INTEGRATED PEST AND DISEASE MANAGEMENT MANUAL FOR CUSTARD APPLE

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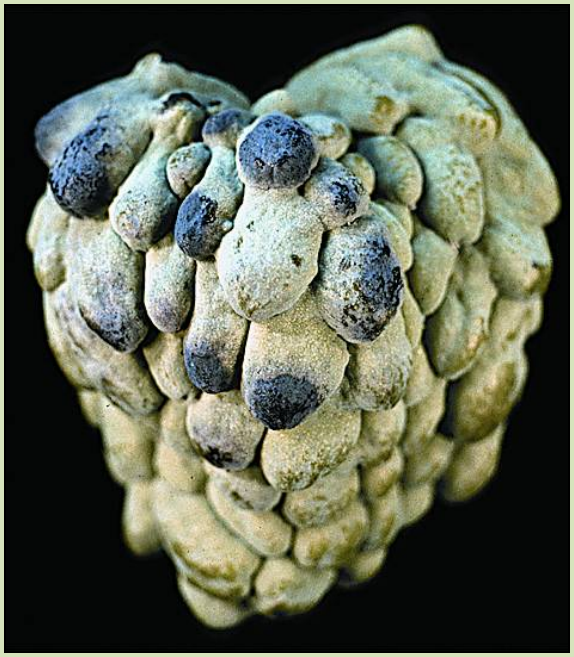

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CHAPTER 1

IPDM – an overview

1.1 AUSTRALIAN CUSTARD APPLE INDUSTRY

The Australian Custard apple industry was one of the first fruit industries to be established in Queensland in the early 1890's. The industry has grown slowly due to the lack of availability of high yielding varieties. However, since the early 2000's, the industry has started to expand rapidly due to the selection and breeding of new, highly productive varieties and the development of new, high yielding tree training and management systems.

The Australian custard apple industry produces about 2 500 tonnes per annum valued at $12-15M per annum. Farm gate prices for first grade and export quality fruit can average $30 per 7kg tray. The industry is set for a rapid increase in size and value due a combination of new, high yielding varieties, new elite germplasm such as the red-skin variety, and the development of new high yielding training systems.

Growing regions spread from the Atherton Tablelands in far north Queensland to northern NSW. With variation in climate between these regions, the production season ranges from mid-February in the warmer, sub-tropical regions to mid-October in the cooler, sub-tropical regions. The bulk of production is consumed on the domestic market with about 10-15% of the custard apple crop exported to Hong Kong and Singapore.

The main varieties of custard apples grown are African Pride, KJ Pinks, Hillary White and Pink's Mammoth. Since 2001, there have been significant new plantings of about 20 000 trees of 'KJ Pinks', a very high fruit setting sport of Pink's Mammoth. These plantings are just starting to fruit and it is expected that this will lead to a large increase in production. Current expansion of the industry is limited by the capacity of nurseries to produce new varieties in sufficient numbers to satisfy industry demand. This issue is currently being addressed.

Since 2006, two commercial processing factories have been established to produce frozen puree for the high-end restaurant trade. Consumption of processed product could increase significantly if recent health and medicinal findings on the anti-cancer and anti-diabetic properties of custard apple can be substantiated through clinical trials.

Awareness and knowledge of custard apple is low in many parts of Australia. Many people outside Queensland do not recognise the fruit and 40% having never tasted it. Consumers have poor knowledge of how to buy, ripen and prepare custard apples, except Asians.

A strong marketing program funded by industry and conducted by Horticulture Australia Limited has seen a significant increase in market penetration, particularly in southern States.

The industry is united and well-organised industry with funding for R&D and market development. It has a world class industry R&D program. The purpose of this manual is to provide to commercial growers information on the major pests and diseases of this crop and how to develop an integrated management approach to their control.

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 mites, 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' custard apples 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 custard apples, 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 - IDM

All plant diseases result from the interactions between a host (in this case custard apple), 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.

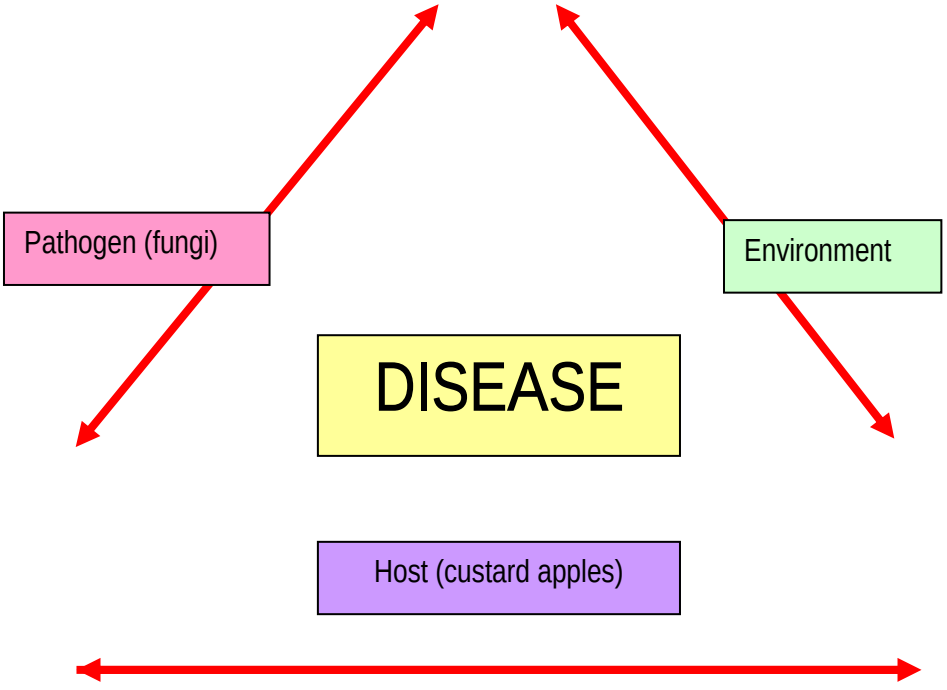


Figure 1. The interaction between fungi, host and disease necessary for the occurrence of a disease.

Table 1 also highlights some of the necessary interactions specifically related to the development of disease in custard apples.

TABLE 1

Examples of how modifications to each side of the disease triangle has provided better control of disease in custard apples.

Questions to ask	Changes that have been made or could be considered.
HOST • Are there other suitable cultivars? • Can the host be changed to resist fungal attack?	Cherimoya rootstock resulted in less bacterial wilt. - Pinks Mammoth is less susceptible to Pseudocercospora and Cylindrocladium fruit rot diseases than African Pride. - Changing the nature of plant surfaces with the use of highly effective chemicals should be used after all other management Options listed above have all been utilised.
ENVIRONMENT • Generally the macro environment cannot be changed. • Can the micro-environment be changed to make life hard for the pathogen?	Pruning to open the centre of the trees improves light penetration and airflow. This reduces humidity thus minimising pressure due to Pseudocercospora and Pinks disease etc. - Similarly raising the tree skirts also increases air flow and makes life difficult for fungal diseases such as Cylindrocladium diseases and Phytophthora fruit rot. - Choosing a good sunny aspect for a new orchard allows good canopy drying, reduced humidity and less fruit and leaf diseases. - Generous mulching under trees reduces rain splash from contaminated soil and undecomposed plant or fruit debris. This will help reduce Phytophthora and Cylindrocladium diseases. - Provision of neat grass swards between rows reduces movement of wind blown and rain splashed fungal spores from bare soil.
PATHOGEN* • Can we exclude the pathogen (disease causing organism)? • Can we reduce or eradicate the amount of inoculum** of the pathogen?	Removal of mummified fruit from trees reduces inoculum of black canker (*Phomopsis*) & diplodia fruit rot (*Lasiodiplodia*). - Removal of prunings takes a lot of inoculum laden waste from the orchard. If removal is impractical it is useful to facilitate quick breakdown of prunings by chipping and covering them with mulch. - Raising the tree skirt minimises splashing *Cylindrocladium* & *Phytophthora* spores from the soil on to the fruit, leaves & limbs. - Ant and mealy bug control minimises spread of *Cylindrocladium* spores into the higher parts of the tree.

*Pathogen = disease causing organism.
**Inoculum = parts of a fungus capable of causing disease.

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:

- *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 CUSTARD APPLES

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 custard apples 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 custard apple industry is very aware of the possible consequences that can occur from the use of unregistered or non-permitted pesticides (Dal Santo, 2008). 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 custard apples as a member of the 'assorted tropical and sub-tropical fruit (inedible peel)' category and are classified as a minor crop.

As a consequence of the issues facing the custard apple industry regarding pesticide access, a Strategic Agrichemical Review Process (SARP) was conducted in 2008 (DAL Santo, 2008) in conjunction with the Australian Custard Apple Growers Association (ACAGA).

The report prioritised the major pests and diseases affecting custard apple (Tables 1 and 2) 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 custard apple industry with sound pesticide options for the future that the industry can pursue for registration with the manufacturer, or minor-use permits with APVMA. A description of the more important pests and diseases affecting custard apple are presented in Chapters 3 and 4.

2.2 PRIORITY PESTS

The major insect pests are presented in Table 1.

The three most important pests are:

- Banana-spotting bug, *Amblypelta lutescens*
- Mealybugs, *Pseudococcidae spp.*
- Queensland fruit fly, *Bactrocera tryoni*

TABLE 1.
*Insect pests of custard apples**

Common name	Scientific name
High priority	
Ants	*Formicidae spp.*
Banana spotting bug	*Amblypelta lutescens*
Fruit flies	*Tephritidae spp*
Fruits potting bug	*Amblypelta nitida*
Leafroller moths	*Tortricidae spp*
Mealybugs	*Pseudococcidae spp.*
Mediterranean fruit fly	*Ceratitis capitata*
Queensland fruit fly	*Bactrocera tryoni*
Scale insects	*Coccidae, Diaspididae, Eriococcidae*
Yellow peach moth	*Conogethes punctiferalis*
Moderate priority	
Blue triangle	*Graphium sarpedon ssp choredon*
Birds	
Caterpillars	
Elephant weevil	*Orthorhinus cylindrirostris*
Fruit piercing moth	*Eudocima salaminia*
Low priority	
Flower eating caterpillars	*Lepidoptera spp.*
Long soft scale	*Coccus longulus*
Loopers	*Lepidoptera spp.*
Painted vine moth	*Agarista agricola*
Two-spotted (Red spider) mite	*Tetranychus urticae*
Lantania scale	*Hemiberlesia lataniae*

* Lists provided in reports by Dal Santo, 2008; Sanewski, 1991; Persley, 1993

The list of insecticides and fungicides registered for use on custard apple is presented in Chapter 7.

Following the Strategic Agrichemical Review of 2009, ACAGA has requested that APVMA issue minor use permits for a range of new insecticides and fungicides for trial on custard apple. A list of these pesticides where minor use permits are being applied for is presented in Chapter 7, section 7.1.4.

2.3 PRIORITY DISEASES

The major diseases and their order of priority is provided in Table 2 below.

The three most important custard apple fruit diseases are:

- Pseudocercospora spot, *Pseudocercospora spp.*
- anthracnose and pepper spot, *Colletotrichum gloeosporioides*
- Purple blotch, *Phytophthora capsicii*

TABLE 2.

*Diseases of custard apple**

Common name	Scientific name	Major plant organ affected
High priority		
Cercospora leaf and fruit spot and Pseudocercospora fruit (Masasso) spot	*Pseudocercospora spp.* *Pseudocercospora annonicola*	Fruit and leaf
Purple blotch or Phytophthora fruit rot	*Phytophthora capsicii*	Fruit, twig and leaf
Moderate priority		
Black canker	*Phomopsis spp.*	Fruit
Anthracnose or Pepper spot	*Colletotrichum gloeosporioides*	Fruit
Cylindrocladium spot	*Cylindrocladium spp.*	Fruit and leaf
Low priority		
Diplodia fruit rot	*Lasiodiplodia sp. (Botryodiplodia theobromae)*	Fruit and twigs
Bacterial wilt	*Psuedomonas solanacearum*	Roots, trunk and tree
Armillaria root rot	*Armillaria luteobubalina*	Roots and trunk
Pink disease	*Corticum salmonicolor*	Twigs and branches
Root rots	*Phytophthora cinamomi*	Roots
	Pythium spp.	Seedling roots
	Rhizoctonia solani	Seedling roots
	Scleroium rolfsii	Seedling roots
	Fusarium solani	Seedling roots

* Lists provided in reports by Dal Santo, 2008; Sanewski, 1991; Persley, 1993

2.4 FRUIT DISEASE SURVEY – NOVEMBER 2009

2.4.1 Survey design

Due to concerns about increased severity of diseases of custard apple fruit in northern NSW in recent years, a survey of the three major diseases affecting custard apple fruit in Australia was conducted in November 2009.

The diseases surveyed were:

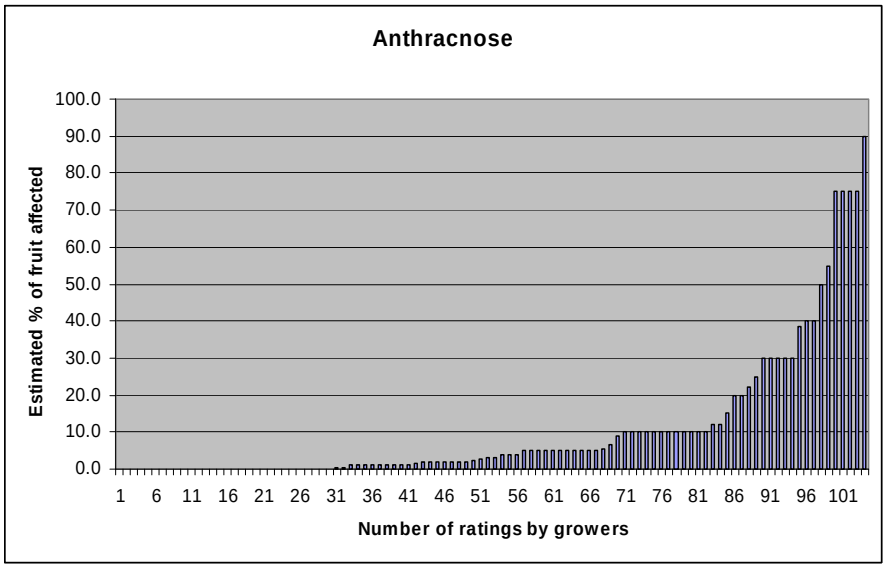
- Anthracnose (*Colletotrichum gloeosporiodes*)
- Purple blotch (*Phytophthora capsicii*)
- Pseudocercospora (*Pseudocercospora annonicola*)

Survey forms were developed by DEEDI in conjunction with the Industry Advisory Committee of ACAGA, the peak industry body representing the Australian custard apple industry. Over 200 survey forms were sent out to growers listed on the National databank. Fifty-seven growers (about 30% of all growers) responded to the survey. Responses were obtained from three States and from over 20 regions/districts.

Some key findings of the survey are presented below.

2.4.2 Variation in disease incidence between growers

Over all growers and regions, the severity of anthracnose was much higher than for the other two diseases. If we set an upper acceptable limit of 5% of fruit affected with anthracnose, then about 45% of growers could be considered to have a problem with this disease. In contrast, using the same acceptable limit of 5%, then only 16% of growers could be considered to have a problem with Pseudocercospora spp. and about 6% of growers with purple blotch (Figure 1).



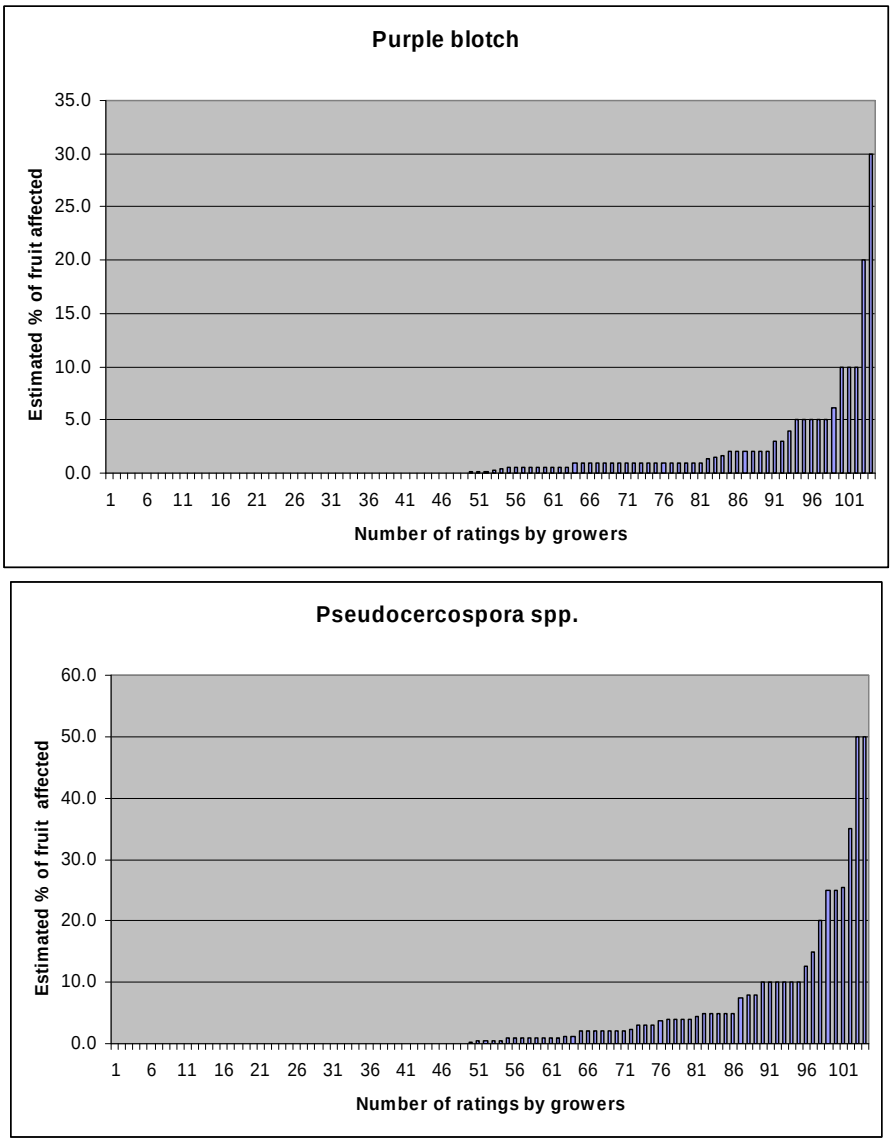


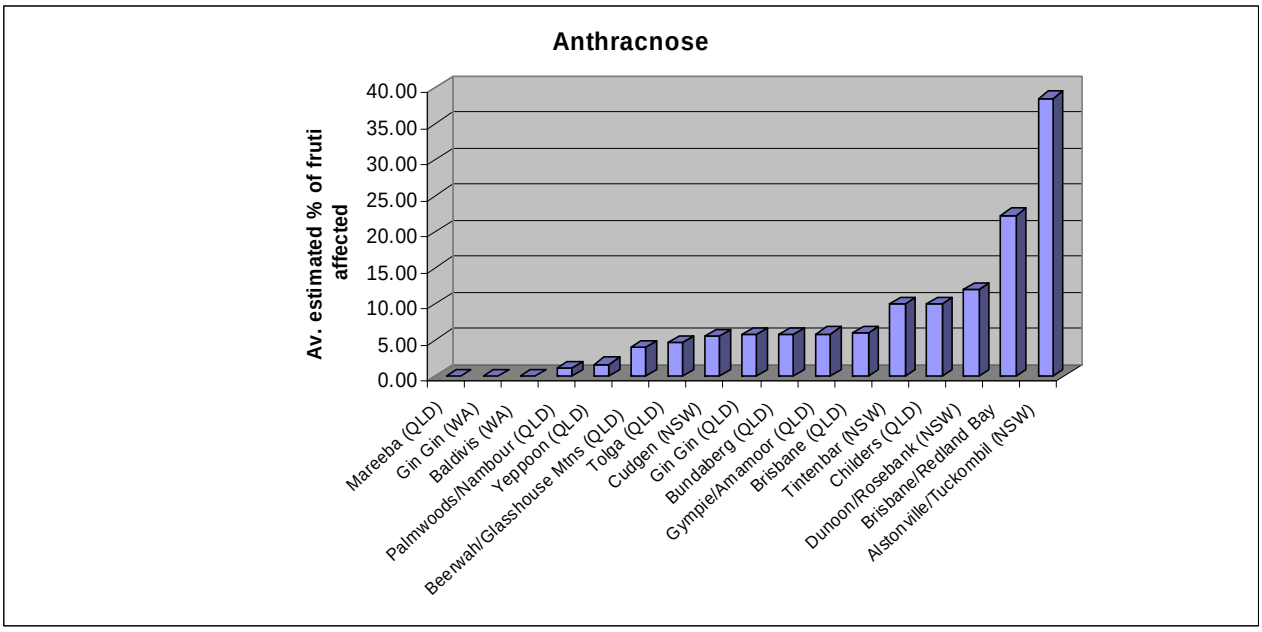
Figure 1. Estimated % of fruit affected by three fruit diseases as rated by individual growers in different regions. Many growers grew more than one variety per orchard so that the number of ratings exceeds the number of orchards surveyed.

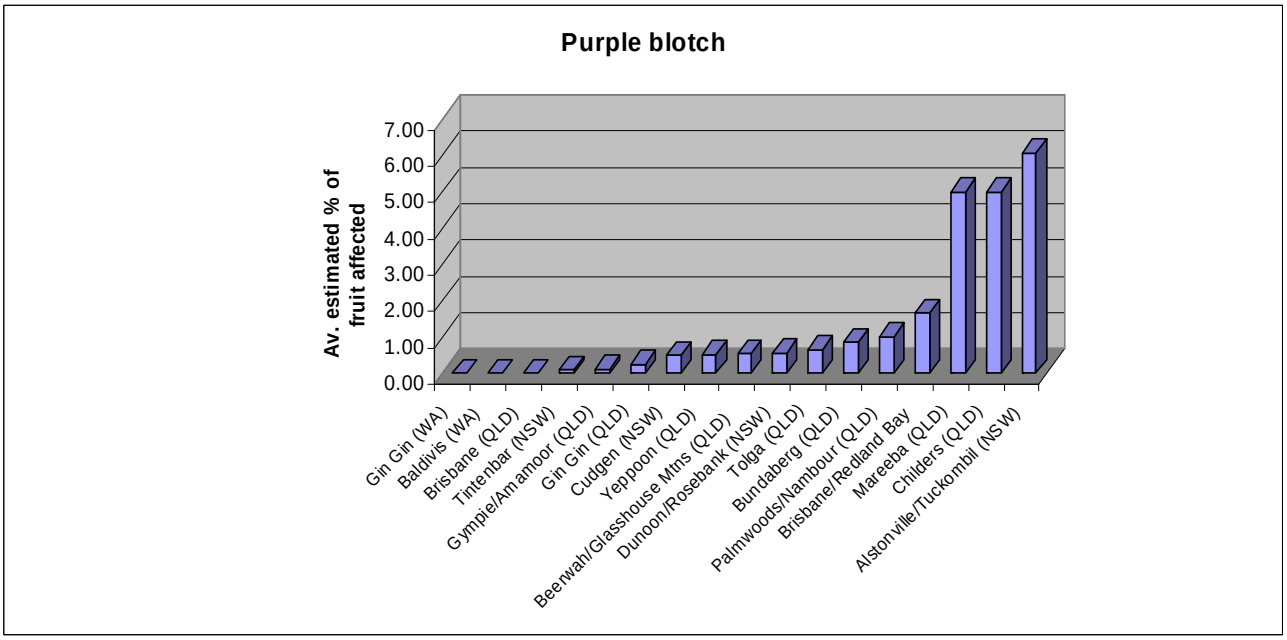
2.4.3 District/regional variation in disease incidence

Again using a 5% upper acceptable limit for disease severity for regions, about 59% of the seventeen districts/regions surveyed could be considered to have a problem with anthracnose and 47% of districts/regions with Pseudocercospora spp (Figure 2). In contrast, only 6% of districts/regions had a problem with Purple Blotch.

A very high incidence and severity of anthracnose infection occurred in the Alstonville and Tuckombil areas of northern NSW (Figure 3). This could be considered a 'hot spot' for this disease. The high level of infection in this area appears to be related to the number of neglected avocado orchards in this region, possibly being sources of inoculum, and the higher rainfall and more moderate temperatures in this region. Surprisingly, the regions with the highest incidence and severity of anthracnose did not exhibit the same incidence and severity in the other two diseases.

No correlation could be found between the severity and incidence of the three diseases in either Queensland or NSW indicating that each disease has its own specific factors for its development.





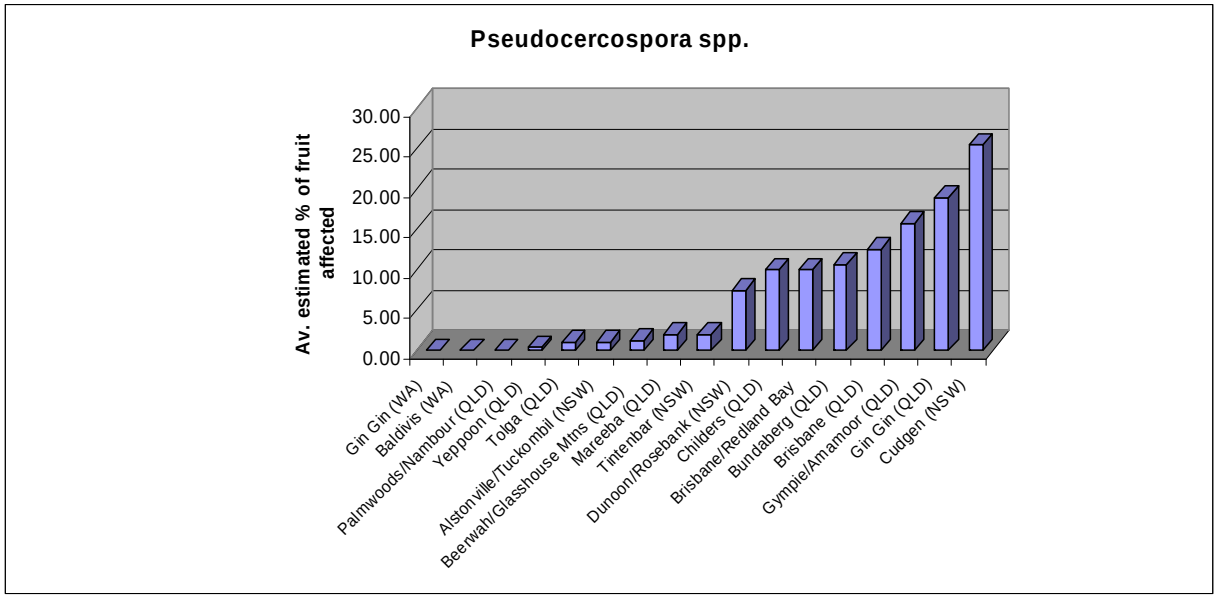


Figure 2. District/regional variation in disease severity. Average of between 2-10 orchards per district/region. Findings from disease survey (George and Redpath, 2009).

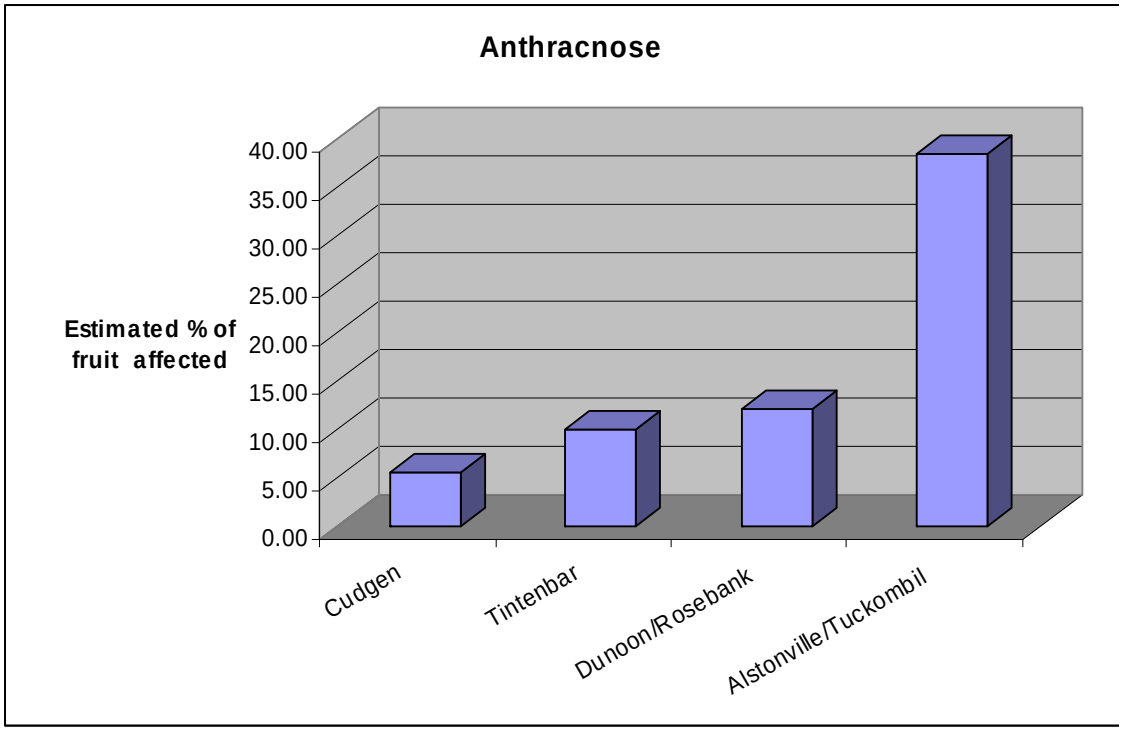


Figure 3. Incidence of anthracnose in selected areas of northern NSW. Note that the incidence of this disease decreases west and north of Alstonville. Findings from disease survey (George and Redpath, 2009).

