread of diseases such as anthracnose. Windbreaks need to be regularly pruned to allow some airflow. Some windbreaks can be attractive to the build up of pests whilst others such as Mock orange can act as an alternative host for pests such as fruit spotting bug (Plate 3).

In the 2009 disease survey on custard apple, George and Redpath (2009) found that densely-foliated windbreaks reduced the incidence of both anthracnose and Pseudocerspora three- to four-fold. George and Redpath (2009) suggest that windbreaks reduce wind-driven splash of inoculum.

6.2.9 Netting

Persimmon orchards are normally netted to exclude birds which are a serious pest. Orchard netting can exclude some insect pests depending on mesh size. Quad netting can exclude fruit piercing moth and some fruit fly. Exclusion netting with a 2mm mesh can exclude fruit fly completely.

On the other hand, netting may increase incidence of some pests such as cluster caterpillar due to exclusion of predators. Netting may also increase the incidence of some leaf diseases such as angular leaf spot, presumably due to less wind movement and slower leaf drying.

Plate 5. Exclusion netting (2 mm mesh) will exclude all fruit flies.

6.3 POST-PLANTING CONSIDERATIONS

6.3.1 Pruning

Persimmon trees are pruned to eliminate dead and weak wood. Young trees are normally vase-shaped to produce a framework of three or four well-spaced main limbs, 450 to 600 mm above the ground. Pruning inside canopies of mature trees, particularly of dead wood, will reduce the incidence of diseases like anthracnose and angular leaf spot. Pruning also improves spray penetration and rate of leaf drying (Plate 6).

Plate 6. Persimmon trees with with well spaced sub-leaders which have been espaliered. These open trees are easier to spray than large vase-trained trees.

6.3.2 Leaf plucking

Leaves adhering to the fruit are excellent sites for caterpillars e.g. light brown apple moth, mites and thrips to hide and breed. High humidity under the leaves also creates a microclimate for the build of diseases such as grey mould. Leaf removal or plucking reduces pest and disease pressure around the fruit.

Plate 7. Leaves adhering to the fruit create a microclimate for pests such as light brown apple moth and diseases such as Botrytis. Right: Leaf removal improves fruit drying.

6.3.3 Under-tree mulching

Mulching beneath trees increases soil organic matter, improves soil structure, reduces root temperature fluctuations, and increases water retention (Plate 8). Under-tree mulching can greatly reduce rain drop splash of disease organisms. Growers should apply a 30 cm deep mulch of straw or similar material beneath the trees annually.


Plate 8. Left: Young trees heavily mulched with straw. Right: Mulch thrower.

Refelctive mulching (Plate 9) may also improve fruit quality by increasing bloom on the fruit and by increasing the rate of fruit drying due to reflected light and heat. In addition, reflective mulch or mesh confuses and repels certain flying insects searching for plants, apparently because reflected ultraviolet light interferes with the insects' ability to locate plants. Most uses of reflective mulch have been against winged aphids, but infestation by other pests including leafhoppers, thrips, and whiteflies has also been prevented or delayed.

Plate 9. Reflective mulch Extenday® improves skin bloom.

6.3.4 Mulching of prunings

Pruning should not be allowed to rot beneath the tree. They should either be chipped to pieces less than 5 cm in size or removed from the orchard. Chipping can be done using either chippers or flail mowers (Plate 10). These chipping should be thrown back under the tree canopy. In the 2009 disease survey on custard apple, George and Redpath (2009) found that mulching of prunings had little or no effect on incidence of anthracnose but reduced the incidence of Pseudocercospora six-fold.

Plate 10. Flailing mover to chip up prunings.

6.3.5 Removal of diseased fruit and diseased prunings

The orchard should be inspected on a weekly basis. Any diseased fruit found in the orchard should be removed and either burnt or buried. Fruit left to rot on the ground are a significant source of infection. Fallen fruit are also a breeding place for fruit fly. If practicable, remove or slash decaying fruit, particularly where fruit fly or fruit borers are a problem. Diseased prunings should also be removed. If not, they should at least be chipped. In the 2009 disease survey, George and Redpath (2009) found that removal of prunings from the orchard reduced the incidence of anthracnose by more than half.

6.3.6 Tree skirting

Skirting is important to encourage fruit development well above ground, and to minimise diseases and pests (snails, Fuller's rose weevil and ants). It improves distribution of water by under-tree sprinklers, fertiliser spread and herbicide coverage. Skirting usually involves mechanical removal of foliage and minor branches up to 600 mm above ground level, and is usually done when tree are dormant (Plate 11).

Plate 11. Skirting persimmon trees will improve air circulation and reduce ant movement and subsequent scale and mealybug populations in the tree.

6.3.7 Nutrition

Nitrogen levels can influence tree growth patterns, and the size and fecundity of pests, particularly soft scales. Deficiencies can lead to delayed development of the pests, smaller scales and fewer eggs.

Excessive nitrogen levels may have the opposite effects. It can make the fruit more susceptible to pests by increasing calyx separation which is an ideal site for pests to breed and hide (Plate 12).

Application of calcium and perhaps silica-based fertilisers may also reduce pest and disease susceptibility by increasing host plant resistance.

Plate 12. Excessive nitrogen application can cause calyx separation providing a site for caterpillars and mealybugs.

6.3.8 Weed control and inter-row cover crops

Cultivation has been a common method of weed control in some orchards. Herbicide usage is now more common because of the increasing use of microsprinklers, closer tree plantings and increased labour costs. Total elimination of weeds within the rows by either cultivation or herbicides can have a detrimental effect on pest management. Most growers now leave grass swards between rows to reduce erosion. This also appears to be more beneficial for pest and disease control than using herbicide-sprayed strips. This sward system results in a more favourable environment for the natural enemies of pests, and provides supplementary food (pollens and nectars) for them.

6.3.9 Dust control

Dust from access roads or cultivated inter-rows is hazardous to beneficial insects, especially small parasitic wasps. Minimise dust by sealing or watering roads and keeping vehicle speeds to a minimum.

6.3.10 Bird control

A few growers claim that diseases such as anthracnose are being spread by birds such as lorikeets. Netting to exclude birds from the orchard may be beneficial.