CHAPTER 3

Diseases

3.1 PSEUDOCERCOSPORA SPOT

3.1.1 Symptoms

Early symptoms consist of a diffuse spot which appear as indentations on the fruit surface (Plates 1 and 2). Spots are small (ranging in size up to 15 mm) and dark purple to grey. Spots often coalesce to form large disfigured areas. Large necrotic spots are commonly seen as the disease progresses. In advanced cases, superficial cracks appear in the skin, and the hardened skin prevents normal fruit development.

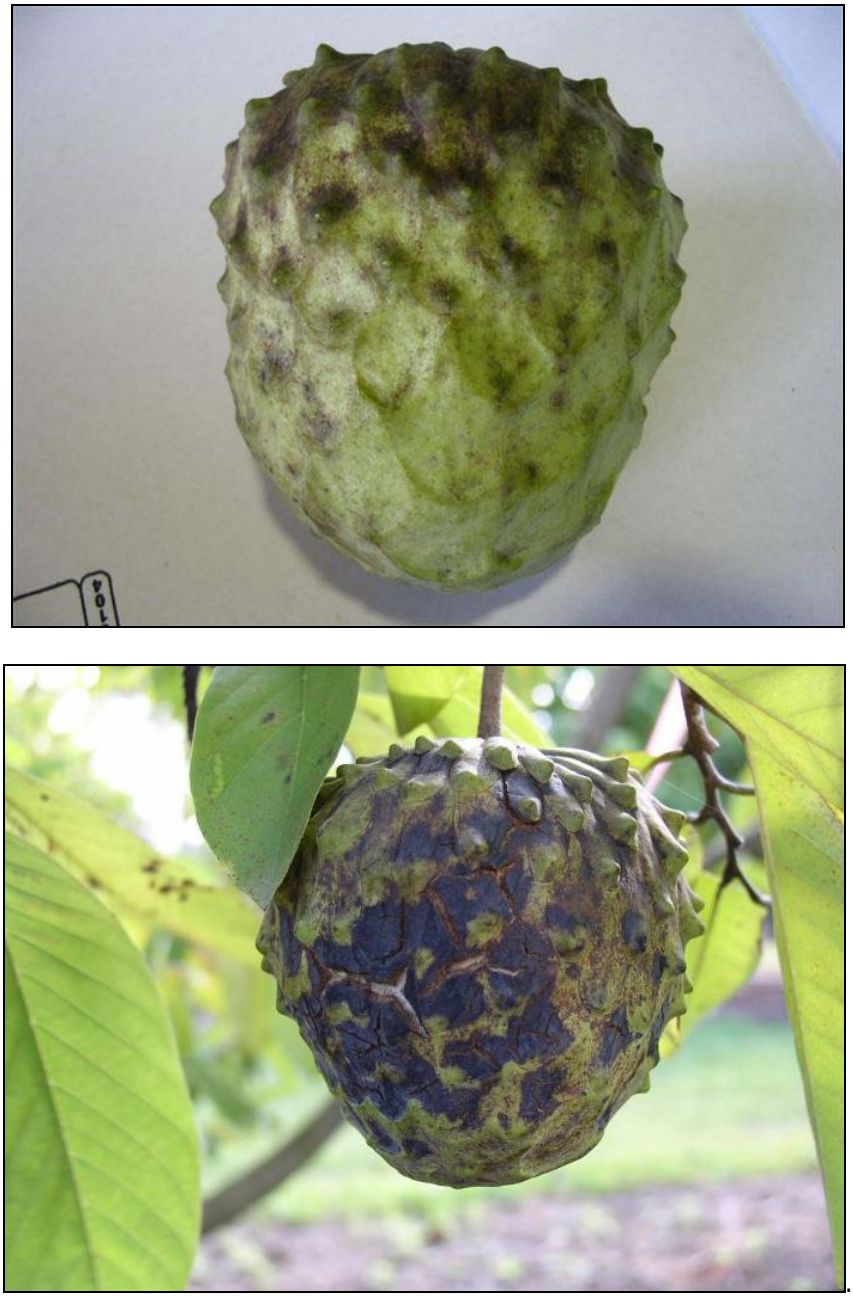


Plate 1. Top: Pseudocercospora spot mild symptoms. Bottom: Advanced symptoms.

Plate 2. Pseudocercospora spot. Less commonly seen symptom.

3.1.2 Causal organism

Pseudocercospora annonicola. This disease organism in custard apple was first reported in Taiwan. It is a different *Pseudocercospora* species that causes husk spot in macadamia.

3.1.3 History

Pseudocercospora fruit spot in custard apples was first recognised in Queensland custard apples in 1987 on the Atherton Tableland, by Mr Ron Peterson, formerly a DPI plant pathologist. He tentatively named it 'Masasso spot' in honour of Mr Joe Masasso, the grower who first brought the disease to the attention of DPI Plant Pathology staff. It was causing up to 35% loss of marketable fruit.

The fungus *Asteromella* spp. was consistently isolated from the spots and identified by John Alcorn. Subsequent work by Roger Shivas furthered the identification of the causal organism of Masasso spot to *Pseudocercospora annonicola* Goh & Hsieh (BRIP 18564a and BRIP 18566a).

The disease has subsequently been identified in south-east Queensland and northern New South Wales by Don Hutton and Roger Broadley, both DEEDI officers.

3.1.4 Occurrence and distribution

Pseudocercospora is major problem especially in wet seasons in all production regions. There appears to be a varietal difference in the susceptibility to the disease with cv. African Pride showing greater susceptibility than either cvs. KJ Pinks or Pink's Mammoth (see Chapter 6).

3.1.5 Chemical control

A chemical trial in the late 1980's by Ron Peterson, former DPI officer, showed that five fungicides gave a measure of control. Copper oxychloride was already registered so presumably it was decided that this would suffice. However, in subsequent years, copper oxychloride alone was shown to give poor control. Consequently this led to further field testing of new fungicides in 2007 by Hutton *et al*.

In field trials, mancozeb was shown to be effective but not as effective as Cabrio® (pyraclostrobin) under higher disease pressure (Figure 1; Plate 3). In 2010, Cabrio ® received a minor use permit for use on custard apple. There is a possible role for applying mancozeb, at least in the early stages of development before disease pressure builds. The need for a companion fungicide to be used with Cabrio® for a resistance management strategy is essential. Only three sprays of Cabrio® per season are recommended (permit number – PER13952). Mancozeb® or copper oxychloride (permit number – PER11943) should be tested in parallel with Cabrio®. The new parafinnic oil formulation Biopest® also gives good control, both alone and in combination with mancozeb.

We recommend maintaining a regular protectant spray program using mancozeb, Cabrio®) and Biopest® with frequency determined by prevailing weather conditions. Start spaying early in the fruit growth cycle (see Chapter 8 for regional spray programs).

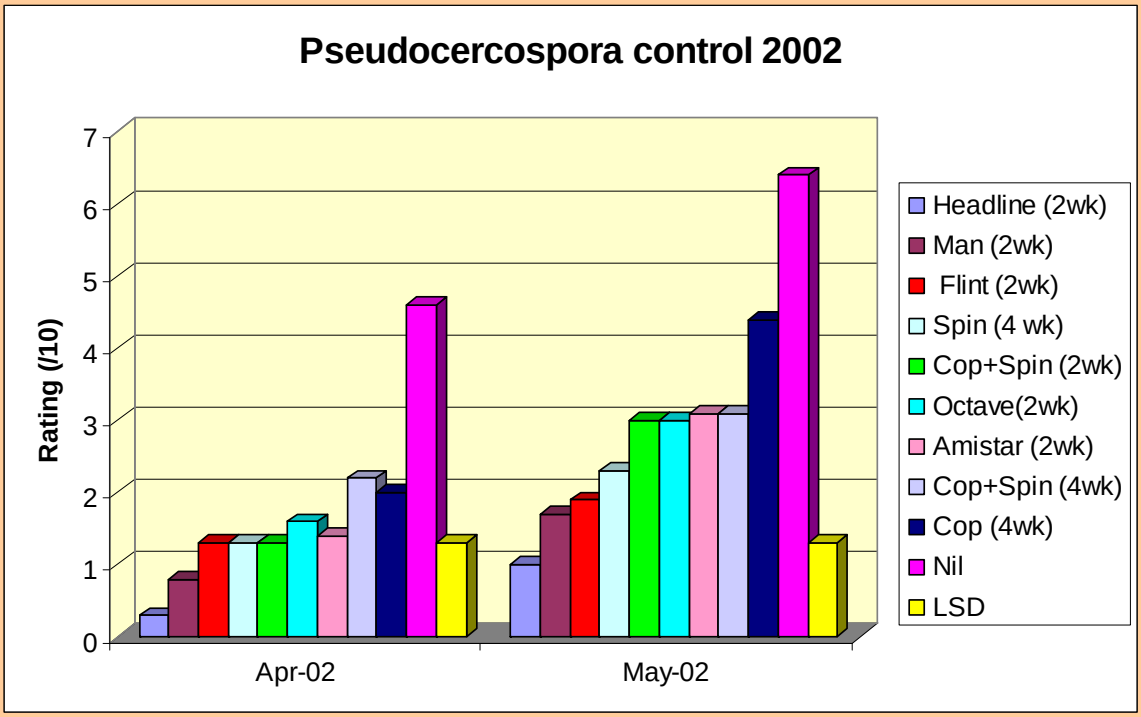


Figure 1. Effects of various fungicides on severity of Pseudocercospora disease in custard apple at Palmwoods, Qld in 2002. Similar findings were found in 2003. Headline® is a similar class of fungicide to Cabrio®. Cop=Copper oxychloride, Man=Mancozeb, Flint® is a strobilurin (Hutton, *et al.,* 2003).

Plate 3. Left: Control fruit severely infected with *Pseudocercospora* spp. Right: Fruit treated with Cabrio® fungicide.

3.1.6 Orchard management strategies

- Spray dormant trees and leaf litter with oil and copper after pruning – several applications may be required.
- 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 when ever 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.
- 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,
- Copper fungicide may also be sprayed onto dead leaves and twigs on the ground under trees when the trees are dormant.

3.2 ANTHRACNOSE

3.2.1 Symptoms

The symptoms are seen in fruit as dark brown to black spots on the unripened fruit, not unlike black canker (Plate 4). A second symptom caused by the same fungus has pepper spot specks on the surface of the fruit (Plate 4). These pepper spots coalesce on badly affected fruit. Leaf symptoms are also seen occasionally (Plate 5).

Pepper spot is also seen in avocados and lychees. Pepper spots are discrete with well defined margins compared with the diffuse spot seen in *Pseudocercospora.* Pepper spot in avocado has been shown to be associated with a stress factor that limits the disease to pepper spots rather than the quite large rotted spots characteristic of the disease in avocados.

Plate 4. Top: Advanced anthracnose caused by *Colletotrichum gloeosporioides*. Bottom: Pepper spot caused by *Colletotrichum gloeosporioides*.

Plate 5. Leaf symptoms of anthracnose more commonly seen on cherimoya.

3.2.2 Causal organism

Colletotrichum gloeosporioides. Colletotrichum spp. attacks a wide range of fruit, including avocado, mango, banana, passionfruit, fig and papaw.

3.2.3 History

Anthracnose disease has become more significant over the past 5 years (George and Redpath, 2009). This fungal disease has been recognised in Queensland since the mid 1950's. It could become an ongoing major disease problem (see Chapter 2).

3.2.4 Occurrence and distribution

In avocados, 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. It is likely that the fungus behaves similarly in custard apples. Wet conditions increase severity of the disease (Figure 2). There are a number of factors which probably contribute to anthracnose in custard apple:

- 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.

- In NSW, there is 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 occur where custard apple orchards are located in close proximity to neglected avocado orchards (see Chapter 6).
- 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.

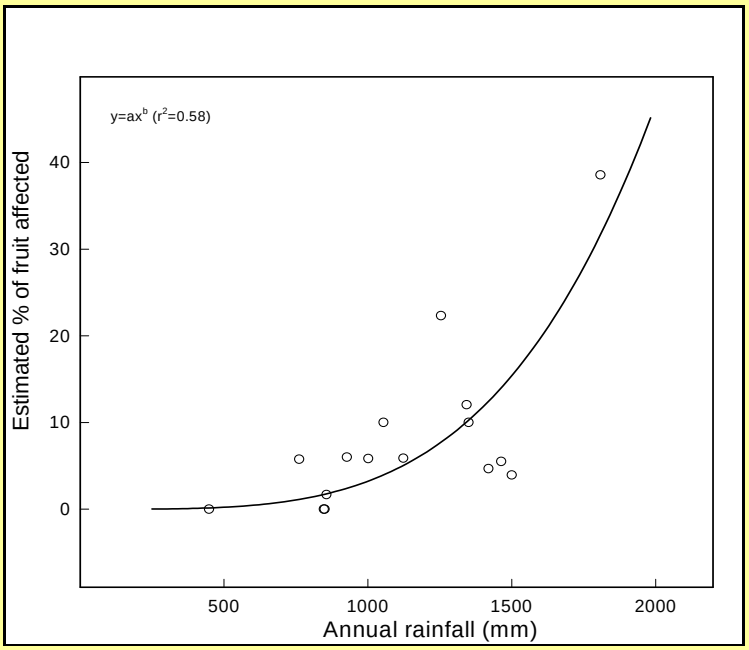


Figure 2. Relationship between annual rainfall for different districts/regions and incidence of anthracnose in custard apple.

3.2.5 Chemical control

1. Spray dormant trees twice with copper oxychloride fungicide and with Biopest oil®. Ensure that these are high volume sprays. Do not apply copper if buds have broken.
2. Spray every two-three weeks with fungicides such as mancozeb, or Cabrio® or with Biopest®. It is best to rotate each of these fungicides in turn to prevent build-up of resistance. Control with these protectants largely depends on the level of coverage achieved. These sprays also control Pseudocercospora, a major problem in cv. African Pride.
3. A minor use permit for Octave (prochloraz) has been issued for control of anthracnose in custard apple (permit number - PER11944). Apply during flowering and early fruit set only. Apply at 21 – 28 day intervals. In prolonged wet weather reduce the interval to 14 days.

3.2.6 Orchard management strategies

Orchard management strategies are the same as for Pseudocercospora spot.

3.3 PURPLE BLOTCH

3.3.1 Symptoms

On small fruit, small purple spots quickly grow to cover the entire fruit surface (Plate 6). On larger fruit, the spots or blotches usually reach 2 cm in diameter before being noticed. The spots quickly expand to 5 cm wide. They have a distinct margin and sometimes a halo around the initial spot. The fruit may be covered by white fungal growth, which develops under moist conditions. Affected fruit drop readily. Internal discolouration is extensive and may affect all of the flesh. More mature diseased fruit do not become hard as they do with black canker or Diplodia rot. When it occurs on individual farms, it is a very severe problem. A small spot on a harvested fruit quickly spreads to the whole fruit, and if packed can affect the whole tray.

3.3.2 Causal organism

Purple blotch is caused by the soil-borne fungus *Phytophthora capsicii*.

3.3.3 History

Purple blotch was previously though to be caused by *Phytophthora palmivora*. Space age molecular technology demonstrated that it was caused by *Phytophthora capsicii*.

3.3.4 Occurrence and distribution

According to Brad Keen, soil microbiologist, NSW DPI, during dry periods *Phytophthora capsicii* will become mostly inactive and survive in a dormant state as oospores or chlamydospores. These structures are very resilient and can survive in the soil, typically protected within organic matter particles for lengthy periods. Oospores in particular have a very thick wall and are very resilient to desiccation and attack from soil microorganisms and survive in the soil for possibly five years or more. When soil moisture and temperatures are favourable these spores will germinate to produce zoosporangia which in turn release zoospores. These zoospores have tails that enables them to swim. They have the ability to recognise electro-chemical signals which means they can swim in a purposeful direction towards the targeted host and towards the soil surface. Under heavy rainfall conditions, the zoospores splash from the ground onto the leaves, braches and fruit up to one metre, or slightly more, above the ground. The zoospores germinate within 24 hours and start producing infective propagules once they arrive at a suitable host. When you have wind-blown rain the spores become airborne in the water droplets which can include the very fine droplets of windblown spray. It has been found even in the tops of large trees. Once *Phytophthora capsicii* is in the soil it is there indefinitely. This disease is usually more of a problem on farms with heavy wet soils and is more prevalent after periods of continuous wet weather.

3.3.5 Chemical control

Mancozeb and copper sprays should be used for control (permit number – PER11943). Fungicide sprays of mancozeb and should be started at fruit set. Phosphonate and Metalaxyl-M (Ridomil® and Ridomil Gold®) are highly effective against Purple Blotch but these fungicides are not currently registered for use on custard apple. Ridomil Gold® will probably be more

effective than straight Ridomil® because it provides both the protective properties of copper hydroxide and the curative and systemic properties of Metalaxyl-M. Efficacy data and residue data are required before a permit can be granted.

3.3.6 Orchard management strategies

Phytophthora capsicii is fairly commonly found in dams and streams. As such, irrigation water can act as a source of inoculum. If micro-sprinklers are throwing water onto the fruit then they are also likely to throwing inoculum onto the fruit. Other strategies are similar to those described for Pseudocercospora.

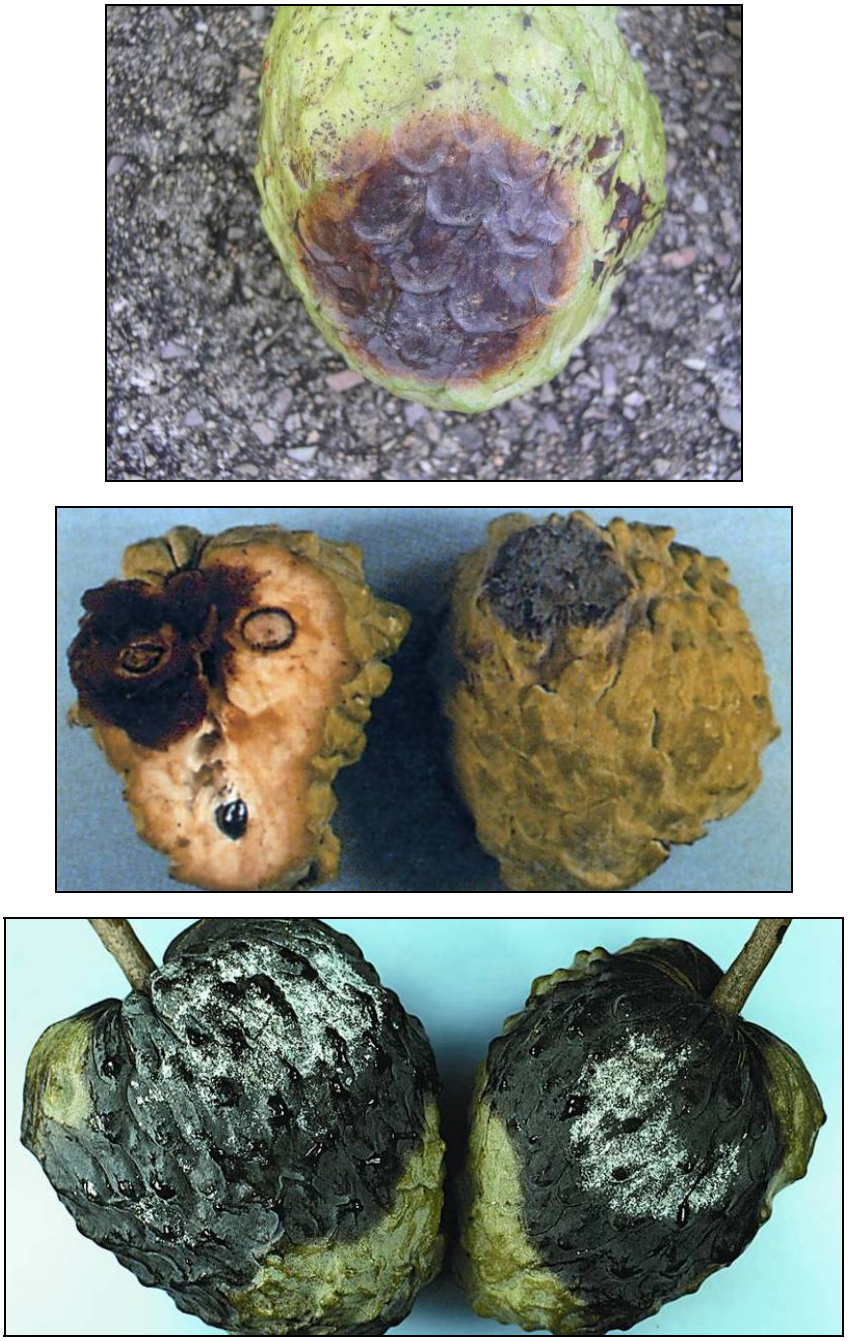


Plate 6. Top: Purple blotch caused by *Phytophthora capsicii*- early symptom. Middle: moderate symptoms. Bottom: severe symptoms.

3.4 DIPLODIA ROT

3.4.1 Symptoms

Spots are very dark, irregular in shape and with a distinct edge (Plate 7). They become hard and cracked. The external symptoms on the fruit are similar to Black Canker. However, with Diplodia rot, the internal discolouration extends well into the fruit, producing a brown, dry, corky appearance. Affected fruit usually shrivel, dry out (mummify) and remain on the tree. Symptoms are sometimes confused with calcium deficiency which tends to occur at the basal end of the fruit.

3.4.2 Causal organism

The fungus *Lasidiodiplodia theobromae.*

3.4.3 History

This disease was a major problem in the 1970s but is far less prevalent now.

3.4.4 Occurrence and distribution

Humid warm conditions favour disease development. The fungus produces sticky spores on dead twigs and in mummified fruit. The spores are spread by rain splash and wind.

3.4.5 Chemical control

Chemical control is rarely required in well-managed orchards. Where an outbreak occurs, spray with an appropriate fungicide such as mancozeb (permit number – PER11943).

3.4.6 Orchard management strategies

Diplodia is normally a problem in crowded, unpruned trees. Mummified fruit and dead twigs should be removed from the tree before fruiting commences.

Plate. 7. Left: Diplodia rot. Right: Suspected calcium deficiency?

3.5 BLACK CANKER

3.5.1 Symptoms

Purple to black, irregularly shaped spots ranging from small specks to large blotches (Plate 8). Spots have an indistinct 'feathered' edge. The spots start as one or two isolated patches but soon develop into large, dry blotches with cracks. Tissue damage under the spots is no more than 10 mm deep.

3.5.2 Causal organism

The fungus *Phomopsis annonacearum.*

3.5.3 History

This disease was a major problem in the 1970s but is far less prevalent now.

3.5.4 Occurrence and distribution

The disease is mainly a problem in crowded orchards.

3.5.5 Chemical control

Chemical control is rarely required in well-managed orchards. Where an outbreak occurs, spray with appropriate chemicals such as copper and mancozeb (permit number – PER11943).

3.5.6 Orchard management strategies

Orchard management strategies are the same as for Pseudocercospora spot.

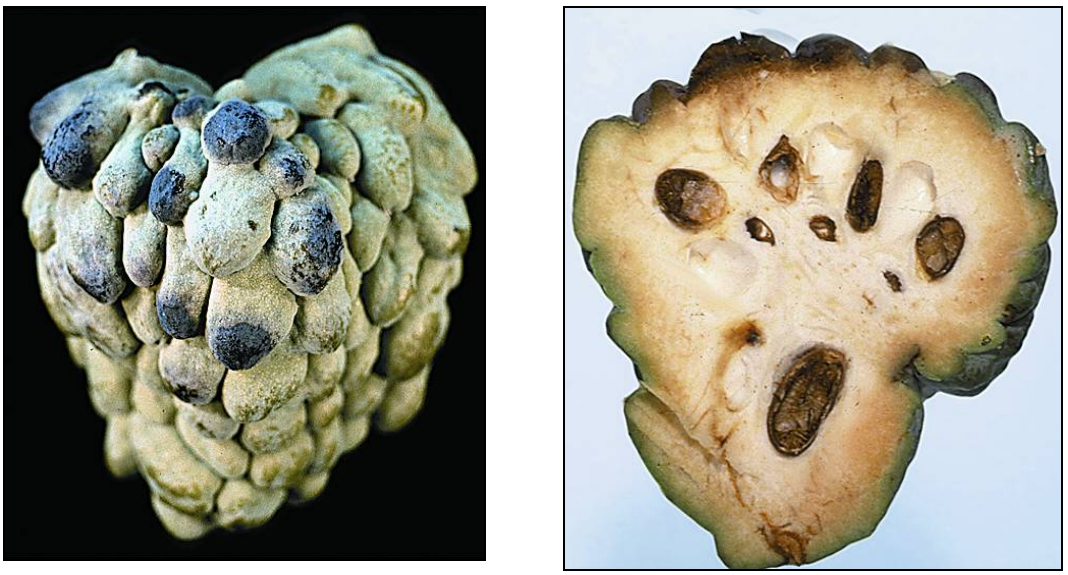


Plate 8. Black canker. Left: irregular shaped spots with an indistinct edge. Right: tissue damage under spots is no more than 10 mm deep.

3.6 CYLINDROCLADIUM FRUIT ROT

3.6.1 Symptoms

Dark purple spots, about 1 to 2 mm in diameter, develop first on the shoulders of the fruit and then spread down the sides (Plate 9). Spots do not become sunken but enlarge and then later dry out and crack. The symptoms are similar in appearance to spotting bug damage, but spots are irregular in shape whereas spotting bug lesions are round, and damage does not extend very far into the fruit. Cylindrocladium also infects leaves and to a lesser extent, roots. On the leaf it produces spots and, when severe, causes leaf drop.

3.6.2 Causal organism

The fungi *Cylindrocladium colhounii* and *Cylindrocladium scoparium*.

3.6.3 History

This disease was reported in the late 1980s. However, since then, it has occurred only rarely.

3.6.4 Occurrence and distribution

The main infection period is from March to June.

3.6.5 Chemical control

This disease is serious only after prolonged wet weather in autumn. Where a severe outbreak occurs, regular sprays of fungicide, used for the control of other diseases, should provide adequate control.

3.6.6 Orchard management strategies

Orchard management strategies are the same as for Pseudocercospora spot. Ants should be controlled to prevent infested soil being carried into the tree canopy.

Plate 9. Left: Cylindrocladium fruit rot damage on shoulder of fruit. Right: Unlike spotting bug, damage does not extend very far into the fruit.

3.7 SOOTY MOULD

3.7.1 Symptoms

The mould is superficial and may grow on leaves, twigs and fruit (Plate 10). 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. Sooty moulds do not infect plants but grow on surfaces where honeydew deposits accumulate. 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 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. Coated leaves may also prematurely senesce and die, causing premature leaf drop. Fruits or vegetables covered with sooty moulds are edible.

Plate 10. 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.

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 as described in the Chapter 4 on Pests.

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 sticky bands placed around the trunk of the tree in spring (see Chapter 4, section 4.3). 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 11). One grower has developed a semi-automated system with the fruit being sprayed with pressurised water to remove mould.

Plate 11. Left: A high pressure sprayers used to clean fruit. Right: A semi-automated system with the fruit sprayed with pressurised water.

3.8 COLLAR ROT (BACTERIAL WILT)

3.8.1 Symptoms

3.8.1.1 Young trees

Young trees may rapidly wilt and decline, often with severe defoliation (Plate 12). Leaves that stay on the tree are dull green and hang almost vertically.

3.8.1.2 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.

3.8.1.3 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 13). Dark streaking of the wood is rarely seen in the branches above the graft union. Roots may also be severely diseased (Plate 13). Wilting is most common in late summer.

3.8.2 Causal organism

The bacterium *Pseudomonas solanacearum.*

3.8.3 History

Bacterial wilt has been present in orchards since custard apples have been grown in Australia. Early plantings in the 1960s and 70s on sugar apple rootstock were highly susceptible with over 70% of trees dying within 10 years after planting.

3.8.4 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.

3.8.5 Chemical control

None available.

3.8.6 Orchard management strategies

3.8.6.1 Host plants

Delay growing custard apples 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.

3.8.6.2 Drainage

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

3.8.6.3 Rootstock selection

The selection of rootstock is also important for control. Cherimoya (*Annona cherimola*) rootstock is less susceptible than the older strains of sugar apple (*Annona squamosa*) that were introduced into Queensland in the 1950s. Some sugar apple rootstocks recently introduced from Thailand and Taiwan may be less susceptible to root diseases and are currently being tested.

3.8.6.4 Mulching

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

Plate 12. Top: Early stage of the disease tree death. Bottom: Rapid tree death caused by bacterial wilt.

Plate 13. Black staining of vascular tissues due to bacterial wilt.

3.9 PINK DISEASE

3.9.1 Symptoms

Patches of pale pink or white fungal growth form on branches (Plate 14). The bark and outer sapwood in infected limbs is killed by the fungus and the bark consequently cracks and exudes gum

3.9.2 Causal organism

The fungus *Corticium salmonicolor.*

3.9.3 History

This disease has occurred sporadically since the 1950s.

3.9.4 Occurrence and distribution

Generally occurs in very old trees under stress. This disease is more common after prolonged wet weather in high-density orchards and in shaded areas of the tree canopy. Only a few trees in the orchard will be affected.

3.9.5 Chemical control

The disease does not warrant special preventative measures. Where the problem is persistent, remove and burn infected limbs and treat affected areas with a slurry of copper oxychloride and water.

3.9.6 Orchard management strategies

Prune trees to open up the canopy and allow better air circulation.

Plate 14. Pinks disease on a limb on an old custard apple tree.

3.10 ARMILLARIA ROOT ROT

3.10.1 Symptoms

The fungus causes a slow decline of trees with dieback of twigs and leaves. The disease can be diagnosed by the white plaques of fungal growth under the bark of the trunk, and the black 'shoestrings' of the fungus on the major roots (Plate 15). After wet weather, honey-coloured mushrooms of the fungus may be found growing at the base of affected trees. These have a distinct mushroom smell.

3.10.2 Causal organism

The fungus *Armillaria luteobubalina.*

3.10.3 History

This disease occurs sporadically in older orchards. The organisms can survive on stumps and roots of various trees for many years.

3.10.4 Occurrence and distribution

Losses are most likely when custard apples are planted into land recently cleared of trees susceptible to the disease. Yellow box (*Eucalyptus melliodora*) is a common tree host.

3.10.5 Chemical control

None available.

3.10.6 Orchard management strategies

Before planting, remove as many roots as possible of previous trees. This requires stick raking, deep ripping and tining. The cultivation of cover crops after clearing further reduces the survival of the fungus. Individual replant tree sites may also be fumigated before planting new trees.

Plate 15. Shoestrings of the Armillaria fungus on the roots of custard apple.

3.11 OTHER ROOT DISEASES

3.11.1 Symptoms

Trees affected with root diseases show pale yellow foliage and weak vegetative flushes. Roots of the affected tree are black with rotting of the fine root tips (Plate 16).

Plate 16. Top: Healthy feeder roots. Bottom: Diseased roots.

3.11.2 Causal organisms

Waterlogging from poor soil drainage, or root dehydration from inadequate irrigation and mulching. 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. is rarely isolated from custard apple trees.

3.11.3 History

This disease occurs sporadically.

3.11.4 Occurrence and distribution

This disease can occur on trees of all ages.

3.11.5 Chemical control

The minor use permit number PER13807 allows phosphorous acid to be used on custard apples for the control of phytopthora.
Curative: Apply every 3 weeks until disease is under control.

Preventative: Apply every 5-6 weeks.

Apply a maximum of 8 applications per crop. Apply as a foliar spray only. Spray to runoff 7.5 to 10L per adult tree.

Some growers have indicated that sick trees recover after drenching with metalaxyl-M (Ridomil Gold®). This fungicide is currently not registered for use on custard apple.

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, cherimoya 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.
- Mulch trees at least annually to maintain a favourable root environment. Addition of an organic fertiliser such as pelleted poultry manure is beneficial. Improve soil drainage where waterlogging occurs after heavy rain.
- 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 FRUIT SPOTTING BUGS

4.1.1 Damage

While feeding, fruit spotting bugs secrete an enzyme which causes extensive breakdown of cells. Damage is small, round 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 the diseases Diplodia rot, Cylindrocladium spot and Black Canker.

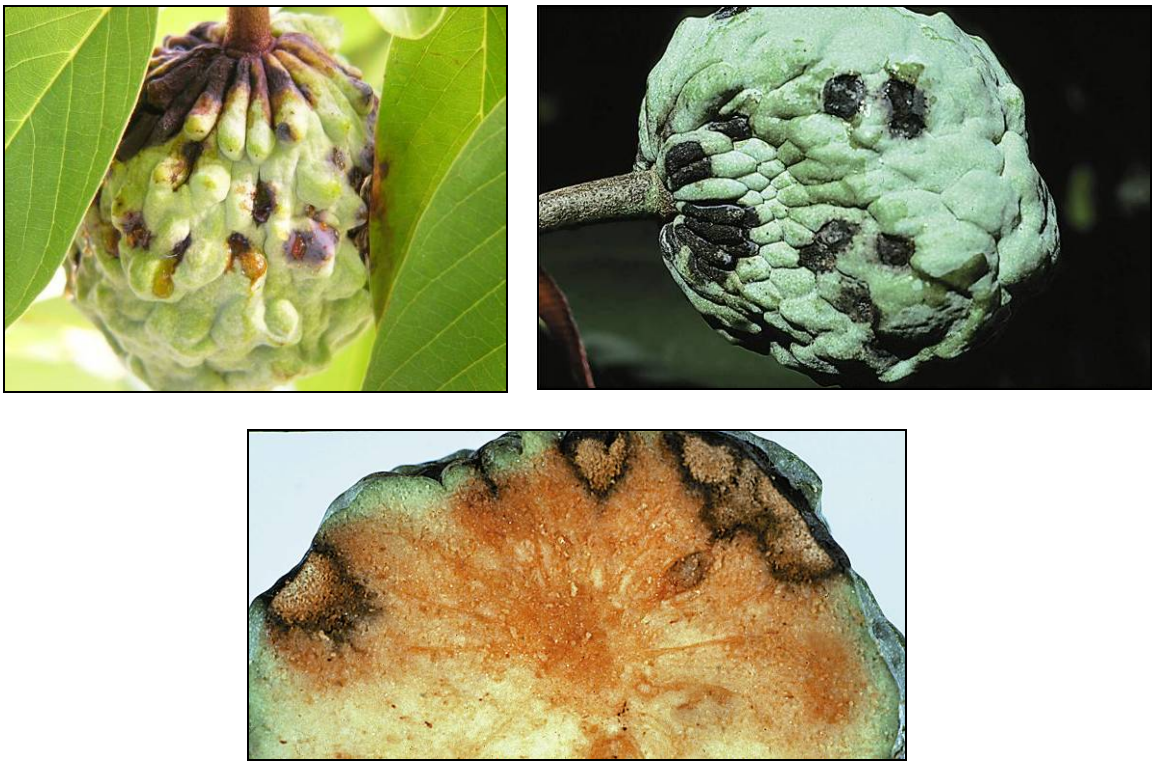


Plate 1. Top: Small, black, round spots on young fruit. Most damage is on the shoulders of the fruit. Bottom: Damage penetrates about 1 cm into the fruit.

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

4.1.2 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) (Plate 3) 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. The scent glands are most prominent in the banana spotting bug.

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

Plate 4. Left: close-up of a late instar nymph of banana spotting bug. Right: adult banana spotting bug.

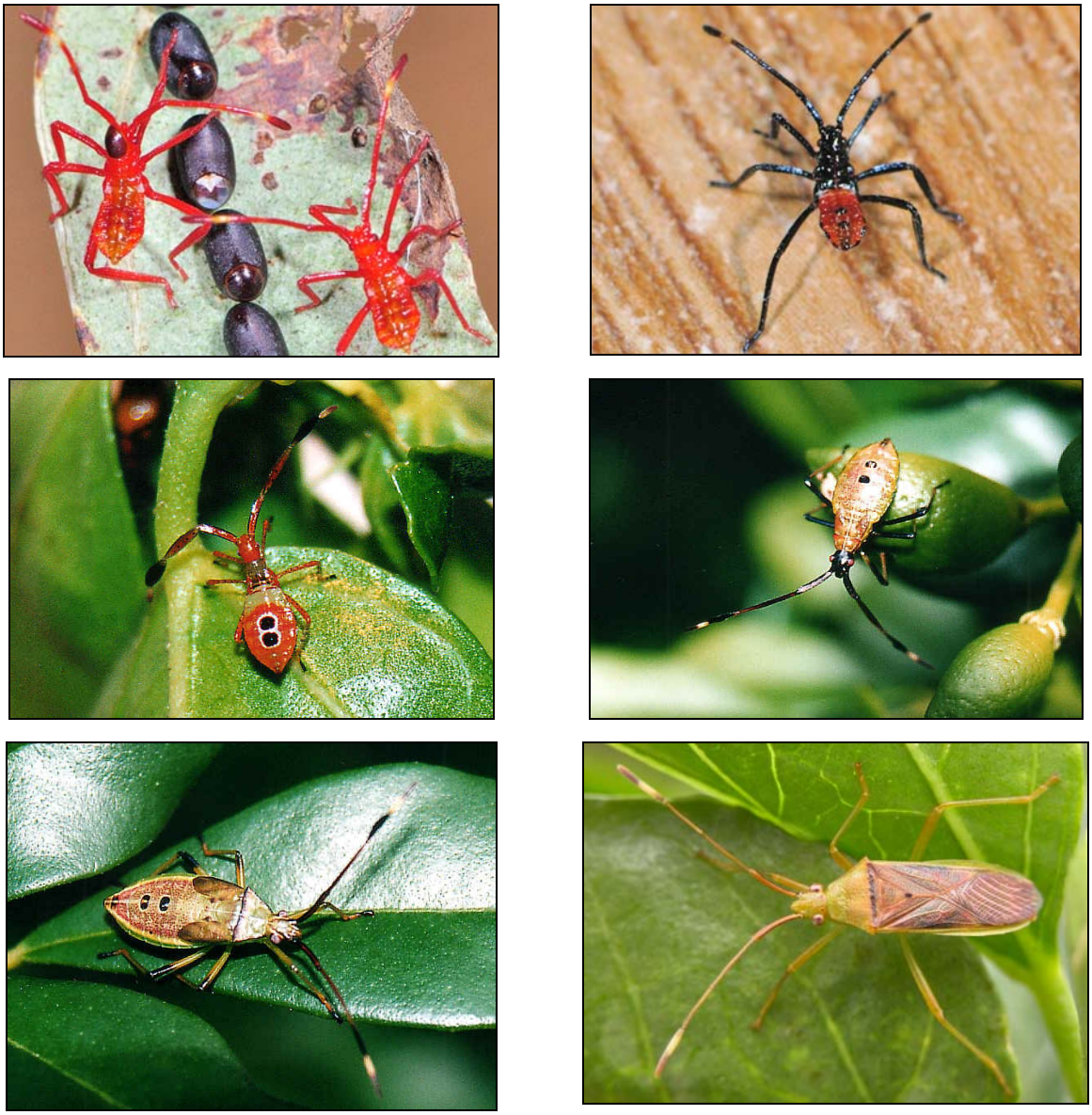


Plate 5. Top left: 1st Instar fruit spotting bug *A. nitida*. Top right: 2ndt Instar. Middle left: 3rd instar. Middle right: 4th instar. Bottom left: 5th Instar. Bottom right: Adult fruit spotting bug. Photos courtesy of Peter Chew, Brisbane Insects.

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).

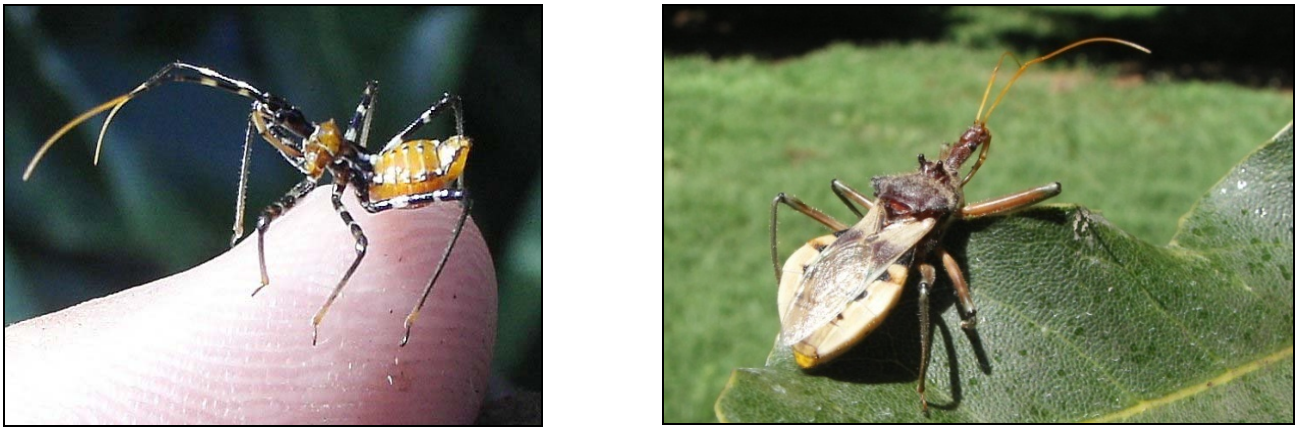


Plate 7. Left: Assassin bug nymph. Right: Assassin bug adult. These are natural enemies of caterpillars.

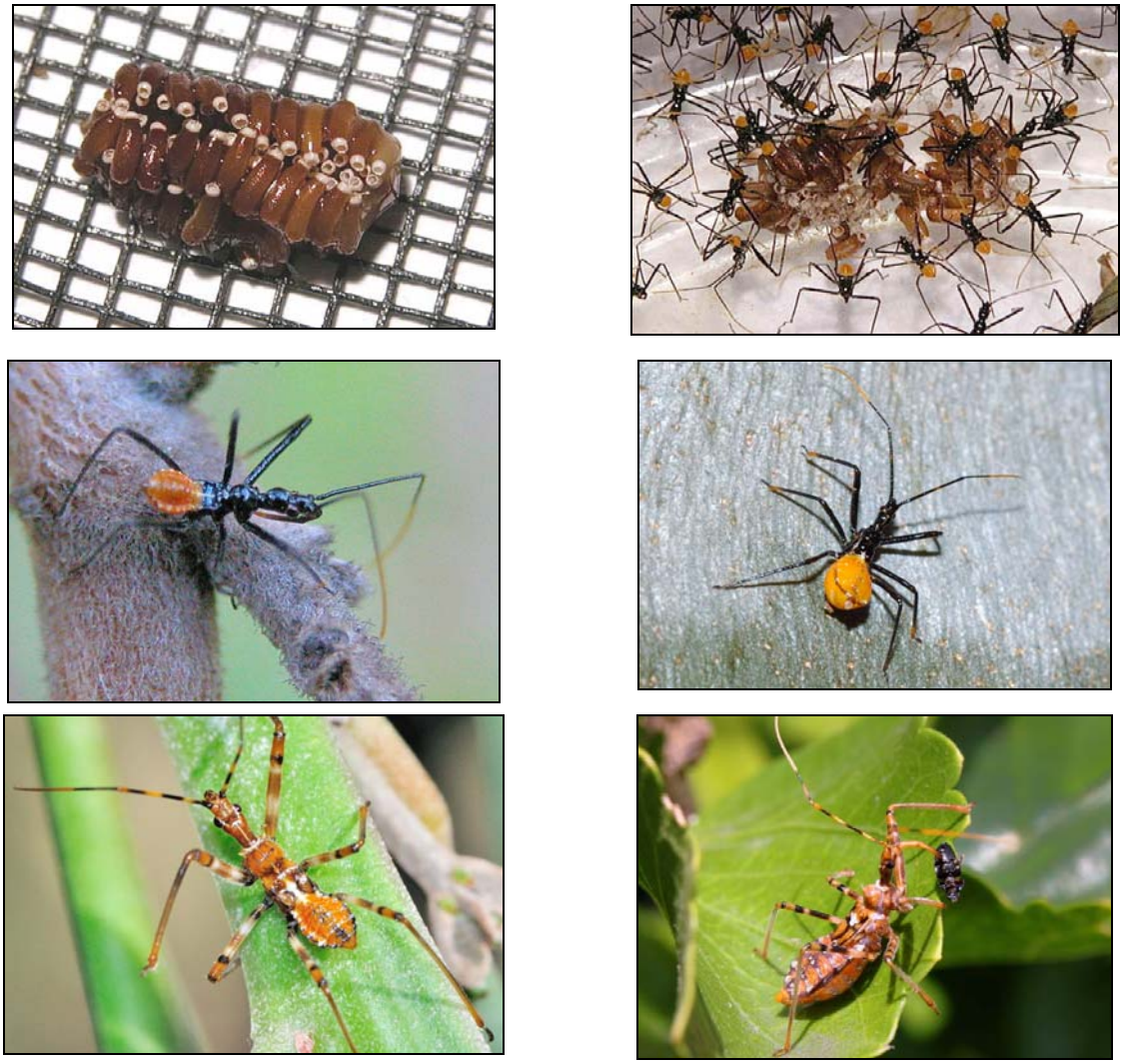


Plate 8. Top left: Eggs of assassin bug. Top right: 1st Instar. Middle left: 2nd instar. Middle right: third instar. Bottom left: 5th Instar. Bottom right: Adult assassin bug. Photos courtesy of Peter Chew, Brisbane Insects.

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 custard apple.

- 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

4.1.3 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).

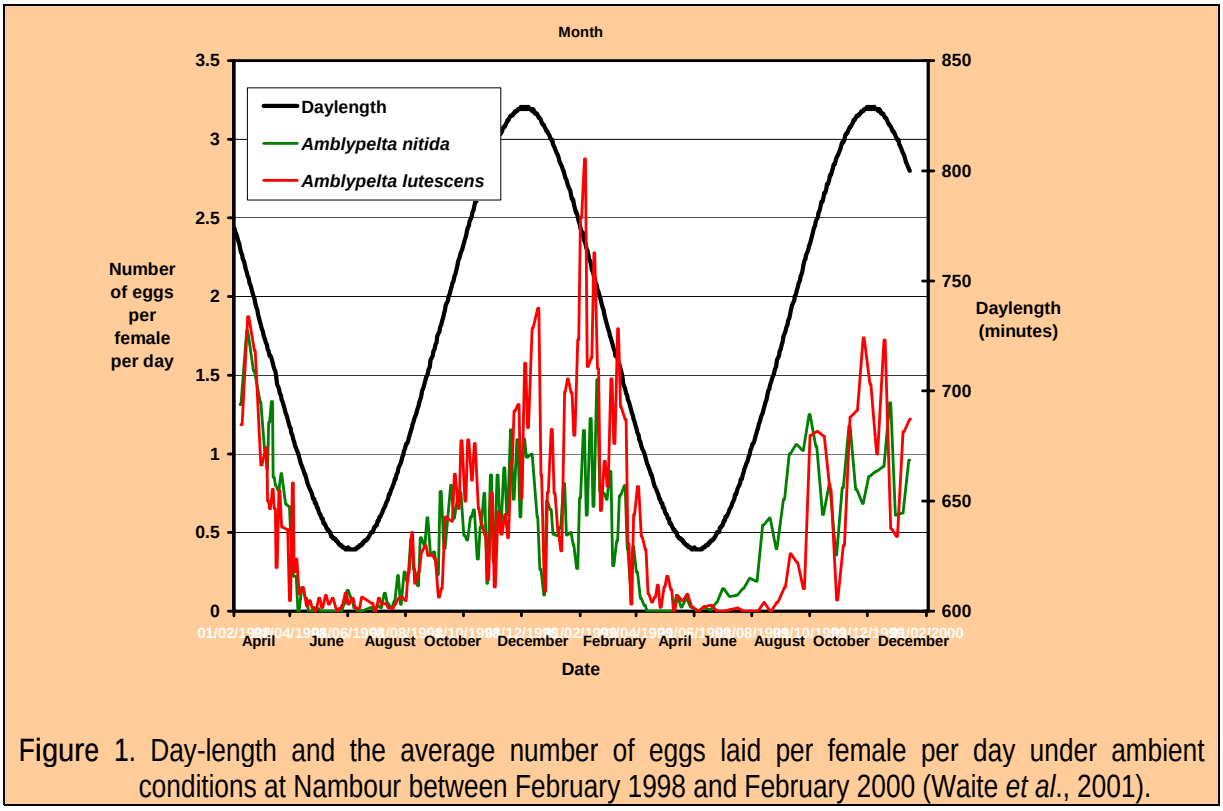


Figure 1. Day-length and the average number of eggs laid per female per day under ambient conditions at Nambour between February 1998 and February 2000 (Waite *et al*., 2001).

4.1.4 Importance and distribution

Both the banana spotting bug (*Amblypelta lutescens lutescens*) and the fruit spotting bug (*Amblypelta nitida*) are problems 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, and the damage can often be insidious when 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. The *Annona* species, *Annona cherimola* (cherimoya), seems to be much more attractive to the bugs than are Annona species hybrids. Within the hyybrids 'African Pride' appears to be more attractive than 'KJ Pinks '.

4.1.5 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.

4.1.5.1 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".

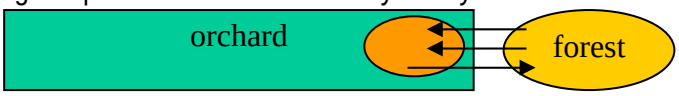
4.1.5.2 Hot spots

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 hotspots 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.

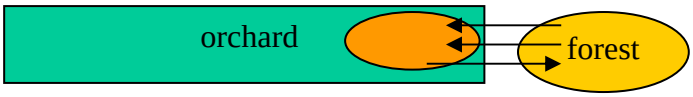


Figure 2: Development of hotspots in orchards

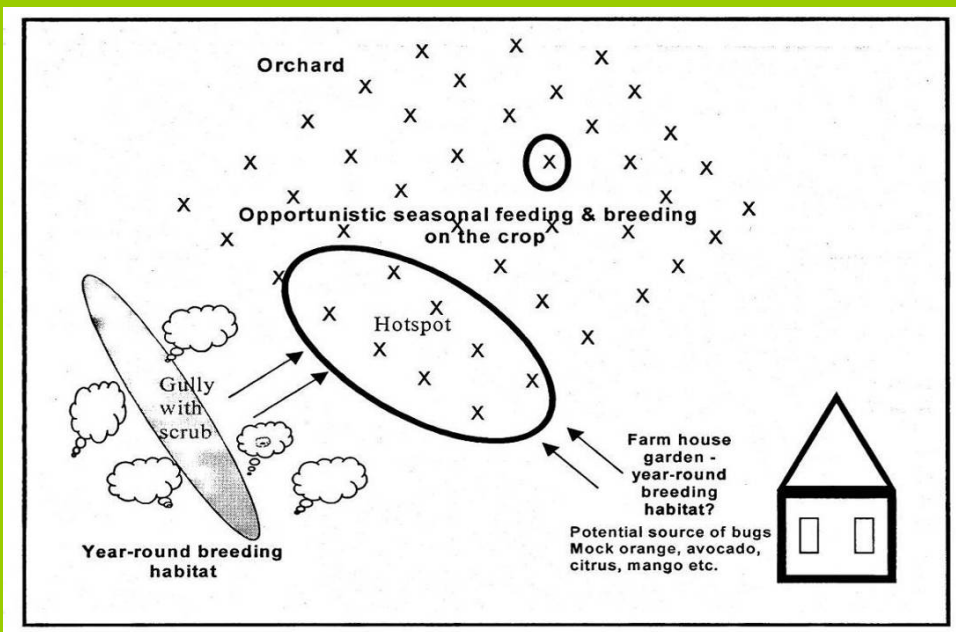


Figure 3. Schematic illustration of where hotspots normally occur.

4.1.5.3 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.

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 hotspots. However, be aware that if individual blocks of trees are very small (less than 1 ha), the whole planting may quickly become one big hotspot.

4.1.5.4 Hot spot spraying

Once hotspots 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 hotspots can change over seasons, but the 'hottest' hotspots are likely to be downwind from rich alternate habitat. So 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 hotspot 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.

4.1.5.5 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 custard apples, but is standard practice for fruit spotting bugs in the macadamia industry. There are two main reasons for this:

1. Monitoring in avocados and custard apples 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.*

4.1.5.6 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 custard apples (Tables 1 and 2).

TABLE 1.

Example 1. Data from a custard apple 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 a custard apple 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.

4.1.6 Chemical control

4.1.6.1 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 should be sprayed first. By spraying "hot spots" instead of the whole orchard would be more beneficial when predators are released.

4.1.6.2 Registered insecticides

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Currently the only insecticide registered for controlling fruit spotting bug in custard apple is methidathion (e.g. Supracide®). It provides adequate control of the pests and 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 e.g. Mareeba, spraying will have to commence earlier (September) compared with cooler regions e.g. Alstonville (December). Under high pressure situations, sprays may need to be applied every two weeks for several months.

A minor use permit for control of spotting bug on custard apple has been issued (permit number – PER80374). Apply only when monitoring of the crop indicates that the pest is present in sufficient numbers to cause economic damage. DO NOT apply more than four (4) applications per year with a minimum of 21 days between consecutive sprays. DO NOT use at flowering.

4.1.6.3 Alternative insecticides under test

Two insecticides used to control fruit spotting bug in avocado are the synthetic pyrethroid, beta-cyfluthrin, (Bulldock®), and trichlorfon (Lepidex®). Neither insecticide is currently registed for use on custard apple. Preliminary studies suggest that Bulldock® may be more effective than Lepidex® due to its longer residual effect.

4.1.6.4 Spray volumes

For large trees, growers may need to spray between 2000-5000 litres per hectare because at lower rates (<1000 litres) fruit spotting bugs simply move to parts of the tree not sprayed effectively.

4.1.7 Biological control

4.1.7.1 Predators

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

- ants (found in good numbers in macadamia farms) (Plate 9)
- spiders (a significant predator in avocados)
- 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 commercially reared but no longer. 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.

4.1.7.2 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.

4.1.7.3 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.

4.1.7.4 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.

4.1.8 Orchard management strategies

4.1.8.1 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.

4.1.8.2 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 grower has indicated that there is considerably less damage on trellised trees. Trellising also improves spray

penetration. However, hotspot studies suggest that orchard location is the most important factor and changes to canopy structure would likely have only a small effect.

4.1.8.3 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 custard apples, 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.

4.1.8.4 Physical barriers on the 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 in avocados.

Surround®, seems to provide some protection from the bugs, and provides protection for those fruit that might suffer from sunburn. Beneficial effects on avocado fruit quality have also been noted.

4.1.8.5 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 would be of little use in custard apples, with their protracted flowering.

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 custard apples.

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.

4.1.8.6 Host plant volatiles and pheromones

Dr Harry Fay and his team from DEEDI 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.

4.2 MEALYBUGS

4.2.1 Damage

Mealybug infestation occurs in fruit crevices (Plate 12). 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. Fruit touching the ground is often covered with tunnels of dirt from ant activity.