6.3.11 Irrigation

Regular irrigation can reduce stress on the tree and consequently reduce susceptibility to disease and pests such as clearwing moth which are attracted to stressed trees.

6.3.12 Hot spot spraying

Wherever possible, spraying hot spots of pests with insecticides is better in terms of maintaining populations of beneficial insects and in reducing chemical usage. However, it requires careful orchard monitoring to determine where hot spots develop (see Chapter 4).

6.3.13 Harvesting methods and timing

Whilst it is important not to harvest immature fruit, it is equally important not to leave over-mature fruit on the trees as these are more susceptibility to fruit fly attack and post-harvest rots. It is also important to prevent fruit damage during harvesting (Plate 13) which can increase susceptibility to post-harvest rots.

Plate 13. This grower is using bubble wrap used to prevent punctures and possible development of post-harvest rots.

6.3.14 Topworking and grafting trees in the field

Top-working trees in the field can result in a surge of infestation of clearwing moth with moths attracted to the cut stumps (Plate 14). This response is presumably due to the release of stress hormones by the tree.

Plate 14. Top working in the field can attract clearwing moth to the stumps.

6.3.15 Packhouse sanitation

All harvest equipment, the packing line and packing boxes should be sanitized regularly. There are a range of techniques available to sanitise packhouses including use of:

- ozone generators
- UV-C lights
- vaporous hydrogen peroxide

- Bactigas® (contains Tea Tree oil)

These methods are described in more detail in an article by Peter Tavener, SARDI, 'Decontamination of cold storage facilities' in Packer Newsletter, Vol 89, December 2007. The efficacy of these methods is still under investigation.

No post-harvest fungicide dips are currently approved for control of post-harvest rots in persimmon.

6.3.16 Spray efficacy

Efficacy of spray application of pesticides is dependant on many factors including:

- selection of the correct spray equipment
- selection of the most appropriate pesticides
- correct sprayer calibration
- correct volume of application

These factors are discussed in more detail in Chapters 8 and 9.

Chapter 7

Pest and disease management programs

7.1 PEST AND DISEASE MANAGEMENT PROGRAMS

7.1.1 Introduction

This section outlines our current strategies and programs for controlling persimmon diseases and pests. The integrated pest and disease control programs and release of beneficials will vary with region, weather conditions and stage of tree growth.

7.1.2 Weather conditions

Pest and disease pressures are two to three times greater in Queensland and northern NSW compared with Victoria and South Australia (see Chapter 2). With insects, the main reason for greater activity is the lower winter mortality of insects due to warmer winter temperatures in Queensland (Figure 1). In addition, under warmer and wetter conditions, activity of insect pests can occur 2-3 months earlier than in cooler regions and the number of life cyles also increases. Generally, fungi that cause plant disease grow best in moderate temperature ranges. Sub-tropical climatic zones are more likely to experience longer periods of temperatures suitable for pathogen growth and reproduction. Consequently, more intensive IPDM programs are needed in Queensland and northern NSW.

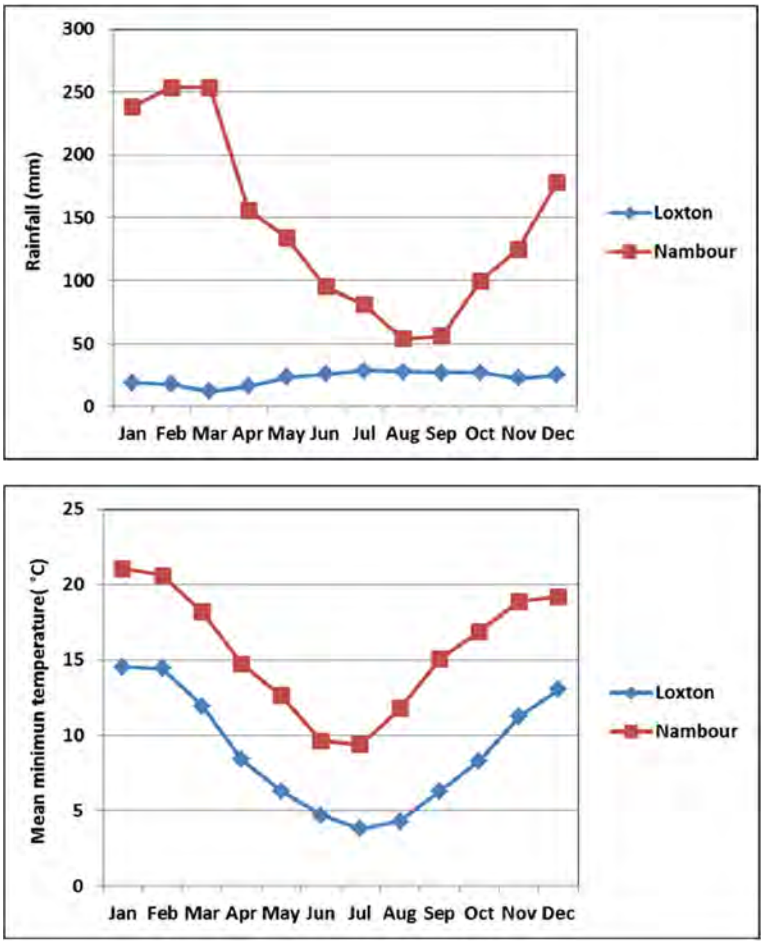

Figure 1. Top: Mean monthly rainfall. Bottom: Mean monthly minimum temperatures. Data for two distinctly different growing regions, Nambour, Queensland, Loxton, SA.

We have also observed an increase in the number of new leaf and fruit diseases on persimmon over the past 5 years. This is probably due to recent introductions of new pathogen species from overseas and/or an increasing awareness by growers of the presence of new diseases and pests.

Besides the effects of weather condition on the build up of inoculum, rain is known as one of the main weather factors that affect the persistence of fungicides on fruit and leaf surface. The frequency of pesticide application will increase during "abnormally wet" seasons and decrease in years with sunny conditions, lower humidities and lower leaf wetness. The combined effect of rain and wind in natural rainfall could also result in a greater washing effect of pesticide residues off the fruit and leaf than just rain alone.

In addition, expanding plant surfaces create unprotected areas in the protective coating of fungicide and can dislodge fungitoxic residues that were present. Besides weather effects, under commercial orchard conditions, performance failures of pesticide sprays often result from poor application leading to insufficient coverage (see Chapter 9). Locally systemic fungicides are able to redistribute within the waxy layer or epidermal cells by lateral diffusion, and this makes them less dependent on spray coverage. Thus, these fungicides could achieve better control than protectants under poor coverage conditions.

Rain-fastness of some commonly used pesticides on persimmon are presented in Table 1.

TABLE 1.

Rain-fastness of some commonly used pesticides for persimmon. Check label for details.

Some products	Rain-fastness
Applaud®	Do not apply if heavy rain is imminent
Dithane®	No restraint but good practice to allow sufficient time for the spray deposit to dry before onset of rain
Dithane Rainshield®	No restraint but good practice to allow sufficient time for the spray deposit to dry before onset of rain
Lorsban®	No restraint but good practice to allow sufficient time for the spray deposit to dry before onset of rain
Mimic®	No restraint but good practice to allow sufficient time for the spray deposit to dry before onset of rain
Prodigy®	Do not apply if rainfall is expected within 6 hours

7.1.3 STAGES OF TREE AND FRUIT GROWTH

Besides weather conditions, timing of IPDM activities will be highly dependant on the stage of tree growth (also called the phenological cycle) and the seasonal life cycles and occurrence of pest and diseases. These factors are discussed below.

Dormancy

- A key strategy in this period is to eliminate carry-over diseases and pests from the previous growing season.
- Trees should be checked for clearwing moth damage. Some varieties such as 'Izu' will be more affected than others. If clearwing moth damage is present then apply 'hot spot' treatments - either mechanically kill grubs or drench trees with DC Tron oil + Supracide® mixture.

- Place four pheromone traps in orchards to measure clearwing moth activity.
- During dormancy, trees should be treated with high volume sprays of petroleum or Biopest oil® and copper oxychloride. Multiple applications (a minimum of 2 and perhaps 3 sprays) of these chemicals are recommended. Copper fungicides are protectant/preventative products. The copper product must be applied onto the plant surface prior to the disease occurring. Copper fungicides inhibit fungal spore germination and mycelial growth. How effectively disease is controlled depends on the quality of the formulation and adequacy of its coverage. Bioavailability reflects the amount of free copper available from a copper fungicide (Also see Chapter 7).
- Coverage of leaf litter and dead prunings on the ground should also be considered, as these are sources of fungal spores.
- Good under-tree hygiene such as mulching of prunings will be highly beneficial for disease and pest control. (These management strategies are discussed in more detail in Chapter 6).

Budbreak

- A new disease, twig blight (Phomopsis?), may become apparent at budbreak. Apply fungicide sprays of mancozeb to control it – two to three sprays at weekly intervals may be needed.
- In northern States, leaf spot diseases (e.g.*Cercospora* spp.) and other fruit diseases can be major problems even in well managed orchards. The greatest risk is during or after prolonged wet weather. Mancozeb® fungicidal sprays are the most suitable response when diseases get out of hand.
- We suggest that the first two applications of mancozeb be made early in the season (budbreak to fruit set) to prevent build-up of inoculum of angular leaf spot (*Cercospora* spp.) and other species of leaf diseases.
- Mulching under trees to reduce soil splash and the annual removal of dead twigs and mummified fruit are important cultural control measures.
- Check pheromone traps for clearwing moth activity. If moth activity is high start cover spray applications of chlorpyrifos to control adult moths and/or place pheromone dispensers throughout orchard (1000-1500 ties per hectare)

Flowering

- Check flowers for thrips and mites. Apply insectide if large numbers are present.
- Airblast trees with a fungicide to prevent petal adherence just after fruit set. This will help remove the petals which adhere to the base of the fruit; these can become a site for thrips to hide under.
- Apply mancozeb spray to reduce build up of inoculum of leaf diseases particularly in northern States under wet weather conditions.

Fruit development

- The main pest threats during the early fruit development period are fruit spotting bug and mealybug.
- For fruit spotting bug, fruit up to marble size generally drop off. Fruit is most susceptible up to about medium size. Very often, damage is in ‘hot spots’ and experience over several seasons may enable just these areas to be targeted.

- The chemical, methidathion, which is used for controlling spotting bug, can have an adverse effect on beneficial insects at this time. We suggest that growers spray methidathion if 2.5% or more fruit (5 fruit out of the 200 inspected) have fresh bug damage.
- As fruit begin to expand, mealybugs pose the biggest threat. Mealybugs are 'farmed' by ants and controlling ant activity in the tree is essential. This is best achieved by skirting the trees during winter to a height of at least 50 cm and removing weeds and grass that may form 'ant bridges'. Use of sticky trunk bands, or applying ant baits on the immediate surrounding soil surface completes the ant management strategy (also see Chapter 4, Section 4.2). Once ants are removed from the system, naturally occurring populations of mealybug enemies such as Leptomastix wasps, Cryptolaemus ladybirds and lacewings will often suppress mealybug populations satisfactorily without further intervention.
- However, where necessary, additional beneficial insects can be added through releases of commercially produced species. There are several beneficial species which are available. Of these, Cryptolaemus ladybirds are the most efficient predators.
- At least 25% of sampled fruit need to have one or more large mealybugs to make it worth treating with an insecticide. The decision to act then depends on the activity of natural enemies. Action is recommended when natural enemies are present on less than 20% of sampled fruit (less than 50% from April to July).
- Sprays of disruptive chemicals such as methidathion (Supracide®) are a last resort. Growers should use Applaud® as an alternative to methidathion even though it may affect instars of predatory ladybirds. Applaud® is only effective on crawlers not adults. Applaud® should not be applied more than twice per season to prevent build up of resistance. Applaud® is compatible with mancozeb.
- In late summer/autumn, Yellow Peach Moth and Light Brown Apple Moth and other lepidopteran insects may become a problem in some orchards. We recommend that Prodigy® be applied on first appearance of frass on fruit or caterpillars under the calyces. Prodigy® is not harmful to predatory insects such as ladybirds or parasitoid wasps.