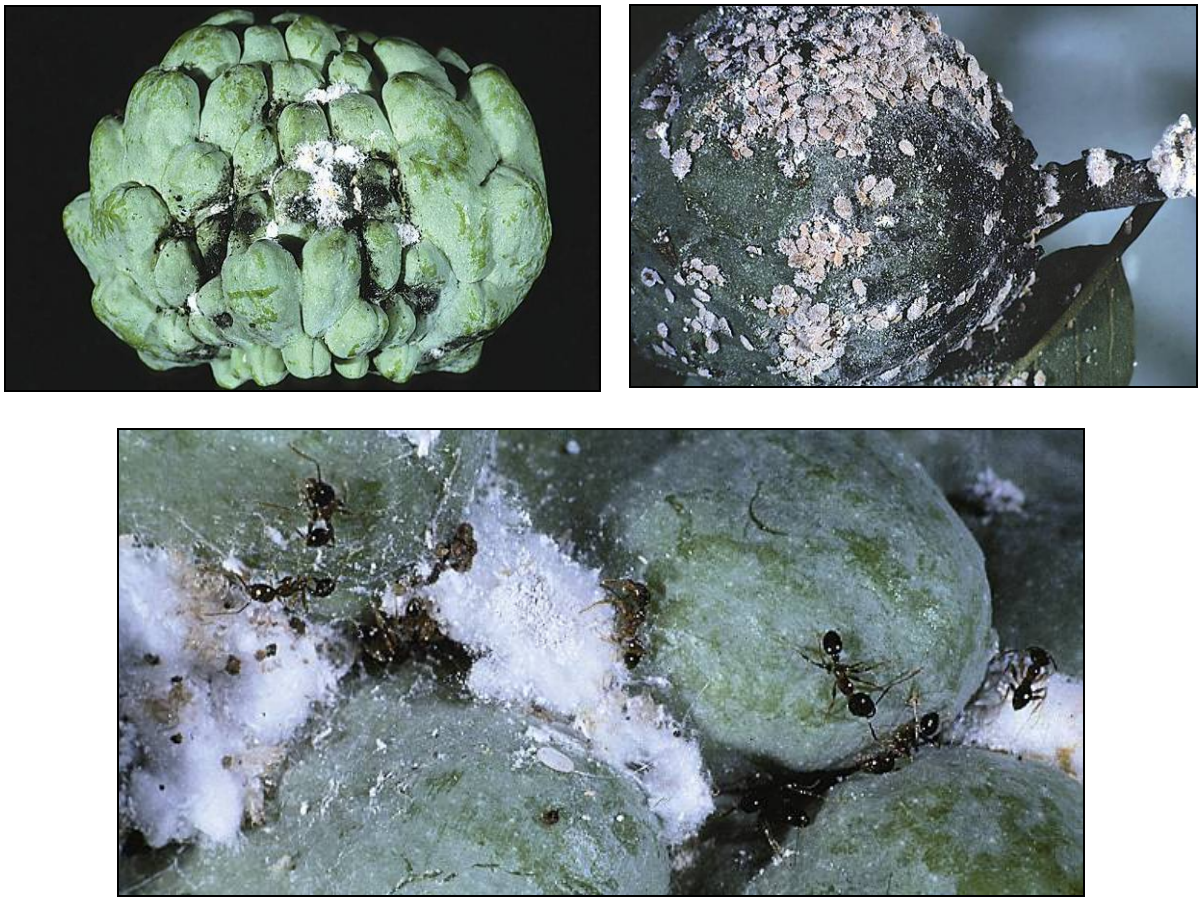

Plate 12. Top: Typical appearance of mealybug in fruit crevices. Bottom: coastal brown ant tends the mealybug for honeydew.

4.2.2 Species and description

Citrus mealybug *(Planococcus citri).* 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.

4.2.3 Life cycle

During summer, the life cycle of the mealybug takes about 4-6 weeks (Figure 4). In Queensland, there are about 6 generations of the mealybug per season whilst in NSW 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.

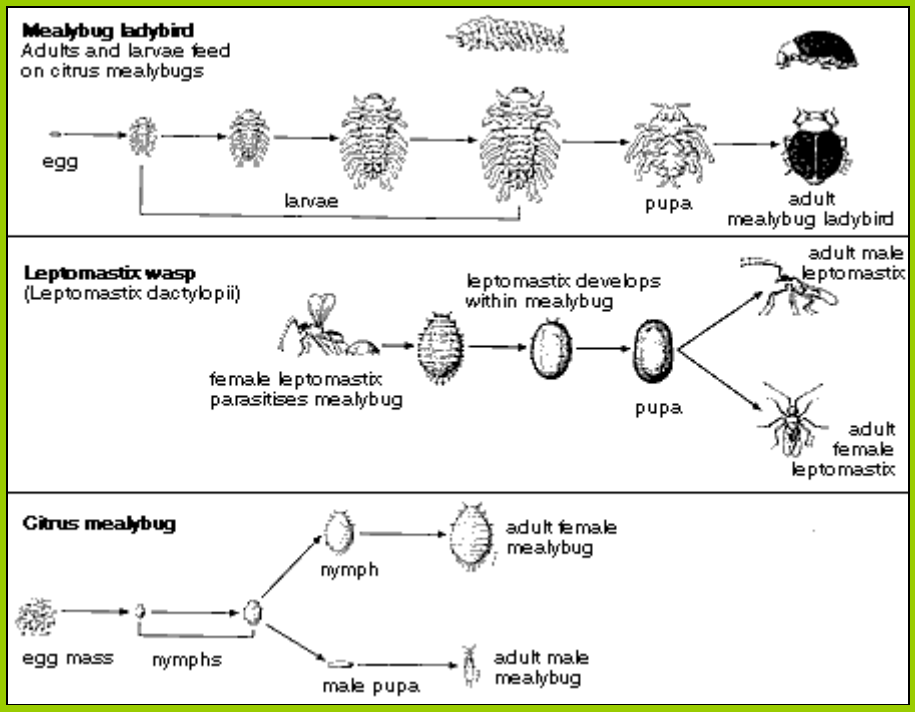

Figure 4. Lifecycle of the citrus mealybug, of the parasitic leptomastix wasp and the predatory mealybug ladybird.

4.2.4 Importance and distribution

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 5). 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 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.

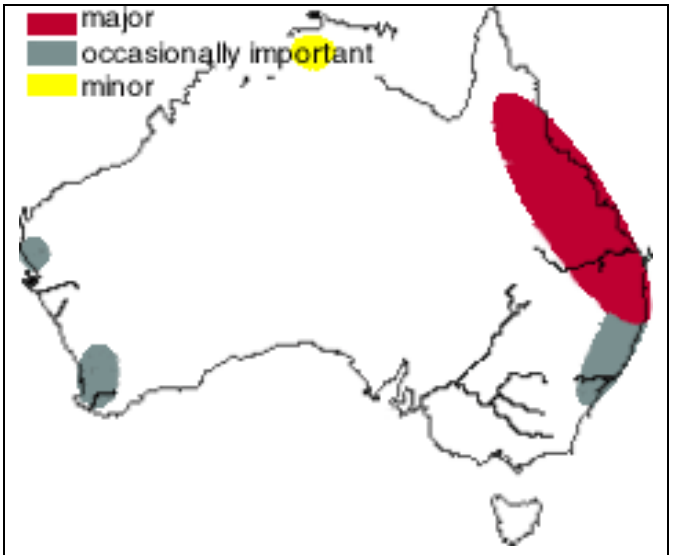

Figure 5. Distribution of citrus mealybug in Australia.

4.2.5 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 a x 10 hand lens will also help.

To monitor the population of citrus 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.

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 April to July). Action involves either releasing Leptomastix wasps or spraying with an appropriate chemical.

4.2.6 Chemical control

4.2.6.1 Clothianidin (Samurai)

A minor use permit for the use of Samurai (clothianidin) has been issued for control of mealybug in custard apple (permit number – PER14894).
Apply as a soil drench application at early flowering and vegetative flush stages.
DO NOT apply after petal fall.
Apply in 1 L water to the soil around the base of the tree.
DO NOT apply more than one (1) application per custard apple block per season.

The effectiveness of mealybug control will depend on the rate and extent that the chemical is taken up by the root system. It is important to achieve thorough drench coverage around the trunk to a distance of 15 cm from the trunk.
Ensure the diluent penetrates the soil around the trunk base and does not run-off. In the event of no rainfall immediately following drench application, irrigation is recommended to take the chemical into the tree root zone.
The higher rate will provide longer residual control. Control may be achieved during the season of application. It is, however, recommended that trees with infestations in autumn are marked and then re-treated during the following season.
Remove trash and weeds from the application zone prior to drench application.

4.2.6.2 Sulfoxaflor (Transform)

A minor use permit for the use of Transform (sulfoxaflor) has been issued for control of mealybug in custard apple (permit number – PER14905).
Apply during fruit development when monitoring indicates mealybugs are at high levels.
Apply a maximum of two (2) foliar applications per custard apple block per season, with a 14 day re-treatment interval between consecutive sprays.

4.2.6.3 Imidacloprid (Confidor)

A minor use permit for the use of Confidor (imidacloprid) has been issued for control of mealybug in custard apple (permit number – PER14905).
Apply as a foliar spray. DO NOT exceed a maximum of two (2) applications per crop with a minimum interval of 14 days between consecutive applications.

4.2.6.4 Parafinnic oils

For cooler subtropical regions, high grade parafinnic oils such as Biopest® and Bioclear® can be sprayed throughout the season except during the hottest summer months when temperatures exceed 28°C. The most commonly used oil spray used throughout the season is Biopest oil®. It is a highly refined food-grade iso-paraffinic oil formulation. It is applied at rates from 1-2L/100L. Use the lowest rate during hot weather. The manufacturers recommend that trees be sprayed with Biopest oil® no more than four times during the growing season with two weeks minimum application interval. Biopest oil® also has anti-fungal activity. They recommend that sprays should not be applied when buds are fully opened and shoot elongation is occurring. Stressed trees should not be sprayed. Avoid spraying when temperatures exceed 28°C and when humidities exceed 80%.

4.2.6.5 Methidathion (e.g. Supracide®)

Methidathion is the most commonly used insecticide to control mealybugs in custard apple orchards. Scheduled insecticide spraying of methidathion may fail to give adequate control due to poor coverage in densely foliaged trees. On older trees mealybugs can hide in the bark crevices and also where fruit touch leaves. It may be necessary to spray inside the tree by hand-wand to be effective but this is time consuming, tedious and dangerous for the operator. Timing of methidathion application may need to be adjusted depending on whether beneficials are released. Growers must decide whether to spray or not to spray with methidathion in

December to 'knock' the mealybug population down but still allow enough spray interval before releasing the predators.

4.2.6.6 Buprofezin (Applaud®)

The insecticide Applaud® has recently been registered for use in custard apple. 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.

The target species in custard apple are scales and mealybug. Applaud® is registered for use in other crops including citrus, grape, pear, persimmon, passionfruit, and mango against scale insects and mealybug. It is also effective against citrus leafhopper and whiteflies in various crops.

Applaud®, because it only kills juvenile insects when they moult, is best applied when crawlers and young juvenile stages of the target pest are abundant, before too many adults are present as these will not be killed. The effects may take up to two weeks to become apparent, unlike knockdown insecticides, which kill pests very quickly. Applaud is not effective if it is applied when there are mixtures of crawlers and adults.

In custard apple, Applaud® is recommended at 30-60 mL per 100 litres of water for dilute spraying at about 1 500 litres per hectare. Concentrate spraying tank mixing instructions are given on the label.

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 21 days later may be required. It is compatible with Dithane Rainshield® fungicide, but is not compatible with Biopest oil® or highly acidic or alkaline products.

Due to the label restrictions, Applaud® should not be applied within 60 days before release of predators i.e. Cryptolaemus which means spraying from late October to early December (normally November) when there is no apparent mealy bug activity. It has been suggested that the 60 days period could be shortened considerably. 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 early spring, when mealybug crawlers are just starting to become active and before *Cryptolaemus* numbers build up. The withholding period for Applaud® is 14 days.

There are a number of species of parasites and predators which make a vital contribution to controlling pests of custard apple, 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.

Crustaceans can be affected, so contamination of waterways should be avoided, and, importantly, animals should not be grazed in treated orchards.

Think carefully about the timing of Applaud® in your custard apple 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.

4.2.6.7 Chemical control of ants

If ants can be properly managed, populations of scales and mealy bug can be reduced by 80%. Ants move pests around on the trees, but more importantly prevent natural parasites and predators from controlling pests. Removing ants allow the parasites and predators to do their job. Control ants in December and, if necessary, again later in the season by spraying the lower trunk and the soil within a 0.5 m radius with a registered ant control spray (also see Section 4.3).

A minor use permit for the use of fipronil has been issued for control of ants in custard apple (permit number – PER14491).
DO NOT spray foliage or developing fruit directly or through spray drift. Applications may only be undertaken in situations where direct contact will not occur with tree foliage or the crop.
Prune tree skirt to provide adequate clearance from ground level. Use hand-held applicators only from trailer-mounted or back-mounted spray equipment. Apply as butt treatment and as a protective radial band treatment within 1.5 m circumference of tree trunks.
Apply to the surface of nests and as a radial band (soil drench) treatment up 1 m from nest extremities. This method should be minimised to the extent possible. Apply a maximum of 2 applications per crop. Allow a minimum of 14 days between consecutive applications.

Currently, no permission has been given by the Australian Pesticides and Veterinary Medicines Authority (APVMA) for growers to mix their own ant baits containing the insecticide fipronil. (Also see Section 4.3 on ants and their control)

4.2.7 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 lutes*). 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.

4.2.7.1 Leptomastix wasp

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

Leptomastix wasps, because they originated in Brazil, 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 13). 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. Their populations usually decline to very low levels over winter in south-east Queensland, necessitating augmentative releases in spring when mealybug numbers are on the increase. Leptomastix wasps survive Queensland's winters but 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. All wasps may be released at once or divided into two or three releases. Release the wasps throughout the orchard, not just in one section.

Once wasps are released, be careful with the use of insecticide sprays 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.

This parasitic wasp is sold by Bug for Bugs Ltd.

Release strategy

Spray or release Leptomastix wasps when:

- more than 25% of fruit (50 fruit out of the 200 inspected) have one or more large mealybugs present
- less than 20% of mealybug infested fruit (40 fruit out of the 200 inspected) show no sign of natural enemies.

Plate 13. Adult and pupae of *Leptomastix dactylopii.*

Leptomastix are supplied in tubes of 100 adult wasps *(from Bugs for Bugs website)*. Release by opening tubes near mealybug infestations. The wasps will soon seek out suitable mealybugs into which to lay their eggs. Aim for 7,500 wasps per hectare as three releases of 2 500 per hectare at intervals of two weeks.

4.2.7.2 Cryptolaemus ladybird

The most effective natural enemy of mealybug is *Cryptolaemus montrouzieri*, but it can be slow in colonizing an orchard and fruit can become heavily infested and blackened before the predator gives control. *Cryptolaemus montrouzieri* commonly known as the Cryptolaemus ladybird or Cryptolaemus, does an excellent job of controlling mealybug populations if released early enough. 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 14). It is similar in size and shape to other species of ladybirds. 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. Its life cycle takes about four weeks.

Plate 14. Left: Adults of the mealybug ladybird (*Cryptolaemus montrouzier*). Right: white cottony larvae. The larvae resembles mealybug but when mature is much larger.

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.
- Releases should be made in blocks with the most advanced fruit as these fruit are almost always the first infested. Concentrating releases in 'hot spots' makes good sense.
- Released beetles spread but do tend to settle where released, if there are mealybugs there for them to feed on.
- Establishing the beetle early in the most mature (and infested) block on the farm will serve as a rearing site for the rest of the farm.
- Releases on small fruit in December run the risk of failing as beetles fly off to better food sources. Late 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 10 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 very sunny.

After release, it may take 6-8 weeks to bring the mealybug under control (Table 3, Figure 6).

TABLE 3.

Mealybug and ladybird beetle populations in eight custard apple blocks at Glasshouse Mountains, Queensland, 2003 (Smith, 2003). Note drop in mealybug numbers after release of ladybirds.

Grower	No. of beetles released per tree	Mealybugs per fruit			C. montrouziera per fruit	
		start	peak no.	at harvest	adults (peak)	larvae (peak)
Grower 1	25	3.5	3.5	0.3	0.6	17.2
Grower 1	0	2.0	3.5	3.5	0.02	0.02
Grower 2	25	18.8	20.0	0.1	0.8	22.8
Grower 2	25	4.1	4.2	0.5	1.7	14.2
Grower 2	5	9.8	12.0	0.25	0.4	9.9
Grower 3	25	19.6	25	0.1	0.85	13.3
Grower 4	25	30.0	30.0	1.5	0.05	2.6
Grower 5	5	3.5	14.0	14.0	0.1	0.9

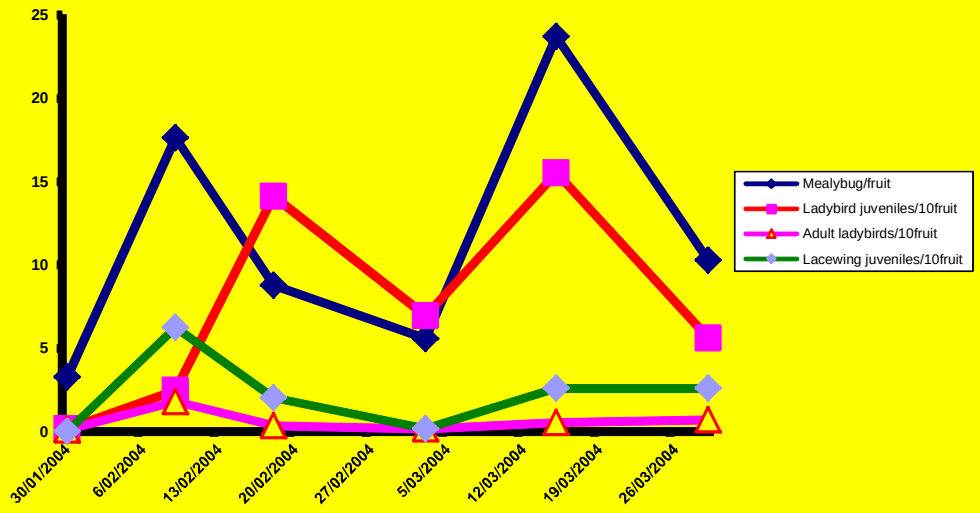

Figure 6. Mealybug ladybird (*Cryptolaemus montrouzier*) reduces mealybug population in a commercial custard apple orchard after release but there was a delay in reducing the mealybug population. *(Smith, 2003)*

4.2.7.3 Lacewings

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 15). 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
- Larvae of the green lacewing are wide-

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 15. 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 16). 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 16. Lacewing release box allows larvae easy access to the host plant (Photo: Dan Papacek, Bugs for Bugs).

4.2.7.4 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 17). 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 custard apple but is not thought, to be as effective as Cryptolaemus or Leptomastix.

Plate 17. *Anagyrus agraensis* a parasite of mealybugs.

4.2.7.5 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 on custard apple. The fragile adult flies (Plate 18), 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 17), often in large numbers, and it is from these that the adults emerge to mate and continue their life cycle.

4.2.7.6 Other beneficials

Other beneficials reducing mealbug numbers include tree frogs and spiders.

4.2.8 Orchard management strategies

4.2.8.1 Control ant movement and populations (see Section 4.3)

4.2.8.2 Skirting

Trim lower branches up off the ground in winter and again in mid-summer (Plate 19) to reduce ant access to the fruit.

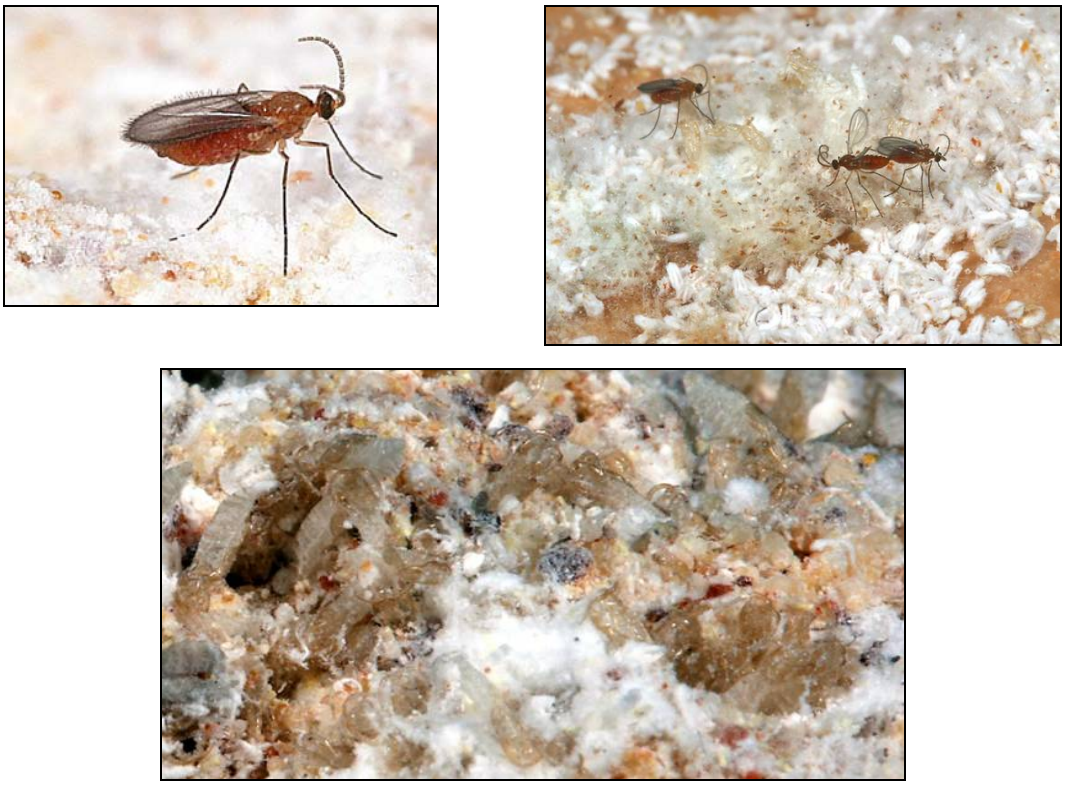

Plate 18. Top left: Adult predatory *Diadiplosis* midge sitting on mealybugs. Top right: Mating adult midges - shows the empty, light brown pupal cases from which the midges emerge - Note that this is not mealybug in the background, but a scale. Bottom: Close-up of numerous light brown and grey pupal cases from which the adult *Diadiplosis* midges have emerged, amongst dead mealy bugs.

Plate 19. Tree skirted to prevent ant movement into the tree.

4.2.8.3 Brushing of fruit

While brushing or using pressurised air (Plate 20) 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 mould will usually result in downgrading of the fruit after harvest.

Plate 20. Compressed air used to remove mealybugs.

4.3 ANTS

4.3.1 Damage

Mealybugs and scale

Custard apples are very susceptible to mealybug and scale infestation (Plate 21). Infestation occurs in fruit crevices. 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 NSW 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.

Plate 21. Typical appearance of mealybug in fruit crevices. Coastal brown ants tend the mealybug for honeydew.

Honeydew

Honeydew secreted by mealybugs and scale is a favoured food source for several common ant species. Ants entering custard apple 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 21, 22 and 23).

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 custard apple 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 22. An ant searching for honeydew produced by green coffee scale.

Plate 23. 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%.

4.3.2 Species and description

There are many local and introduced species of ants in Australia. The main species affecting custard apple are the coastal brown ant (*Pheidole megacephala*) and the black house ant (*Iridomyrex glaber*) (Plate 24). 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 25). 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 24. Left: Coastal brown ants (*Pheidole megacephala*) minor and seed crushing workers. Right: black house ant (*Iridomyrex glaber*)

4.3.3 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 25. Ants nest at the base of a fruit tree.

4.3.4 Importance and distribution

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 (Plates 20 and 21). This honeydew is a favoured food source for several common ant species. Ants entering custard apple 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.

4.3.5 Monitoring

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

4.3.5.1 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.

4.3.6 Chemical control

4.3.6.1 Ground sprays

Chlorpyrifos (Lorsban®) – QLD only
Ground sprays of chlorpyrifos (Lorsban®) (500g/L), which are normally applied around the trunk of the tree, are currently registered for control of ants in Queensland but not NSW. They last only a short time (about 4 to 6 weeks) and subterranean colonies generally survive and rapidly return to pre-treatment levels. The product is mixed at a rate of 200ml to 2.0L/100L with 1000L of mixture applied per hectare. Control studies in California have shown much more effective control of ants at the higher concentrations.

The first sprays are normally applied in December and, if necessary, again later in the season by spraying the lower trunk and the soil within a 0.5 m radius. Timing of application is crucial because most ant populations are at a low by the end of winter. Treatments should be timed just as ants start actively foraging for food in the early spring, before they have had time to start rebuilding colony size. Ant nests are generally concentrated in the raised area beneath the tree, which is warmer.

Spray drift and volatilisation from ground sprays may also harm beneficial insects within the tree canopies.

Fipronil (Regent®) - NSW, QLD, SA, WA, ACT, NT
A minor use permit has been recently granted by the Australian Pesticides and Veterinary Medicines Authority (APVMA) for using fipronil to control of ants in custard apple orchards. (Permit number – PER14491). The permit is active until 30 June 2013. This will allow growers to use products containing: 200 g/L fipronil as their only active constituent. These products include:

- Cropcare Legion 200sc insecticide
- Nufarm Regent 200sc insecticide
- plus all other registered products

Application rate is 12.5 mL product per 100 L water. Fipronil is an expensive product costing about $420 per litre. Therefore it is essential that its efficacy in controlling ants in the orchard be carefully monitored (see section on monitoring)

Mode of action
Besides killing the ants directly, ants tunnelling in the outer reaches of a fipronil (lower concentration) treated soil area, cannot detect the fipronil chemical which readily sticks to the ants body. These ants remain unaffected for a few days, before sudden death occurs. This delayed lethal effect provides enough time for the fipronil chemical to be transferred back to the central colony nest to infect other ants. The "carrier" ants are able to readily spread the fipronil chemical to other ants during regular physical contact with other ants in the colony, particularly when working together in close proximity, grooming and feeding other ants, a regular function of their daily life. Ants cannot detect the fipronil chemical as it has virtually no odour, taste or smell to the ants. Ants cannibalize or carry away dead ants killed by the fipronil on their bodies, further spreading fipronil's deadly effect to other ant colony members.

APVMA permit conditions for application of fipronil in custard apple orchards:

- DO NOT spray foliage or developing fruit directly or through spray drift. Applications may only be undertaken in situations where direct contact will not occur with tree foliage or the crop. Prune tree skirt to provide adequate clearance from ground level.
- Use hand-held applicators only from trailer-mounted or back-mounted spray equipment.
- Apply as butt treatment and as a protective radial band treatment within 1.5 m circumference of tree trunks.
- Apply to the surface of nests and as a radial band (soil drench) treatment up 1 m from nest extremities. This method should be minimised to the extent possible.
- Apply a maximum of 2 applications per crop.
- Allow a minimum of 14 days between consecutive applications.
- DO NOT contaminate streams, rivers or waterways.
- Potential for spray drift and run-off to aquatic areas should be avoided by spraying under suitable weather conditions and not applying when heavy rain.
- Dangerous to bees. DO NOT apply to areas where crops, weeds or pasture are in flower at time of application, or are expected to be in flower in the next 28 days.

Withholding Period:
Grazing: DO NOT graze or cut treated plant material for stock food.

Jurisdiction:
NSW, QLD, SA, WA, ACT, NT
(Note: Victoria is not included in this permit because their 'control-of-use' legislation means that a permit is not required to legalise this off-label use in Victoria).

4.3.6.2 Baits

Ant baits are prepared by incorporating a chemical into a food source known to be attractive to that particular species of ant. Baiting is generally more effective than the application of insecticide sprays as the bait is carried back to the nest by worker ants and the whole colony is destroyed. Most of the new ant baits contain fipronil. Currently, no permits have been granted by the APVMA for growers to either mix their own ant baits containing the insecticide fipronil or to apply them in custard apple orchards.

4.3.6.3 Sticky bands

Sticky bands are applied to the base of the tree to prevent ant movement up the tree (Plates 26 and 27). 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 is 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.

4.3.7 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 custard apple in Australia.

Plate 26. Stick gels applied to the trunk of custard apple trees. 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 27. Stick band trap to prevent ant movement into the tree.

4.4 NIGRA SCALE

4.4.1 Damage

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

4.4.2 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 28 and 29). Younger stages are light brown. The scale surface is smooth.

Other minor scales that can occur on custard apples are long soft scale (*Coccus hesperidum*) (Plate 25), black scale (*Saissetia olea*) and the rosette lac scale (*Tachardia decorella*). These latter species can be controlled through similar methods used for Nigra scale.

4.4.3 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.

4.4.4 Importance and distribution

Nigra scale attacks custard apple, guava, avocado and hibiscus. It can become a major pest of custard apple. Distribution in Australia is presented in Figure 7.

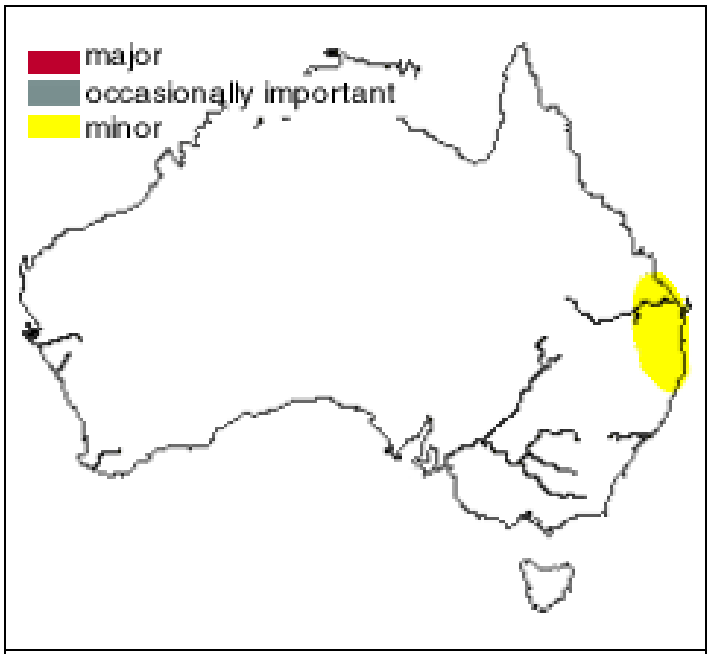

Figure 7. Importance and distribution of Nigra scale.