Fruit maturation and harvest period

- Queensland Fruit Fly and Mediterranean Fruit Fly are the major pests during the fruit maturation period from March to May. Early-maturing cultivars such as 'Izu' and 'Jiro' are particularly susceptible.
- The strategy with controlling fruit fly is to reduce populations to very low levels very early in the season (also see Chapter 4, Section 4.11).
- Fruit fly bait sprays have minimal effect on beneficial insects as they are applied to small areas of the foliage of each tree. We suggest that bait sprays be applied if there are more than 10-15 fruit flies in cue lure trays. Growers can use either the standard bait or Naturalure Fruit Fly Bait™.

- In Queensland, leaf spot diseases (e.g.*Cercospora* spp.) and other fruit diseases can be major problems even in well managed orchards. The greatest risk is during or after prolonged wet weather. Mancozeb® fungicide sprays are the most suitable response when leaf diseases get out of hand. Applications of mancozeb early in the growing season (flowering time) will prevent large build-up later in the season.
- We suggest that the first two applications of mancozeb be made early in the season to prevent build-up of inoculum of angular leaf spot (*Cercospora* spp.) and other species of leaf diseases. In South Australia, leaf diseases are only seen in years with above average summer rainfall.

Leaf fall

- The disease organism (Phomopsis?) which causes twig blight at budbreak may also enter the fresh scars of falling leaves. Apply fungicide sprays of mancozeb – at least two to three sprays at fortnightly intervals may be needed during this period for control.

Chapter 8

Pesticide application methods

8.1 INTRODUCTION

When IPDM is being implemented by persimmon growers, it is important that pests be effectively controlled when action levels are reached. If the appropriate action is spraying trees with a chemical, it is of the utmost importance to use spraying equipment which gives excellent coverage of the trunk, limbs, twigs, leaves and fruit. Good timing and good coverage will maximise pest kills.

Pesticide application is usually required only when the pest populations are out of balance with their natural enemies. Pesticides kill pests, but also further reduce the numbers of natural enemies. This problem can be made worse if spray coverage is poor, as pests that are sedentary or in protected positions will be less likely to come into contact with the spray and will be poorly controlled, while natural enemies, that are more mobile, and more likely to come into contact with the spray, will be killed. However, populations of natural enemies have a greater chance of recovering when only occasional sprays are required, and there is the longest possible interval between sprays.

8.2 SPRAY EFFICIENCY

General principles

Persimmon is one of the easier tree crops to spray efficiently because of the open tree shape and low dense foliage. Poor spray coverage can be due to a number of reasons relating to tree type, problems with equipment and its operation, and environmental conditions. They include:

- inappropriate sprayer
- poor machine design
- incorrect calibration
- poor maintenance of nozzles, pumps and hoses
- excessive spraying speed
- insufficient spray volume
- poor spray penetration in large, dense trees
- poor spray coverage of the inside top of large trees
- poor spraying conditions (windy and/or wet).

It is imperative that attention be given to correctly selecting, setting up and operating pesticide application equipment. Regular tree pruning and skirting are also important to facilitate spray penetration.

Information on spraying equipment and its operation can be obtained from pesticide application and safety courses, IPDM scouts, pesticide application specialists and sprayer manufacturers. It is recommended that all spray operators attend pesticide application and safety courses.

Because many persimmon pests are sedentary (e.g. scale insects) or slow-moving (e.g. mealybugs and mites), a high level of pesticide coverage (90%) is necessary, otherwise the pests will not come into contact with the pesticide. Scales and mealybugs are also protected by a water-repelling, waxy, leathery or mealy covering.

Spray volumes

The majority of persimmon growers apply between 1 000-1500 L of spray per hectare. Compared with citrus, the volume of spray applied per hectare is relatively low. With citrus, it is recommended that between 1 500 – 2 000 L be applied per hectare by air-blast sprayer.

To achieve high mortality, the pests must be thoroughly wetted with pesticides. On mature trees up to 5 m high, this requires high-volume spraying (2 000 or more litres per hectare). Most persimmon growers are unlikely to use more than 1 000 litres per hectare. Low-volume sprayers (200-300 L per hectare) usually give unsatisfactory control of these sedentary or slow-moving pests, unless adapted to apply high volumes. High-volume spraying is not so important for more mobile pests, such as bugs, beetles and caterpillars, and for sprays to combat diseases or to supply nutrients. In these cases, either high-volume or low-volume sprays are acceptable. Table 1 provides a guide to the volume of spray to apply to each tree.

TABLE 1.

Relationship between tree diameter and spray volume

Tree diameter	Normal canopy	Dense canopy
1-2 m	1-2 L/tree	2 L/tree
2-4 m	2-3 L/tree	3-4 L/tree
4-6 m	3-5 L/tree	4-7 L/tree
>6 m	7 L/tree	10 L/tree

Droplet size and nozzles

Sprays should reach their targets and provide good coverage of both leaf and fruit surfaces. Besides the sprayer, the other important choice of equipment is the nozzles. The aim is to achieve about 70 to 100 droplets of spray per square centimetre, with droplets ideally about 50 to 100 micrometres in diameter (1 000 micrometres = 1 millimetre).

Note:

- Droplets smaller than 70 microns are highly susceptible to loss through evaporation and drift.
- Droplets greater than 250 microns are highly susceptible to loss through run-off.
- Droplets are best deposited when they are carried to the target in a turbulent air stream. For this reason, we recommend air blast machines.

Proper calibration can be assessed through using a range of techniques including:

- visual assessment
- water sensitive paper
- fluorescent dyes

Plate 1. Water sensitive paper that show droplet distribution.

Worn nozzles reduce the adequacy of spraying by adversely affecting droplet size and sprayer output. Your nozzle output needs to be checked against published nozzle specifications. If the nozzle output varies by greater than 10% compared to the specification, then the nozzle should be discarded.