4.4.5 Monitoring

Regularly monitor pest levels during the season so that appropriate treatments can be applied before the problem gets too severe. Minimise spraying because it kills the natural enemies of Nigra scale.

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

4.4.6 Chemical control

Where required, spray with an appropriate chemical such as methidathion e.g. Supracide®. Spot spraying of infested trees is recommended.

Control of ant movement will greatly reduce the problem (See Section 4.3).

Plate 28. Nigra scale and associated sooty mould on a shoot.

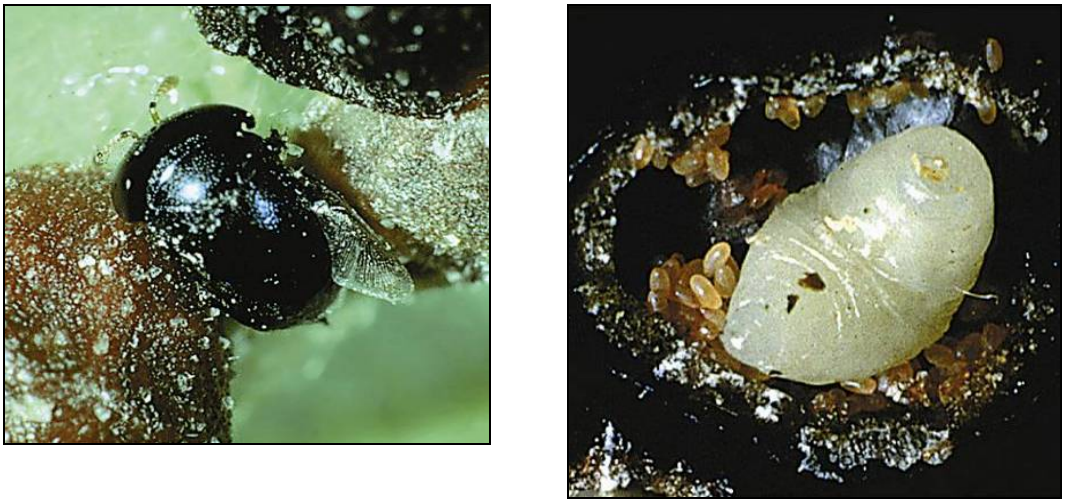

Plate 29. Left: Scale parasite *Scutellista cyanea* adult. Right: Larvae on upturned scale.

4.4.7 Biological control

The most common parasite of Nigra scale is the wasp *Scutellista caerulea* (Plate 30). The fungus *Verticillum lecanii* commonly attacks Nigra scale in wet weather during the summer-autumn (Plate 31).

Ladybirds such as the *Cryptolaemus montrouziera* (see section on mealybugs) and the larva of the moth *Catoblemma dubia* (Plate 32) also preys on Nigra scale.

Plate 30. 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 31. Nigra scale infected with the fungus *Verticillium lecanii*.

Plate 32. Moth *Catoblemna dubia* produces a scale eating caterpillar that feeds on scale.

4.4.8 Orchard management strategies

Control strategies are similar to mealybug (see Section 4.2.8).

4.5 GREEN COFFEE SCALE

4.5.1 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.

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

4.5.2 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 33).

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 33. Green coffee scale along leaf midrib.

4.5.3 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.

4.5.4 Importance and distribution

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.

Figure 8. Importance and distribution of Green Coffee scale.

4.5.5 Monitoring

Green Coffee scale occurs on custard apple varieties in north Queensland. The pest and its natural enemies should be monitored from mid-October onwards. Using a x 10 hand lens, check 5 randomly selected green laterals per tree. There will be a problem with sooty mould if 5% or more of laterals are infested with one or more scales.

4.5.6 Chemical control

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

4.5.7 Biological control

4.5.7.1 Parasites

One or two small parasitic wasps, e.g. *Coccophagus ceroplastae* and *Euryischomyia flavithorax* periodically parasitise this scale causing significant mortality (Plate 34 and 35).

The Kenyan wasp *Diversinervus stramineus* has been established in Australia.

4.5.7.2 Predators

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

Plate 34. 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 35. The wasp, *Coccophagus* spp., a parasite of Green Coffee scale.

4.5.7.3 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 36).

Plate 36. The fungus *Verticillium lecanii* on Green Coffee scale.

4.5.8 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 4.2.8 and 4.3).

4.6 LONG SOFT SCALE

4.6.1 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.

4.6.2 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 37).

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 37. Long soft scale adults and nymphs.

4.6.3 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.

4.6.4 Importance and distribution

Long Soft scale is distributed worldwide. Long Soft scale occurs on a wide range of hosts, including custard apple, lychee, carambola, fig, leucaena, and many ornamentals.

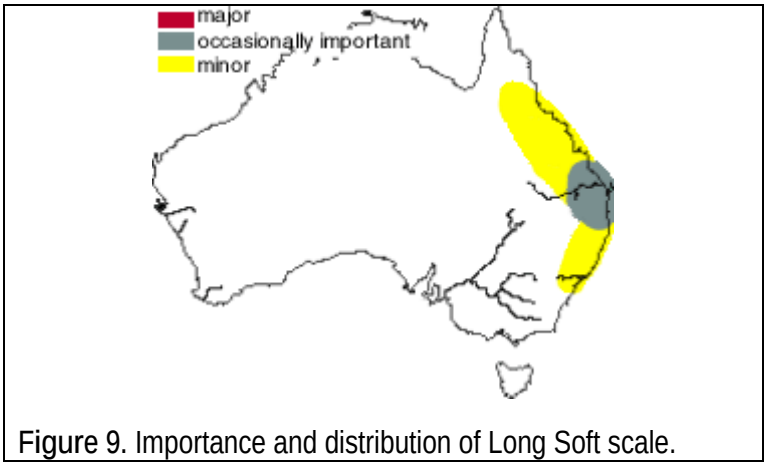

Figure 9. Importance and distribution of Long Soft scale.

4.6.5 Monitoring

The pest and its natural enemies should be monitored during early to late summer. Using a x 10 hand lens, check 5 randomly selected green laterals per tree. There will be a problem with sooty mould if 5% or more of laterals are infested with one or more scales.

4.6.6 Chemical control

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

4.6.7 Biological control

4.6.7.1 Parasites

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

4.6.7.2 Predators

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

4.6.7.2 Pathogens

During prolonged wet weather, the fungus *Verticillium lecanii* can kill many Long Soft scales (Plate 38).

Plate 38. 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

4.6.8 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 4.2.8 and 4.3).

4.7 MUSSEL SCALE (PURPLE SCALE)

4.7.1 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 are often invaded by Citrus Snow scale, and part or the entire limb may die. Infested fruit are difficult to clean.

4.7.2 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 39). 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 39. Mussel scale. Males are thin and females broad. Note the emergence holes made by the small parasitic wasp Aphytis.

4.7.3 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.

4.7.4 Importance and distribution

Mussel scale is found throughout the world. Hosts include custard apple, avocado, eucalyptus, fig, pecan and many ornamental plants. All citrus varieties are attacked, but particularly oranges and grapefruit.

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.

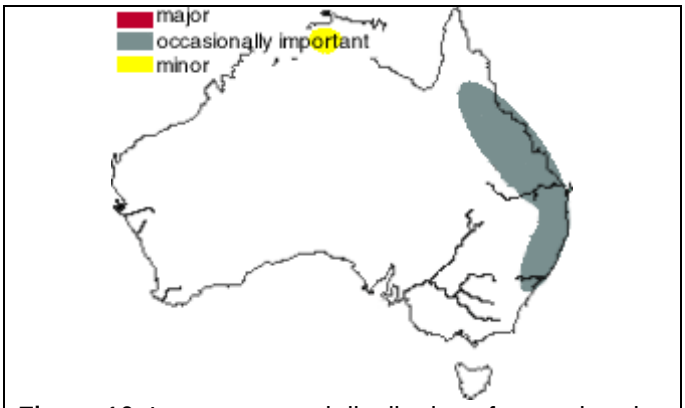

Figure 10. Importance and distribution of mussel scale

4.7.5 Monitoring

The pest and its parasites should be monitored from fruit set until harvest. Using a 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 is required if more than 20% of the fruit are infested with one or more scales.

4.7.6 Chemical control

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

4.7.7 Biological control

4.7.7.1 Parasites

The main parasite of mussel scale is the small yellow wasp *Aphytis lepidosaphes*, which originated in China (Plate 40). It attacks mainly third instar scales, and usually achieves adequate control of the pest.

Plate 40. 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).

4.7.7.2 Predators

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

4.7.7.3 Pathogens

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

4.7.8 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 4.2.8 and 4.3).

4.8 YELLOW PEACH MOTH

4.8.1 Damage

Typical appearance of infestation is the webbed insect frass (droppings) around the entry hole into the fruit (Plate 41).

4.8.2 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. 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 (Plate 41), which have black dots on the wings,

4.8.3 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.

Plate 41. Top: frass on the shoulders of the fruit. Bottom left: larva of Yellow Peach Moth inside fruit. Bottom right: Adult yellow peach 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.

4.8.4 Importance and distribution

The moth attacks the most advanced custard apple fruit (from about 8 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. Cultivars 'Pinks Mammoth' and particularly 'Hillary White' are preferred, with little damage to 'African Pride'.

The pest also breeds on sorghum, and maize and a wide range of fruit crops including citrus, papaw, 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.

4.8.5 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. 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).

4.8.6 Chemical control

4.8.6.1 Methidathion

The normal chemical control is methidathion (Supracide®), but it, and other materials used to date, give poor control, because of the difficulty in penetrating into the fruit where larvae feed. For this reason, it is important to take care with what pesticides are used in the orchard, giving preference to those that are 'softer' on beneficials. This is of course important also for control of other pests like mealybug.

4.8.6.2 Prodigy®

A new insecticide, methoxyfenozide (Prodigy®), is also registered for use against Yellow Peach Moth. Its efficacy as compared with Mimic® is not known but in studies on the control of light brown apple moth it has been shown to be more effective than Mimic®.

Growers should regularly check their biggest fruit from early to late December (depending on district), and at first sign of Yellow Peach Moth attack (small traces of the brown frass), apply the first spray. Further sprays should be applied (not automatically), but when fresh attack is evident.

Spray interval is at least 3 weeks. Spray volume should be sufficient to cover and wet the fruit.

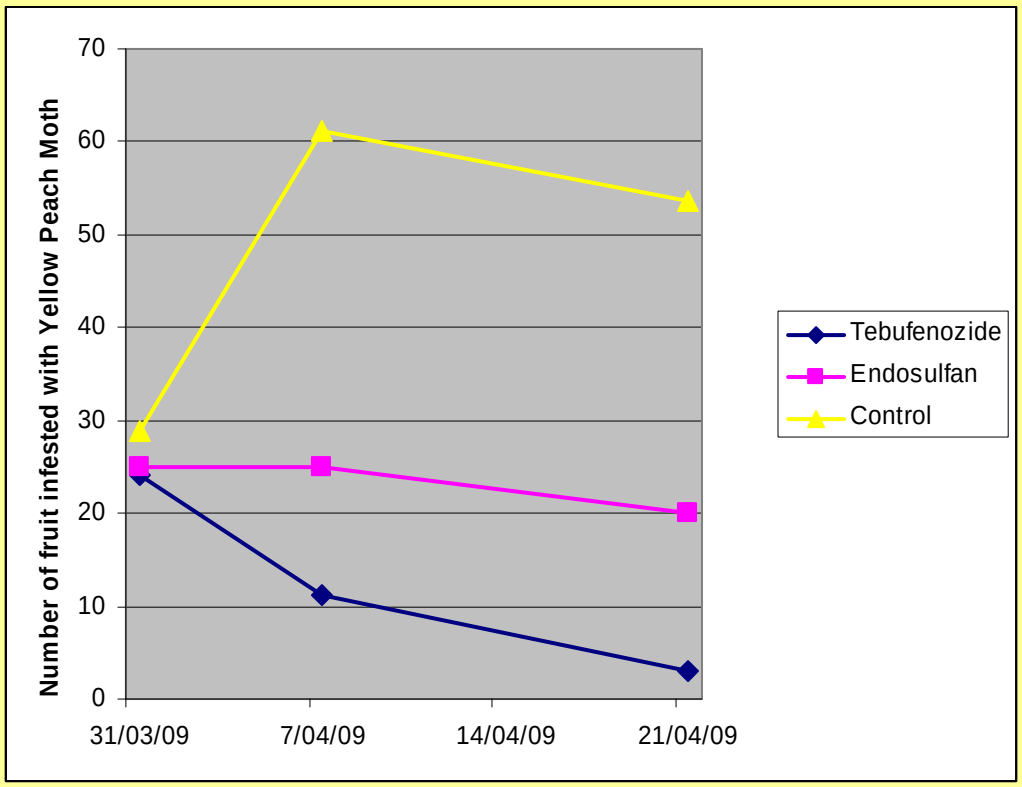

Figure 11. Effects of different insecticides on the activity of Yellow Peach Moth larvae in cv. Pinks Mammoth fruit (Smith, 1999).

4.8.7 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 42).

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

4.8.8 Orchard management strategies

Remove any infested fruit from the orchard and burn or bury it.

4.9 QUEENSLAND FRUIT FLY

4.9.1 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. Egg laying is most common around the stalk end of the fruit particularly in varieties such as African Pride and Palethorpe.

4.9.2 Species and description

Bactrocera tryoni. The adult fruit fly is wasp-like, with an 8 mm long body that is red-brown with yellow marks (Plate 43). 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 43. Top: Queensland Fruit Fly. Bottom left: Larvae (maggots) of the fly in the tissue of the fruit. Bottom right: pupa found in the soil.

4.9.3 Life cycle

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 12). 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.

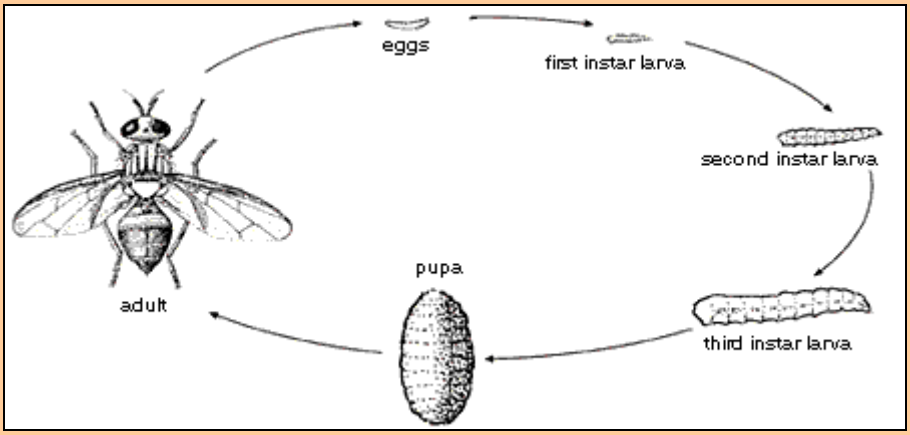

Figure 12. Life cycle of Queensland fruit fly.

4.9.4 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). Our main one 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 custard apple, 'African Pride' is more susceptible to attack than 'Pinks Mammoth' and 'Hillary White'. The custard apple variety 'Palethorpe' appears to be highly susceptible.

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 in Australia is presented in Figure 13.

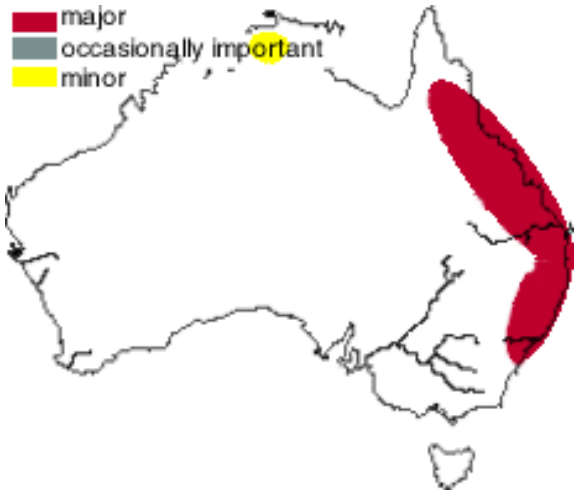

Figure 13. Importance and distribution of Queensland Fruit Fly in Australia.

4.9.5 Monitoring

4.9.5.1 Types of traps

Queensland Fruit Fly larvae is virtually impossible to detect in unripe fruit. Fly activity is monitored by lure traps (Plates 44 and 45). Lure traps attract male flies only. The trap contains a replaceable cotton wick impregnated with a sex attractant (cue lure) and a toxicant. 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, cue-lure traps must

be used in conjunction with weekly insecticide protein sprays, or other control methods such as cover sprays (see section 4.9.6 on chemical control).

Commence placement of traps in the field 6-8 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 trap 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 44. Left: Lure traps, which attract male flies, 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.

Plate 45. Amulet™ cue-lure traps (active constituents: 3.4 g/kg fipronil, 94 g/kg 4-(p-acetoxyphenyl)-2-butanone).

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 northern NSW, replacement should be delayed by about 1 to 2 months.

4.9.5.2 Amulet™ Cue-Lure Stations

Amulet™ Cue-Lure Stations 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. 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 14). Traps have a field life of 3-5 months if hung in permanent shade.

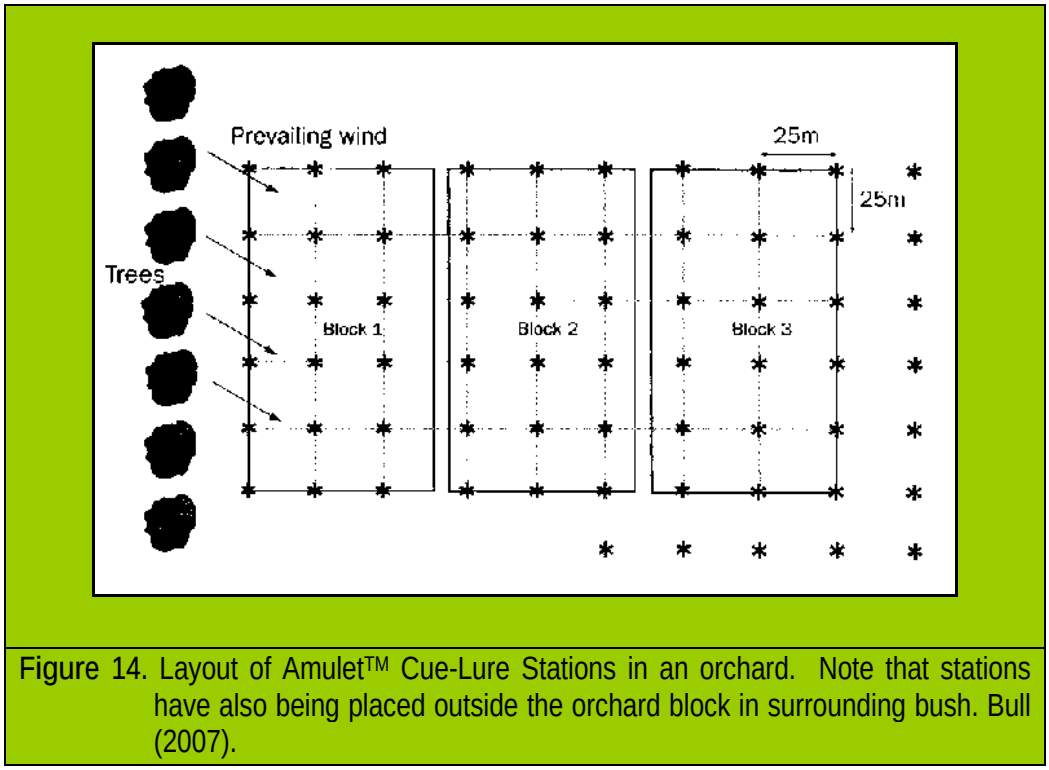

Figure 14. Layout of Amulet™ Cue-Lure Stations in an orchard. Note that stations have also being placed outside the orchard block in surrounding bush. Bull (2007).

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.

4.9.5.3 Modified Steiner traps

The most efficient monitoring traps are those of the Steiner design (Plate 46). 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.

Plate 46. Steiner type fruit fly trap baited with Amulet Cue lure.

4.9.6 Chemical control

4.9.6.1 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 Cue-lure attractant and an insecticide, 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 6-8 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.

4.9.6.2 Standard bait sprays

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. Be more vigilant with cv. 'African Pride' as it is more susceptible. If complying with ICA-18 regulations, apply bait sprays weekly starting six weeks before first harvest and continue until the end of harvest,

The bait spray consists of an insecticide malathion (e.g. Maldison®) or chlorpyrifos (e.g. Lorsban®), or trichlorfon (e.g. Dipterex®)) mixed with a feeding attractant, yeast autolysate. One example of a prepared mixtured 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 is maldison. 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 6 - 8 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 every 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 15).

For smaller orchards, apply baits to every tree. When pressure is high, every tree will need to be sprayed with bait. For interstate certification assurance (ICA 18) baits will need to be applied to every tree (see Sections 4.9.6.7).

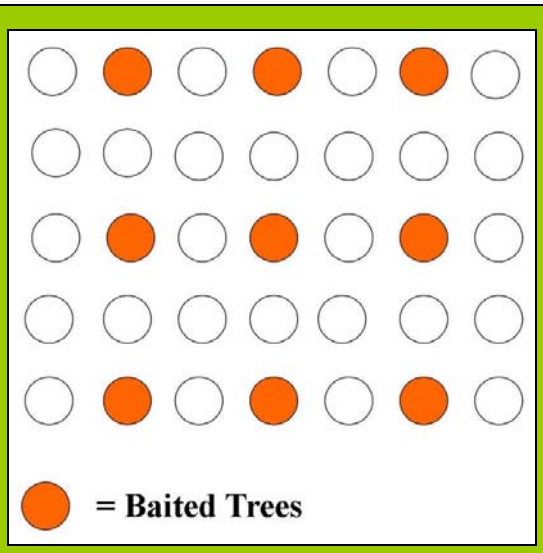

Figure 15. When fruit fly pressure is low, spray bait on every second tree in every second row. When pressure high every tree will need to be sprayed with bait. For ICA 18, every tree needs to be sprayed.

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.

4.9.6.3 Development of new 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) (see section 4.9.6.4) or fipronil (BASF) as insect toxicants.

In large scale field trials carried out by researchers in QLd DPI and NSW DPI, in a variety of commercial crops (citrus, pome fruit, custard apples, passionfruit, blueberries), these new baits has been 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.

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.

4.9.6.4 Naturalure Fruit Fly Bait™

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 crops, and has been written into the ICA 18 regulations. 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.

4.9.6.5 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.

4.9.6.6 Cover sprays of insecticides

An alternative treatment to bait sprays is cover sprays of insecticide; 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 broad spectrum insecticide trichlorfon (Lepidex or Dipterex) can be used to control fruit fly using permit number – PER14743.
Apply only when monitoring of the crop indicates that the pest is present in sufficient numbers to cause economic damage. Repeat treatment if reinfestation occurs.

DO NOT apply more than 6 applications per crop with a minimum re-treatment interval of 7-10 days between consecutive applications.

Apply as a cover spray to point of runoff using airblast sprayer or equivalent.

DO NOT use at rates greater than 5 times the dilute spraying rate.

DO NOT spray any plants in flower while bees are foraging.

4.9.6.7 Disinfestation

Interstate

For Queensland growers to send custard apple to southern states such as Victoria, their fruit must be treated according to interstate certification assurance (ICA-18). 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.

Custard apple and other *Annona* spp. certified for treatment and inspection under this Operational Procedure must comply with the following three requirements: pre-harvest treated, post-harvest inspected and post-harvest treated. More details can be found on the web site: http://www2.dpi.qld.gov.au/extra/ica/procedures/ica/ica-18/ica-18.pdf

1. Pre-harvest treated means:

(a) A program of bait sprays consisting of

- a bait spray mixture of
  - 435 mL of a concentrate containing 1150 g/L maldison,
  - or 780 mL of a concentrate containing 500 g/L trichlorfon, and
  - 2 L yeast autolysate protein lure per 100 litres of water;
- applied to all custard apple and other *Annona* spp. trees on the property, and
- all other fruit fly host trees on the property, with fruit at a susceptible stage (unless receiving a program of cover sprays);
- applied to the leaves at a rate of not less than 100 mL per tree;
- at a maximum interval of every seven days;
- from six weeks prior to commencing harvest to the completion of harvest of fruit for certification.

or

- A bait spray mixture containing Naturalure Fruit Fly Bait™ Concentrate;
- applied to –
  - all custard apple and other *Annona* spp. trees on the property, and
  - all other fruit fly host trees on the property, with fruit at a susceptible stage (unless receiving a program of cover sprays)

- applied to the foliage at a rate consistent with the rate shown on the approved label for the particular product used;
- at a maximum interval of every seven days (plus 1 day when necessary);
- from six weeks prior to commencing harvest to the completion of harvest of fruit for certification.

or

(c) A combined program of bait sprays and cover sprays applied in accordance with (a) and (b) above, at intervals determined by the type of spray in the most recent application.

2. Post-harvest inspected means from a lot that was inspected after harvest and found free of live fruit fly infestation and broken skins.

3. Post-harvest treated means fully immersed for a period of not less than 60 seconds in a dip mixture containing either-

(a) 412.5 mg/L fenthion, or
(b) 400 mg/L dimethoate;

by a Business accredited for an ICA arrangement under the Operational Procedure *Dipping in Dimethoate or Fenthion* [ICA-01]. Post-harvest treatment must be the last treatment before packing.-

Export markets
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.

Fruit fly disinfestation by irradiation is being trialled in a number of fruit crops. Trials on custard apple conducted from 2006-2009 showed that irradiation, even at low dose rates, caused skin discolouration and development of 'off' flavours. At this stage, it does not appear to be a viable option for disinfestation.

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.

4.9.7 Biological control

A small braconid wasp (*Opius* spp.) parasitises Queensland Fruit Fly in the larval stage; however, it does not significantly control the pest.

4.9.8 Orchard management

4.9.8.1 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.

4.9.8.2 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.

4.9.8.3 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.

4.9.8.4 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 (Plates 47 and 48). 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 47. Custard apples grown under fruit fly exclusion netting at Alstonville, NSW.

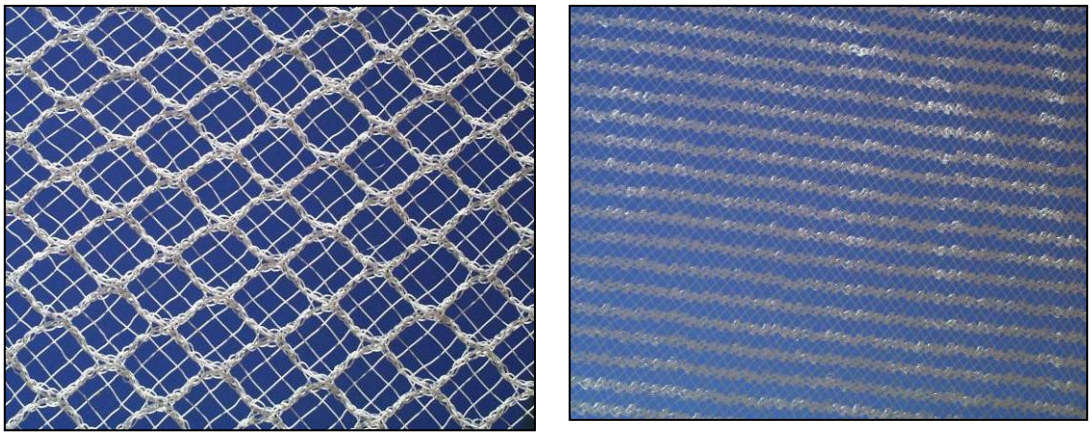

Plate 48. Left: quad netting with cross hairs will exclude some fruit fly. Right: exclusion netting (2 mm mesh) will exclude all fruit flies.

4.10 ELEPHANT WEEVIL

4.10.1 Damage

The weevil chews pieces of bark around the fruit stalk (Plate 49). Where damage is severe, fruit may drop. Occasionally the weevil may damage the trunk or crotches of trees (Plate 50).

4.10.2 Species and identification

Orthorhinus cylindrirostris. Adults 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.

4.10.3 Life cycle

Elephant weevil is a native species that breeds in many native trees, especially Eucalypts. Most beetles emerge during September and October. 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.

4.10.4 Importance and distribution

The beetle is widely distributed throughout Australia. It is occasionally a pest of custard apple. It occurs on a wide range of hosts including citrus, ornamentals and *Eucalyptus* spp.

4.10.5 Monitoring

Check trees regularly for damage. There are no action levels.

4.10.6 Chemical control

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

4.10.7 Biological control

Braconid wasps have been observed to attack larvae.