Wettable powders, such as 'mancozeb', accelerate nozzle wear considerably and often nozzles will need replacing before and during each season. Check during spraying for blocked nozzles which reduce the efficiency of spray application. Spray line filters should be installed and cleaned regularly to decrease the chance of nozzles becoming blocked.

8.3 TYPES OF SPRAYERS

About 90% of persimmon growers use air-blast sprayers. The second choice of sprayer is the mister. Below we described some of the most commonly used sprayers in tree fruit orchards.

Ocillating boom sprayers

For the spraying of scales, mealybugs and mites in large trees, the oscillating boom has built a good reputation over the last 50 years. They are generally not used by persimmon farmers because they are too expensive to buy.

When efficiently operated, the oscillating boom gives at least 90% coverage of the whole tree and, with the normal spraying arm on the top, is the most effective sprayer for large trees up to 6 m high (Plate 2).

Oscillating booms normally apply sprays at rates of 7 000 - 15 000 L/ha, but can apply as little as 3 000 L/ha with appropriate nozzles.

Plate 2. Oscillating boom sprayer.

Oscillating booms have become the yardstick by which other types of sprayers are measured for efficient control of scales, mites and mealybugs in persimmon. Oscillating booms are highly recommended by commercial pest scouts. Most growers use one-sided units. The main disadvantage of the oscillating boom is the loss of spray due to tree run-off. Other disadvantages, and the advantages, are summarised in Table 2.

TABLE 2.
Oscillating booms: advantages and disadvantages.

Advantages	Disadvantages
• 90° spray coverage • wet the whole tree, and both sedentary and mobile pests • give good coverage of the top and centre of • large trees • low spray drift (because of large droplet sizes) • low power requirements (less than 45 kW)	• use high volumes of water and usually require an attendant water tank • usually use more pesticide per ha than low-volume machines • up to 40% of the spray runs off onto the ground (high off-target losses) • cumbersome for spraying trees less than 5 years old • slow for spraying large orchards • not very adaptable for spraying lower volumes against mobile insects and diseases, and for applying nutrient sprays

Set-up and maintenance of the oscillating boom is important; coverage can be reduced by as much as 50% when there is poor maintenance. See Table 3 for set-up recommendations. Boom sprayers without oscillation have been used by some growers, but coverage is generally not as good as with oscillating booms, and is inadequate for scale and mealybug control.

TABLE 3.
Set-up recommendations.

Component	Recommendations
spray volume	3 000-15 000 L/ha
groundspeed*	2.3-2.75 km/h
pump pressure	3 000-5 000 kPa
oscillation rate (preferably two-way)	90-110 oscillations per minute
spray pattern	adjacent cones marrying at about 1.75 m (i.e. narrow cone angle, but the maximum angle consistent with good tree penetration)
Agitation	1 large paddle per 500 L, i.e. a 2 500 L vat should have 5 paddles; paddles should clear the bottom of the vat by about 10 mm and should have the same orientation
boom set	set angle of top boom to match tree size

* If the oscillation rate is lower than 90-110 and/or the oscillations are only one-way, then groundspeed should not exceed 2.5 km/h.

Low-profile air-blast sprayers

Low-profile air-blast sprayers (Plates 3 and 4) are less suitable than oscillating boom for spraying sedentary pests, particularly on persimmon trees over 2 m in height. They are the main type of sprayer used by persimmon growers. They can be adapted for high-volume application by the addition of a full tree-height tower with hydraulic nozzles, or a full tree-height air tower. They normally apply between 200 and 3 000 L/ha. Most persimmon growers apply less than 1 000 litres per hectare. Advantages and disadvantages are summarised in Table 4, and recommendations for set-up are given in Table 5.

Plate 3. Low-profile air-blast sprayer.

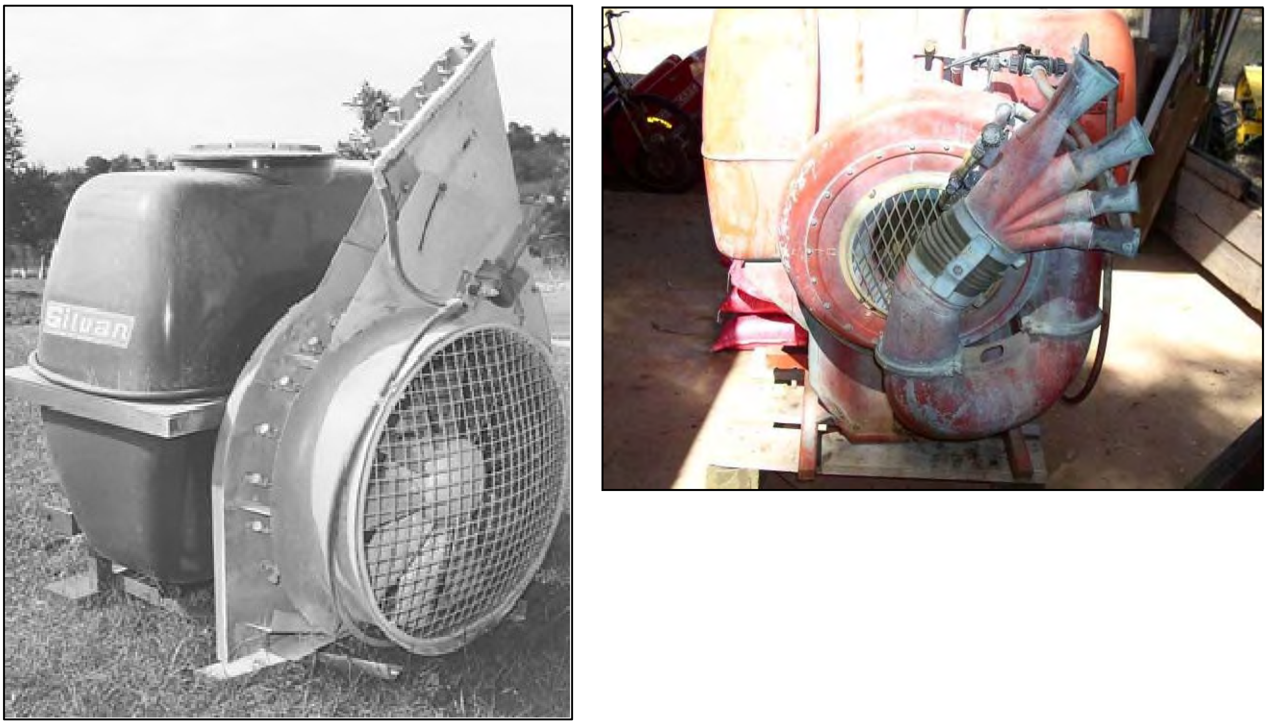

Plate 4. Different types of low-profile air-blast sprayers used by small persimmon growers.