4.10.8 Orchard management strategies

None available.

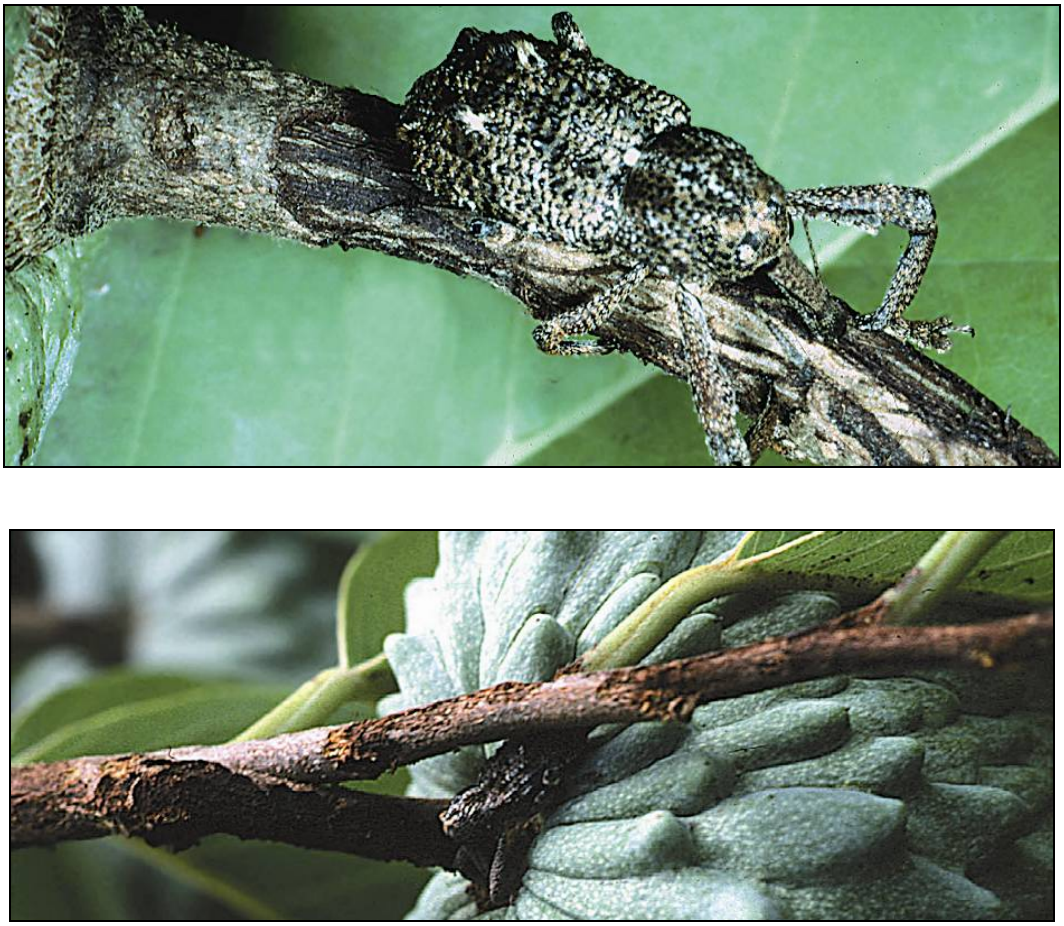

Plate 49. Top: Weevil and chewing damage. Bottom: Pieces of bark chewed from the fruit stalk.

Plate 50. Weevil damage to base of trunk and major branch.

4.11 TRIANGLE BUTTERFLY

4.11.1 Damage

The larvae of the pale green triangle moth are commonly found feeding on foliage usually in late summer and early autumn. The caterpillars cause spots which are dark and corky, and are generally more pronounced on the tips of carpels of fruit (Plate 51).

Plate 51. Triangle butterfly damage. Spots are dark and corky and more pronounced on the tips of carpels.

4.11.2 Species and description

Graphium eurypylus lycaon. The caterpillars are black at first with a pale yellow forked tail (Plate 52). They are rather kite-shaped, being hump-backed in the thoracic region, and tapering from the metathorax rearward. As they grow they become brown and later green. The pupa has a blunt thoracic horn, and is pale green with rows of darker green dots along each side. It has a length of about 2.5 cms. The adult is black with pale turquoise patches and spots. The underside also has some red spots. The blue triangle butterfly (*Graphium. sarpedon choredon*) is almost identical.

4.11.3 Life cycle

Not available. The adults are readily attracted to any nectar bearing flowers.

4.11.4 Importance and distribution

Triangle butterfly is an occasional pest of custard apple and it does not normally cause economic damage.

4.11.5 Monitoring

Regularly check trees for caterpillar feeding on the leaves and fruit. An action threshold of greater than 5% of leaves damaged is suggested before spraying with an insecticide would be worthwhile.

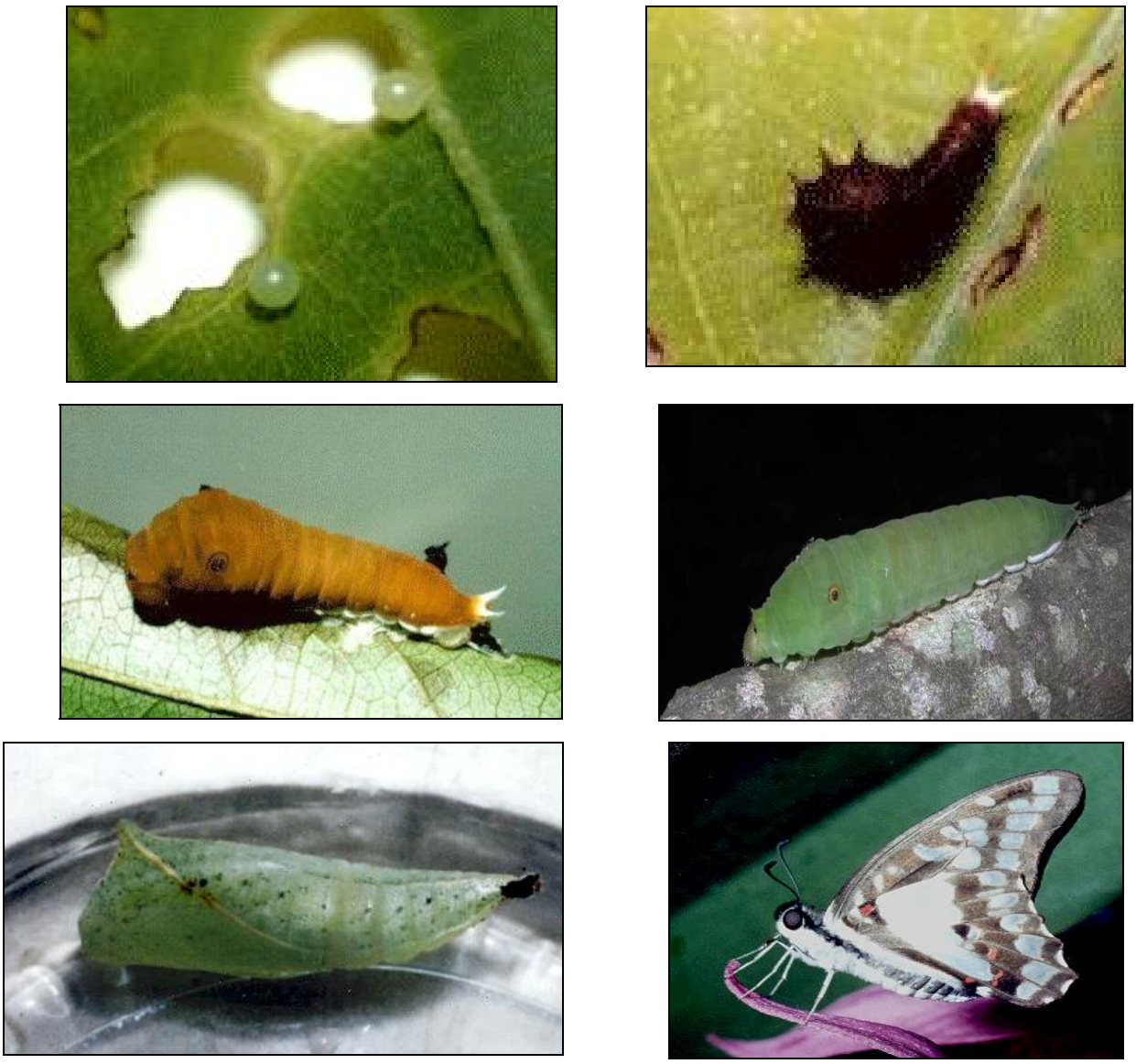

Plate 52. Top left: Eggs. Top right: The caterpillars are black at first with a pale yellow forked tail. Middle: As they grow they become brown and later green. Bottom: The pupa has a blunt thoracic horn, and is pale green with rows of darker green dots along each side. The adult is black with pale turquoise patches and spots. Photos by Don Herbison-evans and Ric Nattrass (with permission).

4.11.6 Chemical control

First check that the problem is worth treating. At least 5% of fruit need to be damaged to make it worth treating. Where required, spray with an appropriate chemical.

4.11.7 Biological control

Unknown

4.11.8 Orchard management strategies

Remove host species.

4.12 TORTICIDAE MOTHS

4.12.1 Damage

Caterpillars of Torticidae moths cause black suture lines along fruit (Plate 53). The symptoms are more obvious where the carpel suture lines are paler in colour, and occur more frequently where the fruit is not symmetrical.

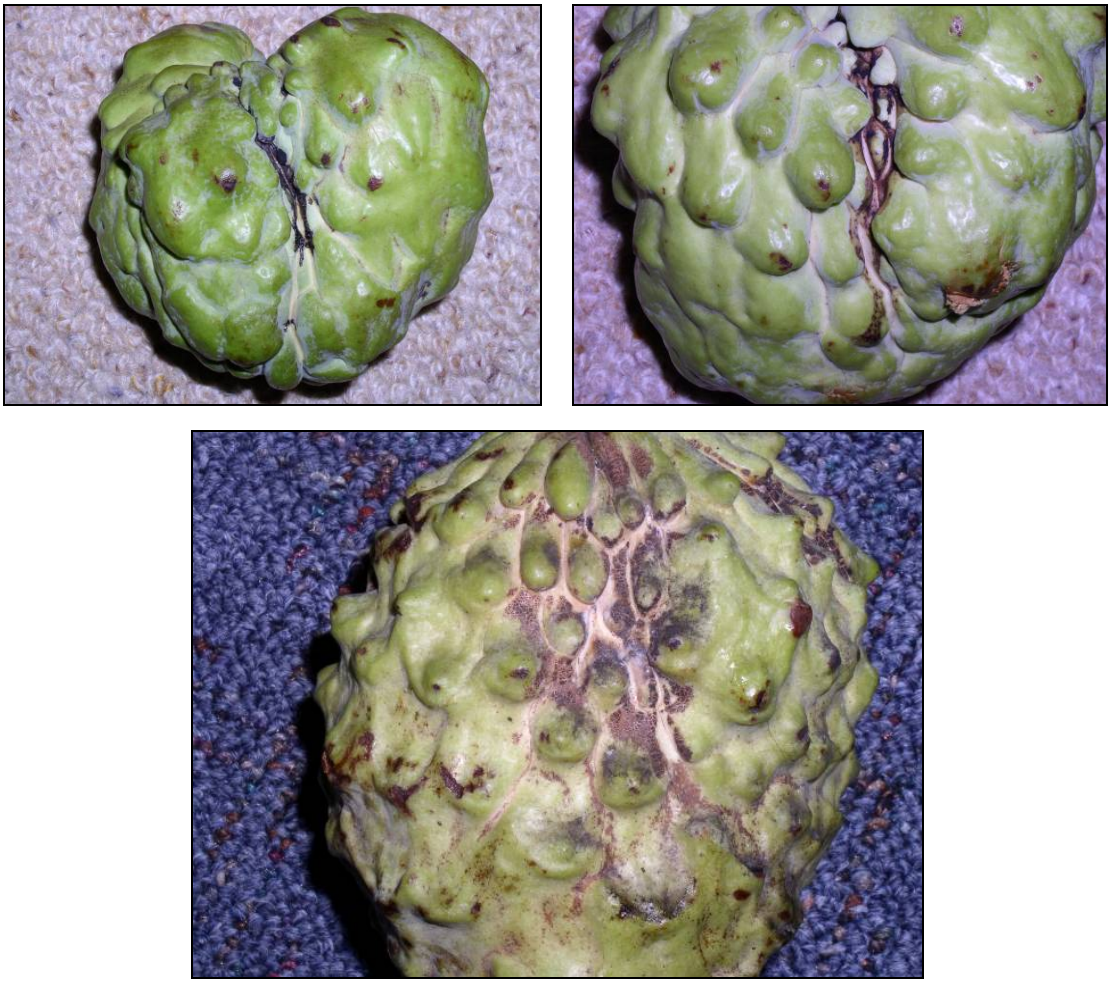

Plate 53. Common symptoms of carpel suture blackening on two different fruit

4.12.2 Species and description

Moths are from the family Torticidae. The exact species attacking custard apple fruit is not known.

4.12.3 Life cycle

Torticidae moths can produce up to three generations per season. The diapausing larvae form the overwintering fraction of populations. They pupate and emerge as moths the following spring and early summer (spring brood of moths). Those moths lay the eggs from which the first summer generation proceeds.

4.12.4 Importance and distribution

Damage appears to be worst on the fruit of the custard apple cv. Pinks Mammoth. There does not appear to be a definite pattern to the occurrence of the symptom. When the symptom of dark coloured suture lines is observed, it is almost invariably assumed that the common cause is insect feeding damage, caused by small caterpillars. The small caterpillars, which can cause a darkening of the areas between the carpels (called carpel suture lines), belong to a family of moths called the Torticidae. This moth family include many caterpillar pests such as light brown apple moth, codling moth, macadamia nut borer, orange fruit borer and so on. They are often found where a leaf touches a fruit, or where two or three fruit are touching and provide a sheltered feeding site.

The ones in custard apple are often found feeding and sheltering in the suture lines, and are quite small in size. If the suture lines are deep, or if the fruit is misshapen, there is more shelter for these caterpillars. However, it is normally very easy to find the caterpillars or signs of their activity by using a binocular microscope. Usually there will be fine webbing under which caterpillars shelter, and/or faecal pellets in or near the webbing. Spider webs can also occur, but the silk patterns are different. Similar symptoms can be generated by spray damage.

In many instances, however, there have been fruit exhibiting symptoms of black suture lines, with no signs of any insect activity or spray damage. As shown in Plate 48, this blackening can often be seen in certain parts of the fruit where there are deep creases, and expansion/contraction pressures are likely to be highest.

4.12.5 Monitoring

Some of the Torticidae moths, such as the light brown apple moth, can be monitored using pheromone traps. However, the exact species attacking custard apples is not known so the use of pheromones may be limited.

4.12.6 Chemical control

First check that the problem is worth treating. At least 5% of fruit need to be damaged to make it worth treating. Where required, spray with an appropriate chemical such as Prodigy®. An alternative would be to use attractant chemicals however these would require registration for custard apple.

4.12.7 Biological control

Not known.

4.12.8 Orchard management strategies

Fallen fruit and broadleaf weeds may also harbour Torticidae moths. Removing these from the orchard will help reduce populations. Thinning fruit also helps control of Torticidae moths by reducing potential feeding sites and leaf-to-fruit and fruit-to-fruit contact. Since Torticidae moths' larvae prefer young foliage, practices that reduce the amount of autumn flush on trees are also beneficial.

4.13 TEA MOSQUITO

4.13.1 Damage

The sucking activities of tea mosquito bugs result in young leaves becoming distorted with lesions along the main veins. Bunched terminal growth develops after severe attack. Puncture marks with dark surrounding sunken tissue occurs on the shoulders of the fruit (Plate 54). Damage is easily confused with that caused by fruit spotting bugs.

4.13.2 Species and description

Helopeltis pernicialis. Adults are 6.5-8.5 mm long, dark brown to reddish brown but with an orange thorax. A dark pin-like process protrudes from the centre of the thorax. The legs are long and fragile, resembling those of a mosquito. The eggs are white and elongated and about one millimetre long. Later instar nymphs are similar in appearance to the adults, although wingless and orange-brown in colour. Legs are spindly and black.

Plate 54. Top: Damage on shoulders of custard apple fruit. Bottom: Tea mosquito

4.13.3 Life cycle

The eggs are laid in plant tissue singly or in small groups. The stems and petioles of young leaves are the main oviposition sites. Eggs take about a week to hatch. Nymphs feed on young leaves and shoots, or other developing plant parts. There are five nymphal instars, with a total development period of 10-16 days. Adults can live for several weeks, and females may lay 30-50 eggs during this time.

4.13.4 Importance and distribution

Tea mosquito bugs are a spasmodic pest of custard apple. Tea mosquitoes are mainly found in north Queensland, but the distribution is poorly known. Host range includes: cocoa, tea, cashew, avocado, mango, guava, passionfruit and sweet potato.

4.13.5 Monitoring

Examine five trees at six widely spaced locations throughout the orchard. Spray when damage is first noticed on developing fruit.

4.13.6 Chemical control

Prompt spray application is required to prevent serious damage. Use registered chemicals.

4.13.7 Biological control

None available.

4.13.8 Orchard management strategies

Green tree ants, once established in an orchard and correctly managed, can suppress tea mosquito damage. Care should be observed with green tree ants as they can also become a pest, especially in wet environments. The ants have symbiotic relationships with sap sucking honeydew producing insects such as mealy bug and scale.

Green tree ants may also cause problems due to aggressive behaviour to beneficial insects and fruit pickers at harvest.

4.14 TWO SPOTTED MITES

4.14.1 Damage

Two-spotted mites cause leaves of custard apple trees to turn a dull greyish colour and in some cases, leaves become chlorotic and fall (Plate 55).

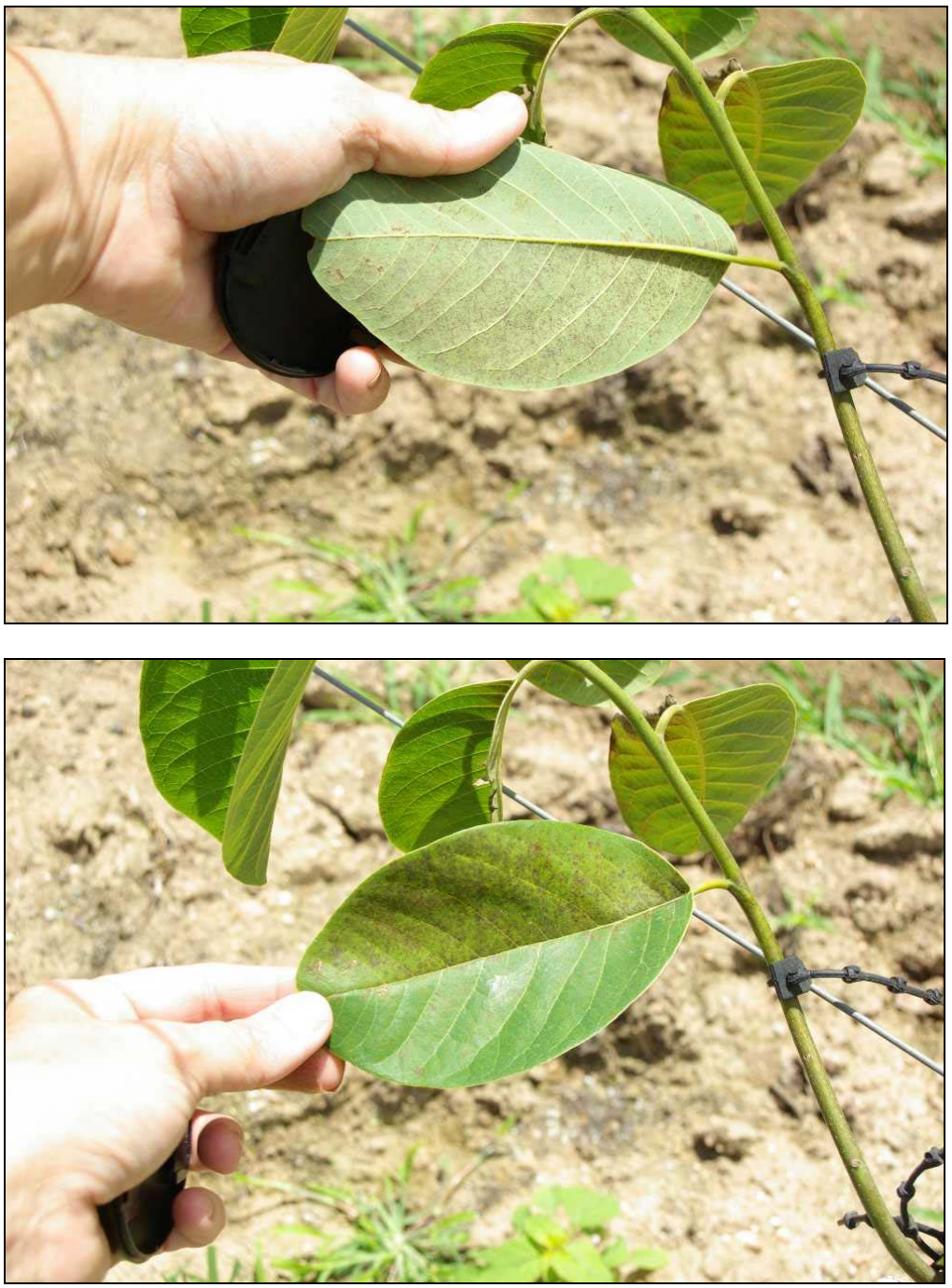

Plate 55. Spotted mite damage on leaves of custard apple cv. Maroochy Star. Note greying of foliage. Photos by Wayne Stewart.

4.14.2 Species and description

Two spotted mite (*Tetranychus urticae*). The adult female two-spotted mite is 0.5 mm long and greenish-yellow with a dark spot on either side of the body (Plate 56). The males are smaller and narrower than the females. Under stressful conditions, two-spotted mites turn a reddish colour.

Plate 56. Two-spotted mite (right) and Chilean predatory mite (left).

4.14.3 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 16).

There are 10 to 20 generations per year.

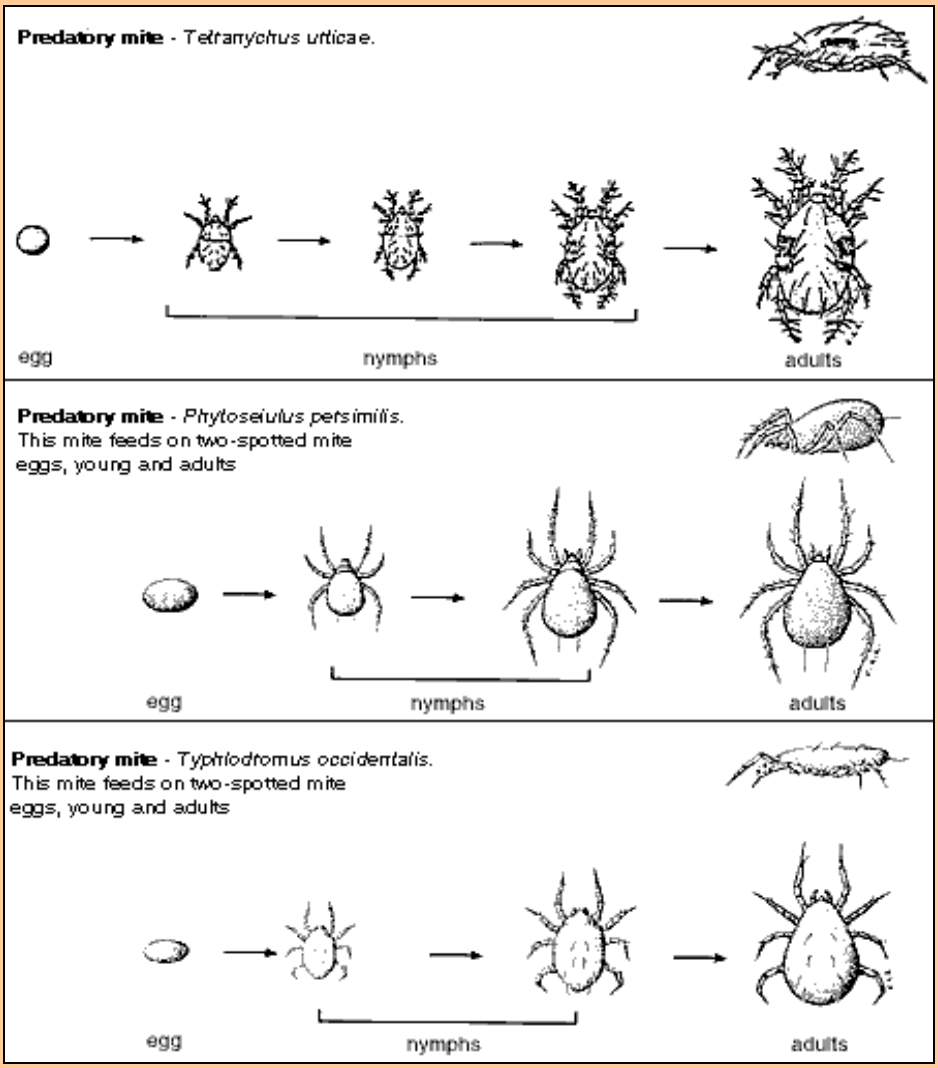

Figure 16. Life cycles of the two-spotted mite, the Chilean predatory mite (*Phytoseiulus persimilis*) and the typhlodromid predatory mite (*Typhlodromus occidentalis*).

4.14.4 Importance and distribution

Two-spotted mites are widely distributed through all the major custard apple growing regions (Figure 17). They can be a problem 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.

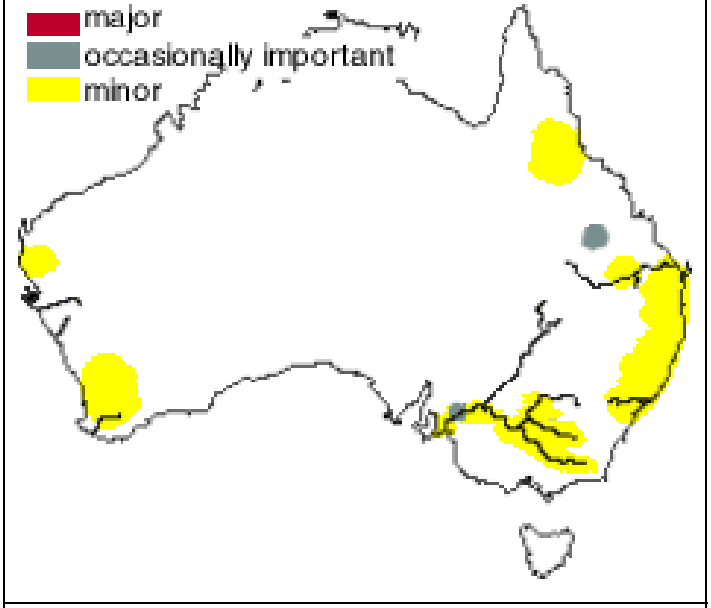

Figure 17. Importance and distribution of two-spotted mite.

4.14.5 Monitoring

Two-spotted mite occurs on all custard apple 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 is required when more than 20% of fruit or leaves are infested.

4.14.6 Chemical control

Currently the selective miticide Paramite (etoxazole) can be used to control two spotted mite in custard apples using minor use permit number – PER14227. Apply when mites first appear. DO NOT apply more than 1 spray per season.

If a persistent problem occurs, periodic releases should be made of the predatory mites, *Phytoseiulus persimilis* or *Typhlodromus occidentalis*.

4.14.7 Biological control

4.14.7.1 Predators

The major natural enemies of two-spotted mite are predatory thrips (*Scolothrips sexmaculatus*) (Plate 57), stethorus ladybirds (Plate 58), predatory mites (Plate 59) 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 57. 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 58. 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 59. 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 custard apple, 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.

4.14.7.2 Pathogens

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

4.14.8 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.

4.15 AVOCADO LEAF ROLLER

4.15.1 Damage

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. 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.

4.15.2 Species and description

Homona spargotis. Marked differences between the sexes occur in the moth stage. 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 60).