TABLE 4.
Low-profile air-blast sprayers: advantages and disadvantages.

Advantages	Disadvantages
• less expensive to buy than most other machines • low maintenance • relatively quick and mobile, especially for young trees • usually use less pesticide per ha than oscillating boom • much less wastage due to run-off than oscillating boom • useful for applying nutrient sprays	• gives insufficient spray coverage for sedentary pests (scales, mealybugs, mites) in trees over 2 m high • spray coverage is uneven in higher trees, with excessive deposition low on the tree and under-dosing in the top • high power requirement (total of about 50 kW (70 hp)) • can produce excessive drift of small droplets • require careful air calibration to ensure airflow matched to tree size

TABLE 5.
Set-up recommendations.

Component	Recommendations
groundspeed	• 2.5-3 km/h
	Airflow to achieve maximum airflow, use the greatest fan blade pitch possible in relation to the available tractor power; tractors with power ratings of 50 kW or higher, and fans capable of delivering around 20 000 cubic metres of air per hour, or greater calibrated output (not fan rating), are required for good results in citrus • use only one side; modify airflow with an air cowling for one-sided spraying (when spraying scale insects and mealybugs, 20 000 cubic metres of air per hour is not enough for two sided spraying) • adjust fan cowling to widest setting to maximise area of air outlet and thus air volume produced • use upper and lower deflectors to ensure air is directed at the tree canopy • use sprayers with straightening vanes; set left and right side of sprayer independently if not using air straightening vanes
nozzles	• use large numbers of fine, abrasion-resistant or wear-resistant, ceramic hollow-cone nozzles of similar sizes, operated at optimum pressure; most air-blast sprayers will give improved coverage if more nozzles are added (at least 15 per side are recommended) • Spraying Systems TX or Delevan HC nozzles (or equivalent) use a different swirl system and give fine droplets at lower pressures (400- 1000 kPa compared to around 2 500 kPa for standard disc-core hollow-cone nozzles)

Component	Recommendations
	• when adding additional nozzles, ensure that the air duct is wide enough to carry all the droplets, otherwise the additional nozzles will not improve spray coverage, and may decrease it • with conventional nozzles and spacings, direct large nozzles towards the top of the trees • rotatable nozzle assemblies enable rapid switching from fine to coarser nozzle sizes or the assembly to be turned off (e.g. for small • trees, upper nozzles can be turned off)

Structurally modified low-profile air-blast sprayers

Much-improved results can be achieved with low-profile air-blast sprayers by adding an overhead hydraulic boom to the front of the unit, before the region of air-blast from the fan (Plate 5). The boom should be as high, or higher than, the trees. Some growers with skirted trees also add a low horizontal boom to pass underneath the trees. A cluster of three or four jets on the end of the boom, passing within about 500 mm of the trunk, is used to spray the inside canopy of the tree. With these modifications, volumes of 3 000 - 10 000 L/ha can be obtained, and the coverage approaches that achieved by the oscillating boom type of sprayer.

Recommendations for set-up are given in Table 6.

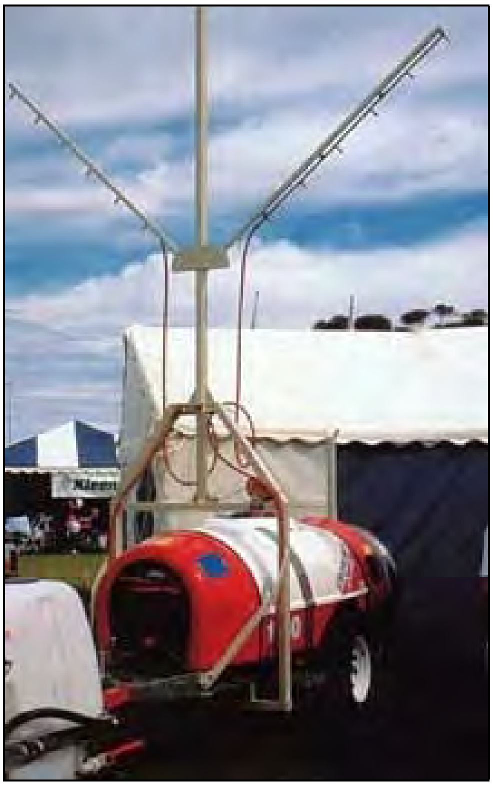

Plate 5. Structurally modified low-profile air-blast sprayers.

TABLE 6.
Set-up of structurally modified air-blast sprayers.

Component	Recommendations
Airflow	• for a one-sided unit, add a cowling (short air tower) with nozzles to convert the airblast component to one side; if the fan rotates clockwise, block off the air on the left side • set other parameters as for the low-profile air-blast sprayer
Nozzles	• use fine, low-output hollow nozzles with air assistance • use high-output, solid-cone nozzles on overhead and under-tree booms with similar spray pattern and nozzle spacings to those used on the oscillating boom • the capacity of standard air-blast pumps is often too low to cope with the flow rate of the additional high-volume nozzles, especially with two-sided units; if this is the case, add a larger pump

Air-blast sprayers with tower air conveyors

Air-blast sprayers fitted with air towers to the full height of the trees can achieve spray coverage approaching that achieved by the oscillating boom (Plate 6). However, poor design in the tower or insufficient airflow often drastically reduces the efficacy of these sprayers against scales and mites. They normally apply between 1 000 and 5 000 L/ha, but spray volume should be increased to 10 000 or more L/ha for sedentary pests.

Plate 6. Air-blast sprayers with tower.