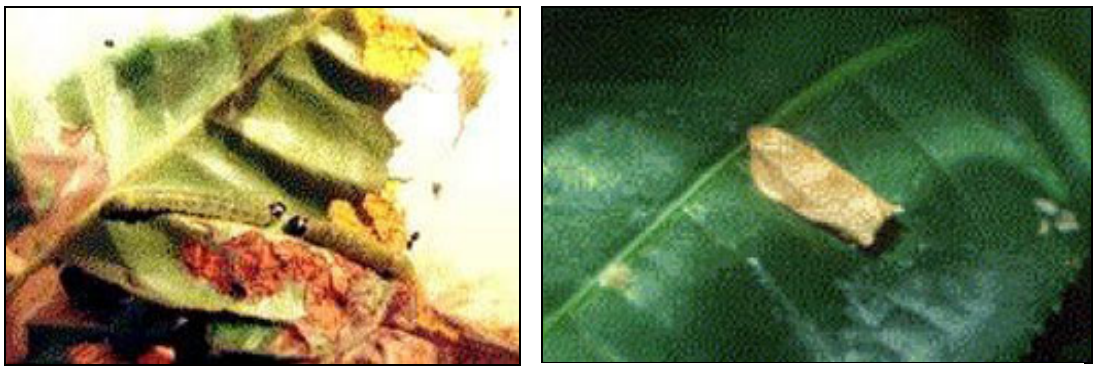

Plate 60. Left: Two avocado leafroller (*Homona spargotis*) larvae feeding on a leaf. Right: Female moth of avocado leafroller. Photos courtesy of Dr Harry Fay, DEEDI.

4.15.3 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.

4.15.4 Importance and distribution

More of a pest in North 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. Large areas of the skin of berries 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.

4.15.5 Monitoring

Action levels are not known.

4.15.6 Chemical control

Check the Australian Pesticides & Veterinary Medicines Authority for chemicals registered or approved under permit to treat this pest on the target crop in your State/location. Always read the label. Always observe withholding periods.

4.15.7 Biological control

Several natural enemies have been recorded attacking leafrollers. These include a predatory of a syrphid fly larva, 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.

4.15.8 Orchard mangement strategies

Not known.

4.16 FRUIT PIERCING MOTH

4.16.1 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. 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 fruitpiercing moths. Early summer to early autumn is the most important period.

4.16.2 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 61). 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.

Plate 61. 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.

4.16.3 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 2½ weeks adults emerge from the pupa.

4.16.4 Importance and distribution

Fruitpiercing moths are found on the east-coast of Australia, north from the Northern Rivers District of New South Wales. 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.

4.16.5 Monitoring

Not determined, but would depend on individual fruit value. 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.

4.15.6 Chemical control

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

4.15.7 Biological control

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

4.15.8 Orchard amanement strategies

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

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.

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, 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 custard apple, 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 custard apple, while monitoring is useful at all times of the year, the critical periods are from November to March. We suggest the following monitoring frequency for custard apple:

- Monitor at weekly intervals throughout the whole year for mealybug, scales, ants and diseases
- Monitor at weekly intervals from November to January for fruit spotting bug
- Monitor fruit fly traps twice weekly. Fruit flies generally become more active in late January and February. 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 variety of custard apple and 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. 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……..
……
……

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.
../../Citrus/Publications/Fieldguide/NewCitrusIPM/practical_ipm/pract04-data.html_-top#top

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 custard apple 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	African Pride	Copper		Mancozeb Thiodan			Release of Cryptolaemus ladybird
B	African Pride	Copper		Mancozeb Thiodan			Release of Cryptolaemus ladybird
C	African Pride	Copper		Mancozeb Thiodan			Release of Cryptolaemus ladybird
D	KJ Pinks	Copper		Mancozeb Thiodan			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.

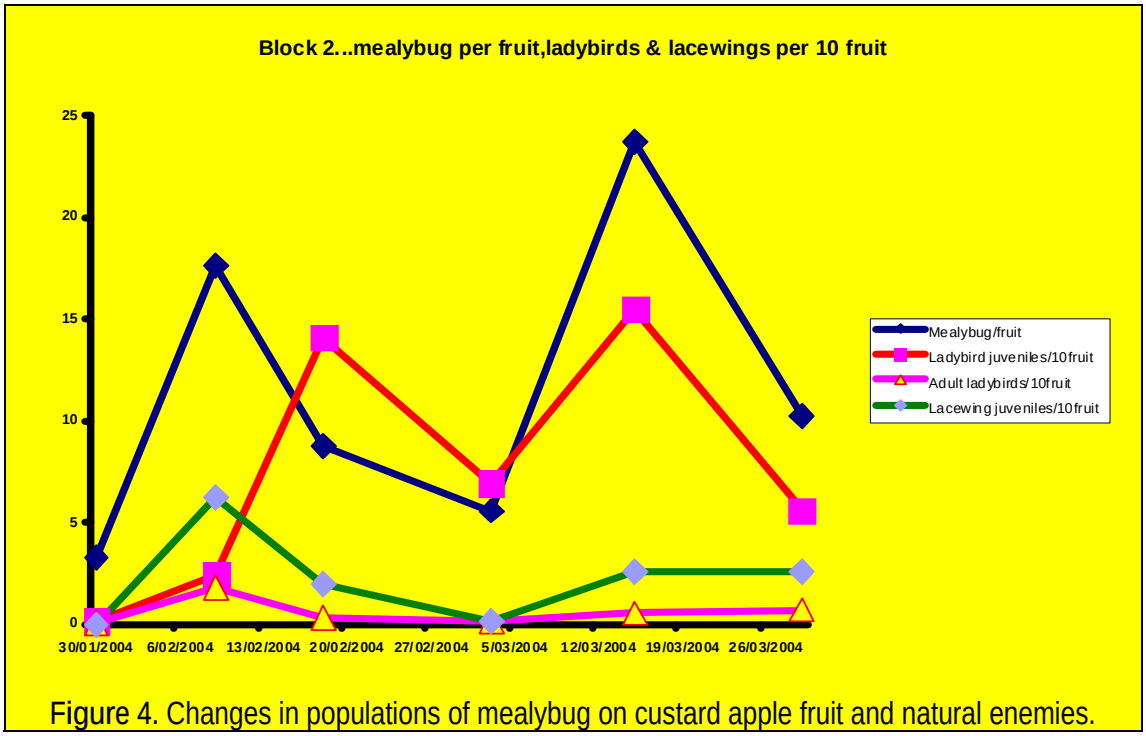

Figure 4. Changes in populations of mealybug on custard apple fruit and natural enemies.

5.6 DECISION MAKING

5.6.1 Action levels

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 custard apple growing areas of Australia.

5.6.1.1 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.

5.6.1.2 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 custard apple 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 juice 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.

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 custard apple industry.

TABLE 2.

Action levels for selected custard apple 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% 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 is required to make it worth spraying.	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	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 hot spots. Monitor natural 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.

Pest	Sample unit	Frequency of monitoring	Action level	Comments
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.	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 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. For ICA 18, weekly bait sprays will be required. 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.
Pale green triangle butterfly	Select 5 trees at random per hectare and record the % of 100 leaves with damage.	Fortnightly intervals during late summer/early autumn.	An action threshold of greater than 5% of leaves damaged is suggested before spraying with an insecticide would be worthwhile.	
Elephant weevil	Examine five trees at six widely spaced locations throughout the crop	Fortnightly	Check trees regularly for damage. There are no action levels.	
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.
Tea mosquito	Examine five trees at six widely spaced locations throughout the crop	Fortnightly	Spray when damage is first noticed on developing fruit.	

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 cultural practices that can be employed after trees are planted.

Cultural practices should help to conserve existing natural enemies of pests. In custard apple, 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 custard apple.

Plate 1. Rootstock of nursery tree showing twisted and strangulated roots.

6.2.2 Varietal selection

In the 2009 disease survey, George and Redpath (2009) found that cv. African Pride was more susceptible to the major diseases compared with the other varieties (Figure 1). Surprisingly, even though 'Hillary White' and 'KJ Pinks' are budsports of 'Pinks mammoth', and would be expected to have similar genetics, with the exception of a few point mutations, 'KJ Pinks' was more susceptible to disease and 'Hillary White' less susceptible than the parent variety, 'Pinks Mammoth'.

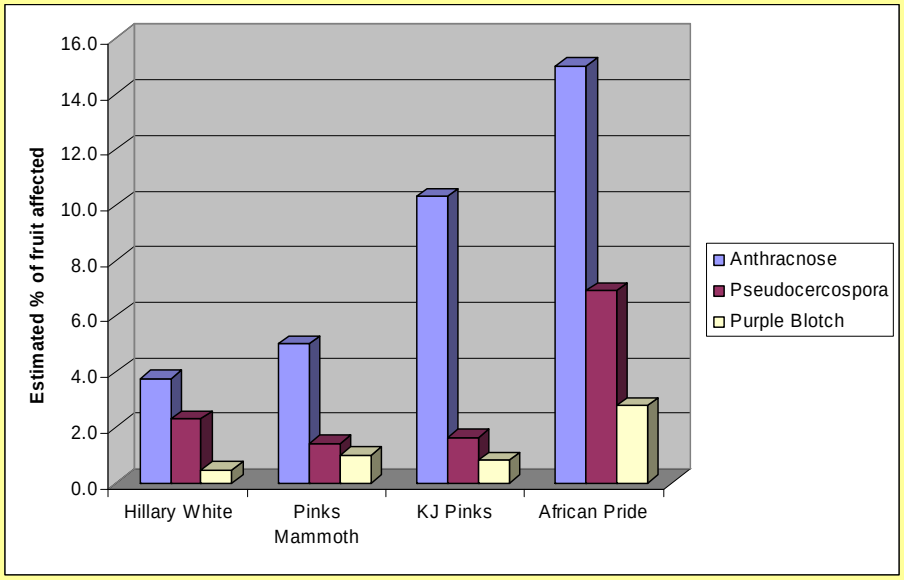

Figure 1. Varietal differences in the incidence of susceptibility to fruit diseases. Pooled data for all growers/regions (George and Redpath, 2009).

6.2.3 Rootstock selection

Low vigour rootstocks such as sugar apple (*Annona squamosa*) are more susceptible to root diseases if poorly managed or if grown under very cool subtropical conditions. Cherimoya (*Annona cherimola*) has greater tolerance of root diseases such as bacterial wilt. Various selections of cherimoya may perform better than others.

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 pressure fast enough leading to wilting and a collapse of the whole tree. In contrast, whilst high root vigour may be a benefit to the tree in escaping root rot diseases, large vigorous trees provide greater shelter for pests and diseases reducing penetration of pesticides sprays.

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.

6.2.5 Tree training system

Large, densely-foliaged trees will be more susceptible to some diseases such as Pseudocercospora but less susceptible to other diseases such as anthracnose due to less wind-driven rain drop splash (Plate 2). Whilst custard apples like high humidity for fruit set (70-90%), excessively high humidity and free moisture are highly conducive for disease development.

Smaller sized trees 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 reducing disease incidence.

Plate 2. Large, vigorous trees are more difficult for pesticide sprays to penetrate.

6.2.6 Proximity to neglected orchards

In NSW, George and Redpath (2009) found that there was a three-fold increase in the number of fruit infected with anthracnose in custard apple orchards located near neglected avocado orchards (Figure 2). The organism which causes anthracnose in avocado (*Colletotrichum gloeosporiodes*) is the same organism which causes anthracnose in custard apple.

Many fruit crops besides avocado are a host for anthracnose including: pawpaw, passionfruit and mango.

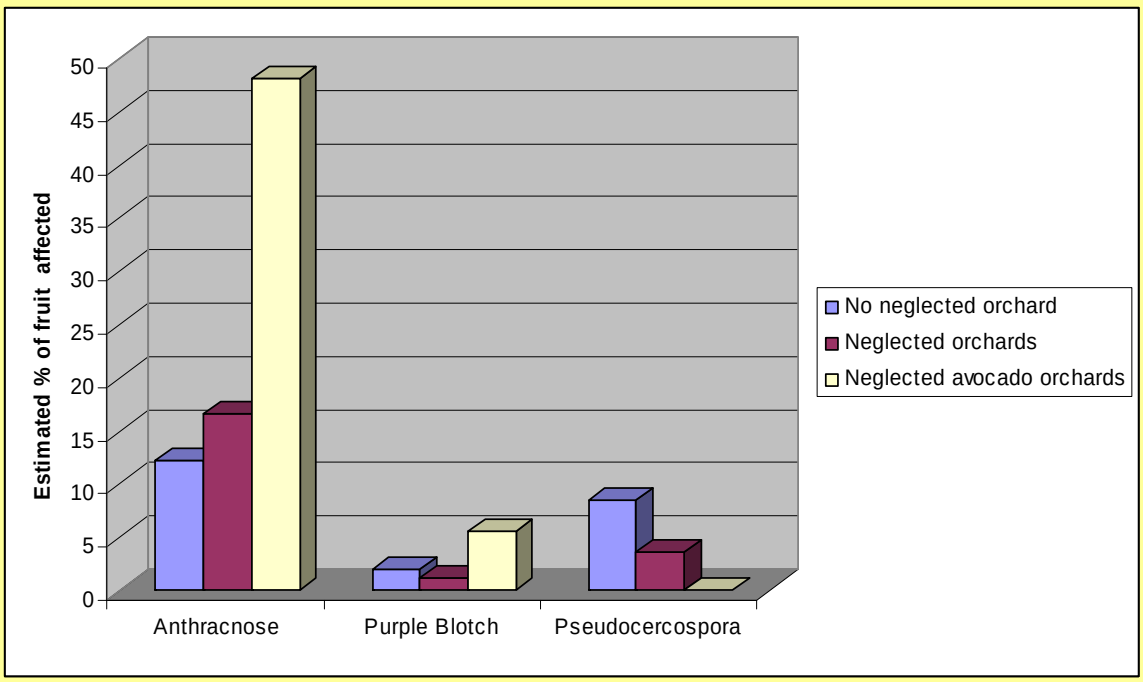

Figure 2. Effects of proximity to neglected orchards on incidence of fruit disease. Data for NSW only as only a few custard apple orchards in Queensland were located next to neglected orchards (George and Redpath, 2009).

6.2.7 Windbreaks

Windbreaks can have positive and/or negative effects on pest and disease incursions. 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 3. Windbreak of mock orange – a host for fruit spotting bugs.

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, George and Redpath (2009) found that densely-foliated windbreaks reduced the incidence of both anthracnose and Pseudocerspora three- to four-fold (Figure 3). George and Redpath (2009) suggest that windbreaks reduce wind-driven splash of inoculum.

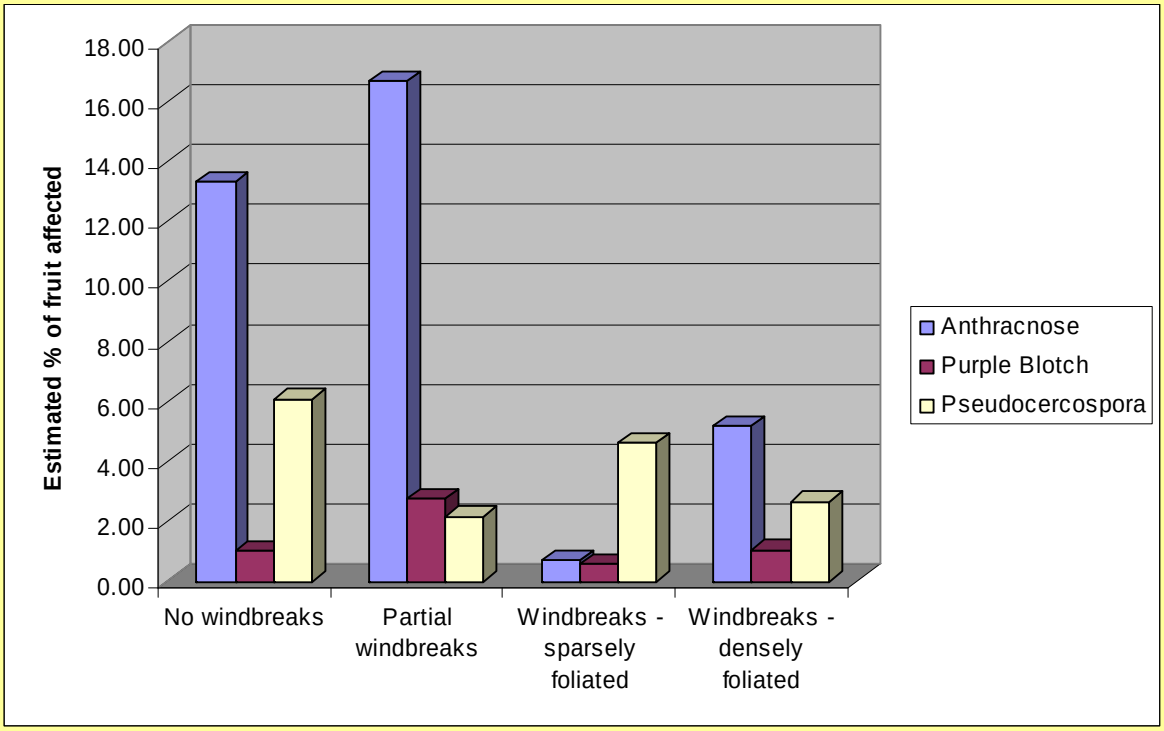

Figure 3. Effects of windbreaks on incidence of fruit disease of custrad apple. Pooled data for all growers/regions (George and Redpath, 2009).

6.3 POST-PLANTING CONSIDERATIONS

6.3.1 Pruning

Custard apple 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 pink disease, anthracnose and collar rot. Pruning also improves spray penetration and rate of leaf drying (Plate 4).

Plate 4. This grower has created light windows/corridors into the centre of the tree by removing upright water shoots growing up through the centre of the tree and through removal of some 3 to 4 year-old branches. This will increase light penetration into the centre of the tree and improve the rate of leaf drying.

In the 2009 disease survey, George and Redpath (2009) found that the incidence of anthracnose fell by more than half on trees that were densely-foliated (Figure 4). Higher tree foliage density greatly reduced wind-driven rain splash of inoculum. In contrast, incidence of Pseudocercospora increased with tree foliage density.

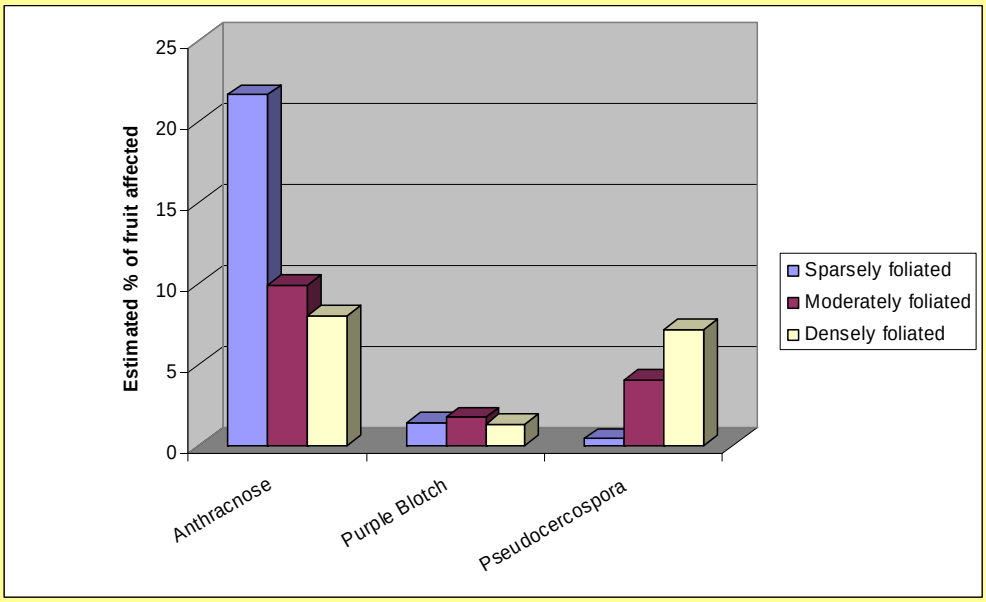

Figure 4. Effects of tree foliage density on disease incidence (George and Redpath, 2009).

6.3.2 Under-tree mulching

Mulching beneath trees increases soil organic matter, improves soil structure, reduces root temperature fluctuations, and increases water retention (Plate 5).

Under-tree mulching can greatly reduce rain drop splash of disease organisms such as *Pseudocercospera* spp. Growers should apply a 30 cm deep mulch of straw or similar material beneath the trees annually.

Plate 5. Left: Young trees heavily mulched with straw. Right: Mulch thrower.

6.3.3 Mulching of prunings

Pruning should not be allowed to rot beneath the tree (Plate 6). 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 7).

These chipping should be thrown back under the tree canopy. In the 2009 disease survey, 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 (Figure 5).

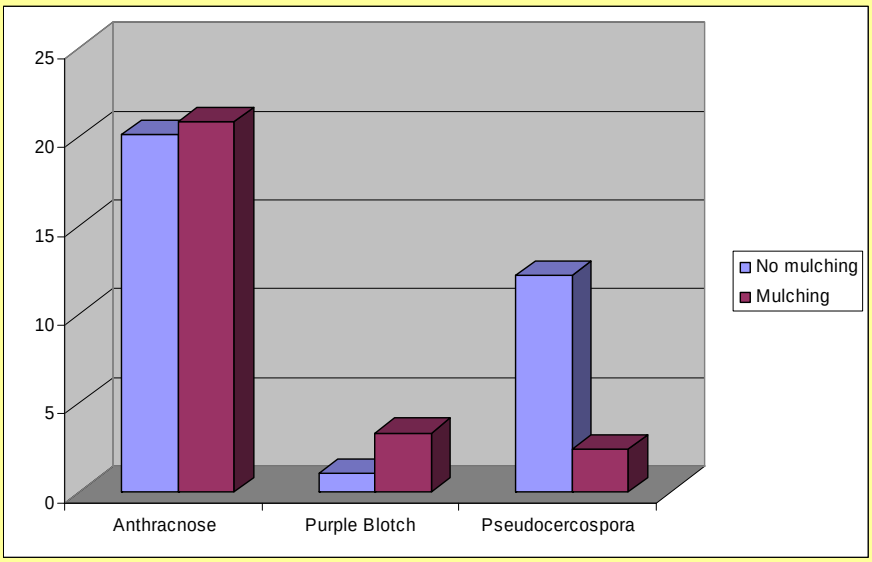

Figure 5. Effects of mulching of prunings on incidence of fruit disease. Data for NSW only.

Plate 6. Prunings allowed to rot beneath the tree. This practice is strongly discouraged as it leads to build-up of diseases.

Plate 7. Flailing mover to chip up prunings.

6.3.4 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 Queensland 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 and the incidence of Purple Blotch to near zero (Figure 6).

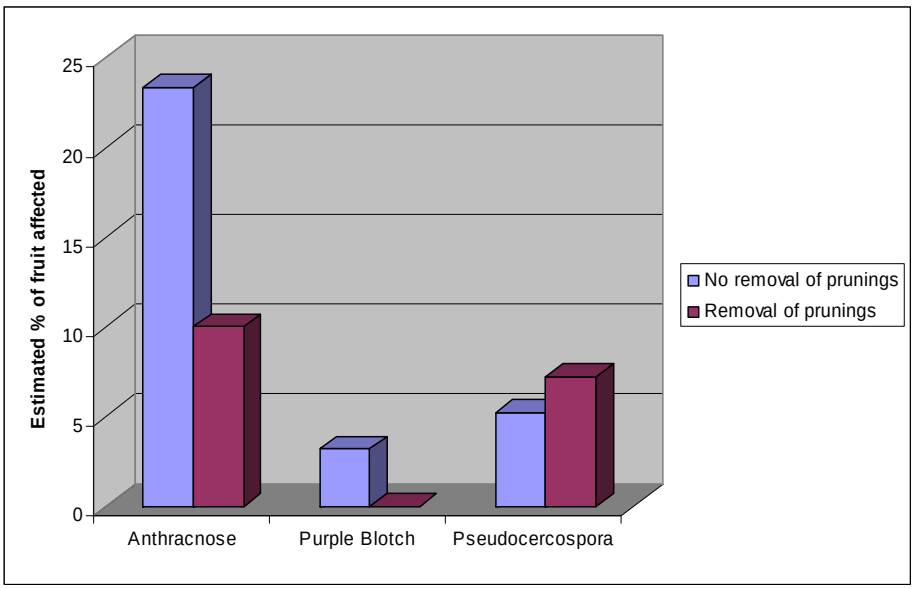

Figure 6. Effects of removal of prunings from the orchard on incidence of fruit disease.

6.3.5 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 900 mm above ground level, and is usually done when tree are dormant (Plate 8).

Plate 8. Skirting custard apple trees will improve air circulation and reduce ant movement and subsequent scale and mealybug populations in the tree.

6.3.6 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. Application of calcium and perhaps silica-based fertilisers may also reduce disease susceptibility.

6.3.7 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 (Plate 9). 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.

Plate 9. Custard apple orchard with an inter-row grass sward which aids in reducing rain drop splash of inoculum and disease spread.

6.3.8 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.

6.3.9 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.

6.3.10 Irrigation

Regular irrigation can reduce stress on the tree and consequently reduce susceptibility to disease.

6.3.11 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).

6.3.12 Harvesting 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.

CHAPTER 7

Insecticides and fungicides

7.1 REGISTERED CHEMICALS

7.1.1 Product registration

Before any agricultural or veterinary chemical products can be supplied, distributed or sold anywhere in Australia they must be registered by the Australian Pesticides and Veterinary Medicines Authority (APVMA). For farmers, food producers, the chemical industry and the general public, registration means that the product is safe and will work when used according to the label. Variations to the formulation of a currently registered product must also be approved, as must proposed new patterns of use and new labels. This includes changes to the current use pattern or the products claims. The product's active constituents and the product label must also be approved by the APVMA before registration.

The list of agricultural and veterinary chemical products registered for use on fruit crops is found on the APVMA PUBCRIS database (see references and sources of information). This database is updated nightly. The data includes the product name, registering company, active constituents and product category.

7.1.2 APVMA approved pesticides

When the Australian Pesticides and Veterinary Medicines Authority (APVMA) registers a chemical product or approves a new label, an approval number is placed on the label. This number is typically found at the base of the rear panel on the main container. The approval number contains the product number, the pack size identifier and the month and year of initial registration. A typical example might be APVMA 54321/1kg/0909. The presence of this approval number means that the product has been scientifically assessed by the APVMA and is safe when used according to label instructions.

Each registered agricultural and veterinary products must have an APVMA approved label. Product Labels provide instructions on how to use products safely and effectively. Product labels must contain a range of specific information including safety directions; first aid instructions and directions for use. The product label must also indicate whether a product has specific handling requirements and restrictions on use.

First aid instructions, safety directions and warning statements for Ag and Vet product labels are compiled by the Office of Chemical Safety and published in the FAISD Handbook

Because of the small size of the custard apple industry, it is sometimes necessary to apply to the APVMA to use chemicals that are currently registered for other crops that may be of benefit in controlling specific pests and diseases in custard apple. These types of permits are called minor use permits and these are described in section 7.1.3.

A list of pesticides registed by APVMA for use on custard apples is presented in Tables 1 and 2.

TABLE 1.

List of insecticides registered for use on custard apple (Source: Infopest, APVMA PUBCRIS *database, May, 2011). Note: Always read the label for manufacturers recommendations.*

Pest	Chemical active ingredient	Common product names	Application rate***	WHP* (a)	WHP** (b)	States of registration
Fruit spotting bug, Banana spotting bug	Methidathion (400g/L)	Supracide 400 Suprathion 400 EC	65mL/100L or conc.	7	NS	QNW
Ants	Chlorpyrifos (500g/L)	Chlorpyrifos 500, Lorsban, Cyren 500 EC	0.2-2L/100L	14	NS	Q
Scale insects	Petroleum oil (825g/L)	Summer oil	1-2L/100L	1	NA	QNW
	Petroleum oil (839g/L)	Summer spray oil	1L/100L	1	NA	QNW
	Petroleum oil (840g/L)	Biocover	1.2L/100L	1	NA	QNW
	Petroleum oil (844g/L)	Sacoa Summer	1.2-2L/100L	1	NS	QNW
	Paraffinic oil (815g/L)	Biopest Paraffin oil	1-2L/100L	1	NS	QNW
	Paraffinic oil (815g/L)	Bioclear	1-2L/100L	1	NS	QNW
	Paraffinic oil (821g/L)	Enspray 99	1-2L/100L	1	NS	QNW
	Paraffinic oil (830g/L)	Trump spray oil	1-2L/100L	1	NS	QNW
	Buprofezin (440g/L)	Applaud	30-60mL/100L	14	NFC	QNVWSNtTA
Black, brown olive scale	Methidathion (400g/L)	Supracide 400 Suprathion 400 EC	0.125L/100L + wetter	7	NS	QNW
Long soft scale	Methidathion (400g/L)	Supracide 400 Suprathion 400 EC	0.125L/100L + wetter	7	NS	QNW
Soft brown scale	Methidathion (400g/L)	Supracide 400 Suprathion 400 EC	0.125L/100L + wetter	7	NS	QNW
Mealybugs	Methidathion (400g/L)	Supracide 400 Suprathion 400 EC	0.125L/100L + oil/wetter	7	NS	QNW
	Buprofezin (440g/L)	Applaud	30-60mL/100L	14	NFC	QNVWSNtTA

Pest	Chemical active ingredient	Common product names	Application rate***	WHP* (a)	WHP** (b)	States of registration
Flower eating caterpillars	Spinosad (800g/kg)	Entrust Naturalyte	6g/100L or conc.	NA	14	QNVWSNtTA
	Spinosad (240g/L)	Success 2	20mL/100L or conc.	NA	14	QNVWSNtTA
Leafroller moths	Spinosad (800g/kg)	Entrust Naturalyte	6g/100L or conc.	NA	14	QNVWSNtTA
	Spinosad (240g/L)	Success 2	20mL/100L or conc.	NA	14	QNVWSNtTA
Loopers	Spinosad (800g/kg)	Entrust Naturalyte	6g/100L or conc.	NA	14	QNVWSNtTA
	Spinosad (240g/L)	Success 2	20mL/100L or conc.	NA	14	QNVWSNtTA
Sorghum head caterpillar	Spinosad (800g/kg)	Entrust Naturalyte	12g/100L or conc.	NA	14	QNVWSNtTA
	Spinosad (240g/L)	Success 2	40mL/100L or conc.	NA	14	QNVWSNtTA
Yellow peach moth	Methoxyfenozide (240g/L)	Prodigy	25mL/100L or conc.	14	NFC	QNVSNtTA
Red-banded thrips	Spinosad (800g/kg)	Entrust Naturalyte	12g/100L or conc.	NA	14	QNVWSNtTA
	Spinosad (240g/L)	Success2	40mL/100L or conc.	NA	14	QNVWSNtTA
Post-harvest	Dimethoate (400g/L)	Dimethoate 400	0.1L/100L	NA	NA	QNNt
	Dimethoate (400g/L	Dimethoate	0.1L/100L (dip)	NS	NS	QNNt
Codes	NA = not applicable NS = none supplied on label UR = under review NFC = not for consumption SL = see label		Q=Queensland N=New South Wales V=Victoria S=South Australia W=Western Australia Nt=Northern Territory A=Australian Capital Territory T=Tasmania			

Withholding periods:
*WHP(a) - In agricultural situations, the withholding period before harvest. In veterinary situations, the withholding period before slaughter.
**WHP (b) - In agricultural situations, the withholding period before grazing/cutting for stock food. In veterinary situations, the withholding period before collecting milk/eggs.
*** Always read the label.