Advantages and disadvantages of air-blast sprayers fitted with air towers are summarised in Table 7. Their main advantage over oscillating booms is their adaptability: they can be used for high-volume or low-volume application. Recommendations on use are presented in Table 8.

In Australia, most units are for one-sided application only. Two-sided units are available from overseas manufacturers, but capital cost and power requirements are extremely high.

TABLE 7.
Air-blast sprayers with air tower: advantages and disadvantages.

Advantages	Disadvantages
• low maintenance • relatively quick and mobile • much better coverage than low-profile air-blast sprayers • ideal for mobile pests, disease and nutrient sprays • usually use less pesticide per hectare than oscillating boom	• not quite as effective as oscillating boom on sedentary pests • high power requirements (50-75 kW) • poorly designed towers or insufficient airflows result in much-reduced coverage

TABLE 8.
Set-up of air-blast sprayers with air tower.

Component	Recommendations
Airflow	correctly designed internal baffles ensure relatively uniform airflow along the whole tower
Nozzles	seek professional help to select and set up

High-velocity sprayers with air-shear nozzles

High-velocity sprayers with air-shear nozzles can be used to apply volumes ranging from 100 L/ha to 1 000 L/ha (Plate 7). They normally use an enclosed centrifugal fan with air-ducting to spray-heads containing constricted air outlets with air-shear nozzles of various types. See Table 9 for advantages and disadvantages of these sprayers.

Air-shear nozzles use air movement to atomise a stream of liquid. Air velocities over the atomisers normally range from 360-650 km/h to shear off very fine droplets, which may be as fine as 50 micrometres vmd (volume median diameter). In comparison, the typical air velocity of a standard air-blast sprayer is about 100 km/h. Pressures required for spray liquid movement to the air-shear nozzles are low, and low-pressure centrifugal pumps and hoses are used. See Table 10 for set-up recommendations.

Plate 7. High-velocity air-shear sprayer with tower attachment.

TABLE 9.
High-velocity sprayers with air-shear nozzles: advantages and disadvantages

Advantages	Disadvantages
• effective coverage for control of mobile pests • good for nutrient sprays • reliable • mobile and fast with high work rate	• high power requirement • unsatisfactory against sedentary pests • can produce excessive drift

TABLE 10.
Set-up of high-velocity sprayers with air-shear nozzles

Component	Recommendations
liquid flow rate and chemical concentration	match to rates and volumes required
fan speeds	high; flooding of nozzles, with consequently larger droplet sizes and poorer coverage, can occur at lower fan speeds, especially at higher flow rates
Towers	use full-height towered units, with two, or preferably three, heads per side

Rotary atomisers

Rotary atomisers have multiple spray-heads, each containing an axial fan and high-speed (6 000–10 000 rpm) rotary cage, drum or disc atomiser (Plate 8). These atomisers produce fine droplets, generally around 100 - 150 micrometres vmd (volume median diameter). The spray-heads are normally powered by hydraulic motors. Current sprayers of this type can be used to apply spray volumes from 200 L/ha to 4 000 L/ha. Most persimmon growers using this type of sprayer are applying about 800 L/ha. See Table 10 for the advantages and disadvantages of these sprayers. The heads on later models have electric drive, requiring much less power from the tractor. They are designed for a much-increased airflow and higher volume application against sedentary pests. See Table 12 for set-up recommendations.

Plate 8. One type of rotary atomiser.

TABLE 11.
Rotary atomisers: advantages and disadvantages

Advantages	Disadvantages
• effective coverage for control of mobile pests • reliable • mobile and fast with high work rate • Ideal for nutrient spraying	• not effective against sedentary pests at volumes under 4 000 L/ha • can produce excessive spray drift • high level of operator expertise required • high maintenance • some types can be unreliable

TABLE 12.
Set-up of rotary atomiser sprayers.

Component	Recommendations
heads	• 4–6 heads per side are normally needed to spray large trees • converging airstreams give additional turbulence and coverage • direct airflows to converge into the tree canopy • have the top head slightly lower than the tops of trees, and a slight upward (not downward) incline for upper heads and slightly more upward incline on lower heads • airflows should converge laterally at 10°–20° • liquid flow can be turned off top upper heads when spraying small trees, or the heads repositioned to suit where all trees are small
liquid flow rate and chemical concentration	• for best results, match to rates and volumes required (i.e. calibrate accurately), and to the speed and capacity of discs, drums or cages
speed of cages, drums or discs	• maintain at specified revolutions per minute to produce droplets of the required size
groundspeed	• operate at correct groundspeed for the available airspeed and coverage requirements, i.e. accurately calibrate for airflow

Multi-head sprayer

A multi-head sprayer with a large (500 mm diameter) 3 000 rpm fan, and three-phase AC electric drive is also available (Plate 9). Air capacity of a 4–6 head sprayer is very high, and power requirement is low, compared to air-blast sprayers. Hollow cone nozzles spraying through the fan are used instead of a rotary atomiser, to apply high (10 000 L/ha) or low volumes.

Plate 9. Prototype of a multi-head sprayer.

Fly bait sprayer

Bait sprays for fruit fly control need to be applied with different equipment because:

- small volumes of spray are being applied (up to 35 L/ha)
- the spray is being directed to the lower part of the canopy only
- the spray is best applied as a coarse spray rather than the fine spray required for other pests and diseases

A suitable sprayer, with coarse nozzles mounted either side, can be built on a fat-track motorbike. The sprayer is best operated at a pressure of about 350 kPa delivering about 50 to 100 mL/tree. Make sure the sprayer has adjustable nozzles so that the spray band can be positioned to suit the changing height of the leaf canopy. An example of one type of bait sprayer is presented in Plate 10.

Plate 10. Small sprayer used to apply fly baits to trees.

9.4 Spray calibration

There are many options for calibrating sprayers. However the most efficient method is based on row volume. This method of spray calibration is described in detail by Geoff Furness, SARDI, in his book "Orchard and Vineyard Spraying Handbook for Australia & New Zealand". The handbook also provides helpful hints on how to set up all common types of orchard sprayers. It is available from Winetitles Online Bookstore (ISBN 9780730853435).

Traditional approaches to spraying don't take into account critical variables such as the size of the canopy and the density of the foliage. This grower friendly handbook is the first to explain the concept of distance spray calibration and will help growers deal with recent pesticide label changes. It contains simple look up tables to take the guesswork out of spraying.

The approach is a very simple to use technique, which is in fact a chart based version of the Unit Canopy Row (UCR) method, initially developed and implemented a few years ago. Some growers may prefer to use this original formula based approach, especially if they would like a little more precision. A fact sheet is available.
The adoption rate has been high because the method is so simple and easy to understand. In contrast, other canopy volume methods based on cubic metres of foliage per hectare, such as the Tree-Row-Volume method, developed some time ago in USA and Europe, have not generally been adopted because they are too complicated and difficult to understand. The new technique also has a good chance of being adopted as the industry standard world-wide,

Advantages of the method include:

- Compatible with the new pesticide label format for fruit trees and grapevines, in which rates per ha are no longer provided. Discussions with Agricultural Chemical companies is indicating that they will, in future, almost certainly also provide advice on spray volumes in litres per 100 m instead of litres per ha as new pesticide labels are developed.
- Reductions in pesticide use overall.
- Eliminates wide dose variations that occur when simple hectare based calibration is used, thereby avoiding overdosing and residue problems on small canopies and underdosing and hence poor efficacy on large canopies.
- Reduced off-target pesticide contamination of the environment; improved and more reliable efficacy (especially important for Integrated Pest Management strategies}.
- Reduced costs for growers.

Plate 11. "Orchard and Vineyard Spraying Handbook for Australia & New Zealand'. This handbook also provides helpful hints on how to set up all common types of orchard sprayers. It is available from Winetitles Online Bookstore (ISBN 9780730853435).

9.0
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FURTHER INFORMATION

- For further information on the production of minor tropical fruit contact the DEEDI Business Information Centre on 132523 (local call) 8am to 6pm Monday to Friday or visit DPI&F Information Centres in Mareeba, South Johnstone, Applethorpe, Gatton, Maroochy or Redlands.
- The DEEDI library provides a personalised information search service that may be useful for producers seeking information on minor and exotic crops. Contact DEEDI InfoSearch on 07 3239 6989.
- Visit the DEEDI website on www.deedi.qld.gov.au for other QPI&F notes on fruits.
- For enquiries on a Permit for minor use, contact: Australian Pesticides and Veterinary Medicines Authority PO Box E240 Kingston ACT 2604, Tel: (02) 6210 4700
- ChemCert is a national body that arranges training in chemical useage. Contact 02 6933 2177 or visit the ChemCert Australia web page: http://farrer.riv.csu.edu.au/chemcert
- Infopest CD-ROM contains current national information on registered agricultural chemicals and is available from Infopest, DPI&F, GPO Box 46, Brisbane Qld 4001 or by email from infopest@dpi.qld.gov.au
- Fruit fly traps. Consulting entomologist Richard Bull. Phone 33780340 Richard.bull@uqconnect.net
- Mauri Yeast Australia Pty Ltd Mr. Lindsay Thorburn PO Box 450, Toowoomba, QLD 4350, AUSTRALIA, Phone: (617) 4 632-3500, Fax: (617) 4 639-2031,mauritmba@hotmail.com
- The Good Bug Book, 2nd edition. Published by Integrated Pest Management Pty. Ltd.

WEB SITES

- Persimmons Australia Inc. www.persimmonsaustralia.com.au/
- Australian Pesticide and Veterinary Medicines Authority website: www.apvma.gov.au
- Bugs for Bugs:www.bugsforbugs.com.au
- ChemCert Australia web page: www.farrer.riv.csu.edu.au/chemcert
- Chemical classes: Web address: www.croplifeaustralia.org.au
- Codex MRL database at CSIRO: www.ento.csiro.au
- Disposal of chemicals: www.chemclear.com.au
- DPI & F Note: Banana-spotting & fruit-spotting bugs in rare fruit: http://www2.dpi.qld.gov.au/horticulture/5107.html
- DPI F& F Note: FSB in lychees and longans http://www2.dpi.qld.gov.au/horticulture/5427.html
- Freshcare Australia: www.freshcare.com.au

- Fungicide Resistance Action Committee (FRAC). Details of their classification of fungicides can be found on their web site: www.frac.info
- Fruit spotting bugs. Richard Llewellyn's Bioresources Pty. Ltd. http://www.bioresources.com.au/FSBbiocontrol/Home.html
- HAL Final Report HG97010 Ecology and Behaviour of fruitspotting bugs by G K Waite et al. 2000. http://www.horticulture.com.au/reports/order_a_final_report.asp
- Horticulture facts website: http://www.hortnet.co.nz/publications/hortfacts/hf401032.htm
- Images of spotting bugs at Brisbane insects:http://www.brisbaneinsects.com/brisbane_bugs/GreenCoonBugs.htm
- MacTrix site, biocontrol of macadamia nutborer: www.bioresources.com.au/MacTrix
- Minor use permits. http://www.apvma.gov.au/minor_use/subpage_minor.shtml
- NSW DPI website: http://www.dpi.nsw.gov.au/agriculture
- Organic Federation of Australia: www.ofa.org.au
- PestWeb, a regional insect pest-monitoring program and web based information-sharing tool for farmers and researchers in the Northern Rivers Region of NSW: www.pestweb.org.au
- Plant Health Australia: www.planthealthaustralia.com.au
- QLD DEEDI: www.deedi.qld.gov.au
- Registered chemicals: APVMAPUBCRIS databasehttp://services.apvma.gov.au/PubcrisWebClient/welcome.do;jsessionid=GLxdxXd0tR0PM3JDSpGLgq1FNQCdc0vn
- Spiders:http://www.brisbaneinsects.com/brisbane_spiders/SpidersFieldGuide.htm
- Standards Australia: www.standards.com.au
- Western Australia Department of Food and Agriculture: www.agric.wa.gov.au
- Withholding periods for most farm chemicals can be found at the Agtech site: www.agtech.com.au/label/
- Peter Chew, www.brisbaneinsects.com