TABLE 2.
List of fungicides registered for use on custard apple (Source; Infopest, APVMA PUBCRIS *database, May 2011). Note: Always read the label for manufacturers recommendations.*

Disease	Chemical active ingredient	Common product names	Application rate***	WHP* (a)	WHP** (b)	States of registration
Pseudocercospora fruit spot	Mancozeb (750g/kg)	Manzate DF	0.2kg/100L or conc.	1	NS	QNVWSNtTA
	Mancozeb (750g/kg)	Mancozeb 750 DF	0.2kg/100L or conc.	1	NS	QNVWSNtTA
	Mancozeb (750g/kg)	Penncozeb 750 DF	0.2kg/100L or conc.	1	NS	QNVWSNtTA
	Mancozeb (750g/kg)	Mancozeb 750 DF	0.2kg/100L or conc.	1	NS	QNVWSNtTA
	Mancozeb (750g/kg)	Manfil	0.2kg/100L or conc.	1	NS	QNVWSNtTA
	Mancozeb (750g/kg)	Dithane Rainshield	0.2kg/100L or conc.	1	NS	QNVWSNtTA
	Copper as oxychloride (500g/kg)	Coppox WC	0.3kg/100L or conc.	1	NS	QW
Purple blotch	Copper as oxychloride (500g/kg)	Coppox WC	0.3kg/100L or conc.	1	NS	QW
Codes	NA = not applicable NS = none supplied on label UR = under review NFC = not for consumption SL = see label		Q=Queensland N=New South Wales V=Victoria S=South Australia W=Western Australia Nt=Northern Territory A=Australian Capital Territory T=Tasmania			

7.1.3 Minor use permits

The Agricultural and Veterinary Code Regulations 1995 state that a minor use "in relation to a chemical product or an active constituent, means a use of the product or constituent that would not produce sufficient economic return to an applicant for registration of the product to meet cost of registration of the product, or the cost of registration of the product for that use, as the case requires (including, in particular, the cost of providing the data required for that purpose)".

Off-label Permits (OLP) Off-label Permits allow registered agvet products to be used for a purpose or in a manner that is not included on the approved label. OLPs can only be granted for a use defined as a 'minor use'.

Supply/Use Permits (SUP) Supply/Use Permits allow unregistered agvet products to be supplied and/or used for a specific purpose. SUPs can only be granted for a used defined as a 'minor use'.

Export Permits (XP) Export Permits allow unregistered agvet products to be supplied (exported) to persons outside of Australia.

Emergency use Emergency Permits (EP) are granted in response to genuine emergency situations such as outbreaks of exotic diseases or pests. EPs will allow the use of registered agvet products or the supply and/or use of unregistered products, as the situation may require.

Research Research Permits (RP) allow research and development of registered or unregistered agvet products or for other genuine scientific purposes. RPs can allow use as well as supply, as the situation may require.

A list of insecticides and fungicides with minor use permits for use on custard apple is presented in Table 3.

TABLE 3.
Details of permits to allow minor use of chemical products on custard apple (APVMA web site, February 2015).

Permit No.	Description
PER14227	**Paramite (etoxazole) / Custard Apple / Two spotted mite**
PER80374	**Various Registered Products / Custard Apple, Lychee, Mango, Persimmon / Various Insect Pests**
PER14905	**Sulfoxaflor (Transform Insecticide) / Custard Apples / Citrus Mealybug**
PER14894	**Clothianidin (Samurai Systemic Insecticide) / Custard Apples / Citrus Mealy Bug**
PER14743	**Trichlorfon / Custard Apple, Lychee, Mango & Persimmon / Various Insect Pests**
PER14491	**Various Fipronil products / Custard Apple / Ants**
PER13952	**Cabrio WG Fungicide and Cabrio Fungicide (pyraclostrobin) / Custard Apple / Pseudocercospora leaf spot**
PER13951	**Sunny Plant Growth Regulator (uniconazole-P) / Custard Apple / Plant Growth Regulation**
PER13807	**Phosphorous acid / Custard apple / Phytophthora**
PER12450	**Trichlorfon / Specified Fruit crops / Fruit fly**
PER11970	**Imidacloprid / Custard Apple / Citrus Mealybug**
PER11944	**Octave WP Fungicide (prochloraz) / Custard Apple / Anthracnose**
PER11943	**Copper & Mancozeb / Custard Apple / Anthracnose**

7.2 WITHHOLDING PERIODS

The withholding period (WHP) is the "minimum recommended interval that should elapse between the last application of a formulated product to any crop, and the harvesting or cutting thereof". Put another way, it is "the minimum period which must elapse between the last application of the product and when the produce or animal is harvested".

When chemicals are applied to a crop or animal, they break down over time to other products. A chemical residue is what remains of the chemical at a particular time and can occur as the chemical itself or as breakdown products. All chemicals, when applied to crops, animals, water or soil, will leave residues. The size and nature of the residue, and the time it takes to break down, varies from chemical to chemical.

The WHP allows sufficient time for chemical residues in the produce to fall below the legal Maximum Residue Limit (MRL). The MRL is a legal limit and is measured in milligrams of the residue per kilogram of the produce (mg/kg). The MRL is "the maximum concentration of a residue, resulting from the use of a registered agricultural or veterinary chemical that is legally permitted or recognised as acceptable in or on a food, agricultural commodity, or animal feed". The Australian Pesticides and Veterinary Medicines Authority (APVMA) sets MRLs. It is a legal requirement for all chemical users to adhere to WHPs.

The withholding periods for some of the more commonly used pesticides for custard apple are presented in Table 5.

TABLE 5.
Withholding periods (WHPs) for a range of pesticides commonly used on custard apple. Due to various formulations, check labels for WHPs.

Pesticide	Chemical	Withholding period (days)
Insecticide	Supracide®	7
	Thiodan®	7
	Applaud	14
	Prodigy®	7
		1
	Dithane®	
	Copper oxychloride®	1
Fungicides	Cabrio®	3

Details of WHPs for most farm chemicals can be found at the Agtech site: www.agtech.com.au/label/.

7.3 TOXCICITY OF PESTICIDES TO BENEFICIALS

Table 6 rates the relative toxicity of commonly used pesticides to natural enemies. It shows which pesticides are least compatible with IPM (those of high toxicity) and those that are most compatible (those of low toxicity). Table 6 is a guide only.

TABLE 6.
Chemical toxicity to natural enemies.

Chemical name	Trade names	Cryptolaemus spp.		Leptomastix spp.	
		Applied	Residual (weeks)	Applied	Residual (weeks)
Insecticides					
Buprofezin	Applaud®	H	3	L	0
Chlorpyrifos	Lorsban®	H	2-3	H	2-3
Dimethoate	Rogor®	H	4	H	4
Methidathion	Supracide®	H	4	H	4
Petroleum spray oils	Various	(L)	0	(L)	0
Fungicides					
Mancozeb	Dithane®	L	1	L	1

Key to toxicity ratings:
Applied = toxicity of chemical when sprayed on the beneficials
Residual=suggested waiting time (in weeks) before introducing beneficials
- = waiting time unknown
L=low, M=moderate, H=high, ( )=estimated toxicity, - = toxicity unknown.

7.4 CHEMICAL CLASSES

All pesticides contain active ingredients that control pests by interfering with their natural body functions. These functions may be similar in non-target species including humans and therefore may present a hazard to health. The chemical structure of the active ingredient determines what chemical class that a particular pesticide belongs to. The class is often not written on the pesticide label or the Material Safety Data Sheet (MSDS).

However, it is useful to understand the properties and modes of action of the most common chemical classes in order to:

- use these pesticides effectively
- minimise potentially adverse health effects

These chemical classes should not be confused with the authorisations listed on the back of a Licence to Use Pesticides. The licence authorisations depend on the type of pest control work that you are qualified to undertake, not the chemical class of pesticide that you are permitted to apply. A chemical class may also be referred to as a chemical family or chemical group.

Chemical classes for insecticides and fungicides commonly used on custard apple are presented in Table 7. A new system of classification of fungicides has been recently developed by the Fungicide Resistance Action Committee (FRAC). Details of their classification of fungicides can be found on their web site: www.frac.info

Wherever possible, pesticides which belong to different classes and which have different modes of action should be alternated to prevent the build up of pest and disease resistance.

TABLE 7.

Chemical classes for insecticides and fungicides commonly used on custard apple.

Activity Group Code	FRAC code	Activity group	Chemical family	Active constituent	Some trade name
M1	M1	Multi-site activity	Inorganic	copper oxychloride	Various
M3	M3	Multi-site activity	Dithiocarbamate	mancozeb	Various e.g. Dithane®
1B	-	Acetyl choline esterase inhibitors	Organophosphates	dimethoate maldison Chlorpyrifos	Various e.g. Dimethoate® Malathion® Lorsban®
2B	-	GABA-gated chloride channel antagonist	Phenylpyrazoles	fipronil	Fipronil®
16A	-	Ecdysone agonists/moulting disruptors	Diacylhydrazines	methoxyfenozide	Prodigy®
11K	11	Quinone outside inhibitors	methoxy carbamate	pyraclostrobin	Cabrio®
17A	-	Insect growth regulators - chitin synthesis inhibitors	thiadiazinan-	buprofezin	Applaud®

CropLife Australia represents the developers, registrants, manufacturers and formulators of plant science solutions for use in agriculture and the management of pests in other settings.

This group has developed pesticide resistance management strategies and activity group identification to assist in reducing the development of resistance to pesticides for a range of agricultural pests. Further information about CropLife Australia or their Resistance Management Strategies can be obtained from their office:

CropLife Australia Limited
Level 2, AMP Building, 1 Hobart Place, Canberra ACT 2601
Locked Bag 916, Canberra ACT 2601, AUSTRALIA
Phone: (02) 6230 6399, Fax: (02) 6230 6355, Email: info@croplifeaustralia.org.au

7.5 MODE OF ACTION

7.5.1 Insecticides

Insecticides can be classified as either:

- contact
- systemic

Contact insecticides kill the pest on direct contact. In contrast, systemic insecticides are absorbed by the plant and translocated systemically to other plant tissues where they are still active.

7.5.2 Fungicides

Fungicides are classified as either:

- protectant
- eradicant
- systemic

Protectant fungicides are applied before infection occurs and are effective through their ability to inhibit spore germination, or by lethal or sub-lethal effects on fungal hyphae. Eradicant fungicides, which also act as protectants, can also eradicate established infections at the site of application.

Systemic fungicides can be transported from the site of application to other parts of the plant through translocation e.g. root system. A description of the modes of actions of the some of the more important pesticides is presented below.

To understand differences in mobility, it's important to know the difference between absorption and adsorption (Beckerman, 2008). Fungicides that can be taken up by the plant are absorbed. Fungicides that adhere in an extremely thin layer to plant surfaces are adsorbed. Because fungicides are either adsorbed or absorbed, they have two basic forms of mobility: contact and penetrant.

Regardless of the type of mobility that a fungicide possesses, no fungicide is effective after the development of visible disease symptoms. For that reason, timely fungicide application before establishment of the disease is important for optimal disease management.

The following descriptions are provided by Beckerman (2008, Purdue University – see Figure 1).

Contact Fungicides
Contact fungicides are adsorbed. They are susceptible to being washed away by rain or irrigation, and most (but not all) do not protect parts that grow and develop after the product is applied. Older, multi-site fungicides (such as captan, chlorothalonil, mancozeb, and copper) are contact fungicides.

Contact fungicides:

- Must be applied *before* spores land on and infect leaves.
- Prevent spore germination, so they are preventative treatments.
- Have no effect once the infection is established.

Penetrant Fungicides
Penetrant fungicides are absorbed, so they move into plant tissues, and penetrate beyond the cuticle and into the treated leaf tissue itself. There are various kinds of penetrants, characterized by their ability to spread when absorbed by the plant.

Localized penetrants remain in the area of initial plant contact and undergo very little movement within the plant (a process called translocation). All penetrant fungicides are systemic, because they are absorbed by the plant and translocated to other plant tissues — in other words, they move through the plant's system.

Systemic fungicides can be further subdivided based on the direction and degree of movement once they have been absorbed and translocated inside the plant:

- *Xylem-mobile* fungicides (also called *acropetal penetrants*) move upward from the point of entry through the plant's xylem.
- *Amphimobile* fungicides (also called *true systemic penetrants*) move throughout the plant through its xylem and phloem.
- *Locally systemic* fungicides (essentially synonymous with localized penetrant) have limited translocation from the application site.
- *Translaminar* fungicides are absorbed by leaves and can move through the leaf to the opposite surface they contact, but are not truly systemic and do not move throughout the plant.

Systemic fungicides:

- Can stop or slow infections within 72 hours of exposure.
- Must be applied soon after initial infection.
- Are ineffective once the fungus begins producing spores.
- Have limited curative activity.

Fungicide application

Contact fungicide

Systemic fungicide

Translaminar fungicide

Amphimobile fungicide

Figure 1. The red areas show the mobility of fungicides in plants. Note that where the fungicide is applied is important. Contact fungicides remain on plant surfaces only where applied. Xylem-mobile fungicides are absorbed by the plant and translocated upward to other tissues. Amphimobile fungicides move throughout the plant. Translaminar fungicides can move across and through the leaves, but are not truly systemic. (Beckerman, 2008, Purdue University, with permission).

7.6 WATER QUALITY

Efficacy of some pesticides may be affected by pH of the pesticide tank mixes. Some insecticides such as methidathion are more affected than others. Under high pH conditions (alkaline), some pesticides may start to break down over time but the process is so slow that most of these pesticides will remain highly effective in the tank for hours or even days. Emulsifiable concentrates may react with nutrients in water. Growers need to consider three factors in terms of water quality. These are:

- Water pH – Acid or Alkaline
- Water Hardness
- Turbidity

High concentrations of hydroxyl ions (OH-) in alkaline water (> pH 7) can cause a breakdown in the structure of a chemical, resulting in reduced efficacy. The most susceptible chemicals are organophosphates and carbamates. Hard water contains high levels of calcium (Ca), magnesium (Mg), sodium (Na), or iron (Fe). Other cations can cause hard water, but these are the usual suspects. Ca, Mg, Na, and Fe cations (positively charged ions) attach to negatively charged pesticide molecules. Often, the association between herbicides and these cations renders the pesticicde less effective. Measure the concentration of Ca, Mg, Na, and Fe in

water used for pesticide mixing. If the sum of the concentration (ppm) for all of the cations exceeds 400ppm, action may be necessary.

Turbid water, or water containing suspended solids, soil, or organic matter can reduce effectiveness of pesticides. Water should be clean and clear for all pesticide applications, however, some pesticides are not as sensitive to turbidity as others. Pesticides are measured for their ability to bind to soil particles. This information is typically used to assess their potential for off-site movement or leaching through the soil profile.

7.7 DESCRIPTION OF SOME OF THE MORE IMPORTANT PESTICIDES USED IN CUSTARD APPLE ORCHARDS

7.7.1 Organophosphates (OPs)

Organophosphates (OPs) (e.g. fenthion, dimethoate, maldison) have traditionally been used due to their effectiveness against a variety of pests and because pests do not appear to develop resistance to this class of pesticides as they do to others. The use of OPs is diminishing however, in favour of pesticides which are seen to be more environmentally sound in terms of persistence and toxicity. Common OP products used in pest control in custard apple include chlorpyrifos and fenthion.

OPs exist in a variety of forms, such as liquid, mist, bait, powder, paste and dust. In general, OPs are extremely toxic, particularly in concentrated form. OPs are generally more persistent than other chemical classes currently used. Whilst some OPs start to breakdown within hours of application, others have a much higher persistence and will take longer. OPs can breakdown chemically under the influence of environmental factors such as sunlight, air, rainfall, and soil moisture, or biologically through plants, animals and microorganisms like bacteria and fungi. The more exposure OPs have to these elements, the faster they will breakdown. Some labels and MSDSs contain information regarding the “half-life” of the pesticide. This refers to the time that it takes for the concentration of the applied pesticide to reduce by half. If a half life of one week is specified, after 7 days, the concentration will be half that originally applied, after two weeks, it will be a quarter, and so on.

OPs can be absorbed directly through the skin or through the lining of the stomach or respiratory tract following ingestion or inhalation. They affect the nervous system by attaching to the enzyme acetylcholinesterase. When functioning normally, nerves transmit messages through the production of a chemical called acetyl-choline (ACh). After a message is sent, the enzyme acetylcholinesterase breaks down the ACh to end stimulation of the nerve and return it to its normal state.

OPs inhibit the enzyme, causing an accumulation of ACh and overstimulating the nerves. This causes the insect to lose control of their nervous system, resulting in weakness, paralysis and respiratory failure. Because OPs affect acetylcholinesterase, they are known as “anti-cholinesterase compounds”.

As the human nervous system also relies on acetylcholinesterase, they are also susceptible to OPs. If humans inhale, ingest or absorb enough OP pesticide through the skin, they are at risk of experiencing adverse health effects similar to those experienced by pests. This could result in acute symptoms such as stomach cramps, sweating, muscle contraction, twitching and

weakness. Chronic poisoning, from long term exposure, could result in general feelings of illness, loss of appetite, anaemia, or liver, kidney or nerve damage.

7.7.2 Carbamates

Carbamates (e.g. pyraclostrobin) are broad spectrum pesticides which mean that they are effective against a variety of pests. Carbamates are considered slightly less toxic than OPs because they are rapidly metabolised (processed by the body) and excreted. In addition, they do not persist in the environment for as long as OPs, and usually breakdown within days to weeks. Certain environmental conditions will cause some carbamates to persist for longer. Carbamates generally have low vapour pressure and low water solubility. This means that they are slow to evaporate and do not dissolve readily in water.

In humans, however, they are considered to be reversible inhibitors, which mean recovery from over exposure is typically faster than with OPs. As they do not remain in the body like other pesticides can, the risk of chronic poisoning is minimised. Acute carbamate poisoning symptoms will usually begin within minutes of exposure and will last a few hours as the body works to metabolise the chemical.

Symptoms normally present as stomach cramps and sweating, although if exposure continues symptoms may be similar to OP poisoning with slurring of speech, twitching and jerky movements, difficulty breathing, blurred viand weakness. Chronic exposure may result in loss of appetite, weakness, weight loss, a general feeling of sickness. Chronic poisoning is not as common with carbamates as the body is able to metabolise and excrete these carbamates.

7.7.3 Oils

7.6.3.1 Types of oils

This article is extracted with permission from NSW DPI Agfact “Using petroleum based spray oils in citrus“ by Beattie and Hardy, (2005). (See references for details).

The new oil classification is based on the degree of refinement of the oil. It recommends three new categories:

- Mineral oil (MO)
- Agricultural mineral oil (AMO)
- Horticultural mineral oil (HMO)

HMOs and AMOs come from the lubricating fraction of petroleum oils. These high quality oils should be refined from virgin distillates and not from recycled products. Only HMOs and AMOs should be applied to plants in leaf. They are used to suffocate (that is, drown) or alter the behaviour of susceptible pests and to control some pathogens. Both types are suitable for use on custard apples, but greater caution is required when using AMOs.

Oil sprays have been used for over a century to control insect pests. The use of petroleum products in Australia commenced with the use of kerosene in the late 1880s. During this time there have been significant changes in the way oils are formulated, in their quality and in the emulsifiers used. Petroleum-based spray oils play an important role in the control of pests in citrus. They are important in integrated pest management (IPM) programs, but also as additives to other biocides.

Petroleum-based spray oils offer many benefits over broad spectrum pesticides:

- They are as effective as or more effective than broad-spectrum synthetic pesticides for a wide range of pests and diseases.
- Many pests can be controlled simultaneously.
- They have less harmful effects on the natural enemies of pests.
- They do not stimulate other pest outbreaks.
- Pests are not known to develop resistance to them.
- The oil deposits are broken down within weeks to form simple, harmless molecules.
- When using oils only minimum protective clothing needs to be worn.
- They are suitable, depending on the emulsifiers and additives used to formulate products, for use in organic farming.
- They are not toxic to humans or other animals.

7.7.3.2 Properties of spray oils

Crude oils are basically composed of hydrogen and carbon atoms and are generally classified as paraffin, naphthene and aromatic. Because each oil is a complex of molecules of different molecular weights, they may be refined to produce a range of products with specific uses and characteristic properties. Effectiveness as a pesticide and the risk of phytotoxicity both increase with increasing molecular weight. Four properties increase with increasing molecular weight: distillation temperature, n-paraffin carbon number, viscosity and pour point.

Distillation temperature
Oils may be separated into fractions with specific boiling or distillation temperatures. The 10, 50 and 90 per cent distillation temperatures and the range between the 10 and 90 per cent distillation temperatures are widely used to classify refined oils.

Carbon number
This property separates oil fractions according to the number of carbon atoms in their molecules. This property is used in a similar way to distillation temperature to denote the 10, 50 and 90 per cent distillation points. It was developed recently to standardise laboratory procedures and overcome problems associated with classification based on distillation temperatures.

Viscosity
Viscosity measures flow rate. Commonly ‘heavy and thick’ and ‘light and thin’ are used to describe high and low viscosity oils. It is a convenient, though no longer widely used, way to simply describe oil.

Pour point
The pour point is the lowest temperature at which oil will flow. Two properties not related to molecular weight are unsulfonated residue and gravity˚ API.

Unsulfonated residue (UR)

UR gives a measure of the degree of refinement of spray oils. It is expressed as a percentage following determination of the extent to which the oil reacts with sulphuric acid under standard conditions. The minimum value for AMOs and HMOs is 92% UR.

Gravity °API
This is a measure of the density of spray oils. It is a function of molecular size and structure, and is indicative of paraffin content. A value of 37° is characteristic of very high paraffin content. Values greater than 32° are considered optimal.

7.7.3.3 Pesticide effectiveness of oils

Paraffinic oils are used because they are more effective pesticides than naphthenic oils, which also tend to be more phytotoxic. Aromatic oils are not used because they are too phytotoxic. When insects and mites are sprayed they suffocate. Death may take several days depending on size and stage of the insect or mite, oil type and formulation, spray concentration and volume, and spray coverage.

7.7.3.4 Formulations of oils

Mayonnaise oils are emulsions of about 85 per cent oil emulsified in about 15 per cent water with casein and ammonia. Undiluted emulsions resemble mayonnaise. They were common before 1980.

Clear miscible spray oils are emulsive formulations of oil and an emulsifier (surfactant or surface active agent). They form emulsions when added to water. They are now the most common type of product.

Concentration of emulsifiers in modern clear oils range from about 1 to 3 per cent. Increasing the concentration of emulsifiers can reduce effectiveness, but higher concentrations are required to mix oil with water as UR values increase. Products are formulated so that sprays break on impact to leave a film of oil after the water and emulsifier drain away.

When stored in hot situations over one or more summers, mayonnaise oils may deteriorate and the oil separate out. This type of oil is not suitable for use on custard apples. Most custard apple spray oils are now formulated as clear oils. It is wise to use products within 2 years of purchase.

7.7.3.5 Standards for HMOS and AMOS

There are a number of standards recommended for spray oils. Unfortunately this type of information is not usually on the registered label. You need to contact the manufacturer for these details.

- They must be virgin paraffinic oils (Cp > 60%). This means that they must not be recycled oils and that more than 60% of the carbon-hydrogen molecules must be in chains rather than rings.
- The concentration of unsaturated molecules must be 8% or less. The unsaturated molecules can oxidise in sunlight (particularly in summer) and produce acids which can burn plant tissue.
- The unsulfonated residue (UR) must be 92% or higher. The higher the UR, the lower the risk of phytotoxicitity (damage).

• The n-paraffin carbon number (nCy) of HMOs are mostly nC21 and nC23 as well as nC24. The n-paraffin carbon numbers of AMOs are mostly nC24 or nC25. This number relates to the weight of the oil: the lower the carbon number, the lighter the oil. For example, a nC21 oil is lighter than a nC24 oil.

7.7.3.6 Pest control using oil sprays

Oil sprays control pests either by suffocation or by altering their behaviour (such as reducing feeding and egg-laying). Plate 1 shows how insect pests are suffocated by oils. This mode of action has been known since early last century and was the principal mode of action recognised until the 1990s.

Since 1990, research (mostly within NSW DPI and the University of Western Sydney) has shown that a wide range of pests including citrus leafminer, greenhouse thrips, bronze orange bug nymphs, citrus red mite and Queensland Fruit Fly are susceptible to significant impacts of spray deposits on their feeding and egg-laying behaviour. This mode of action may be more important than death from suffocation, as it has increased the range of pests for which oil sprays can be used effectively.

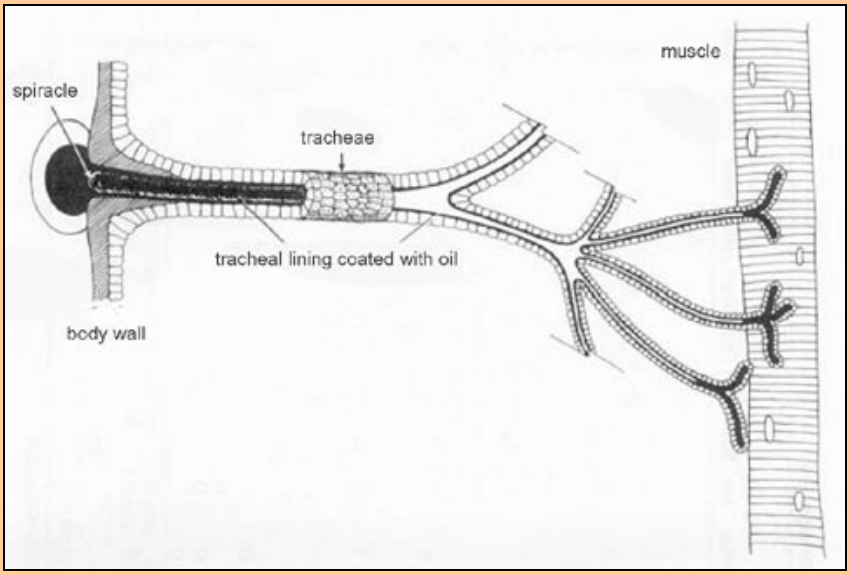

Plate 1. Anoxia (suffocation) from oil moving into the tracheae (breathing tube) of the pest. (Johnson, W.T.,1994).

7.7.3.7 Things to know when using HMOs and AMOs:

• You need to apply oils so that you achieve a thin even coating of oil over the plant or fruit surface.
• It is better to apply a higher volume of spray mix than to use a higher concentration of oil in the mix.
• In subtropical regions, during dormancy, where only one or two applications of a higher concentration (1%) oil spray are used annually for control of pests such as scales and mealybug, apply at volumes which exceed the point of run-off (which is when the spray on leaves is continuously dripping).

• Timing of oil sprays is critical. Apply them when the target pest numbers exceed acceptable levels and they are at their most susceptible stage, or when susceptible new growth on trees starts to appear.
• For most pests you need to thoroughly coat all plant surfaces: the upper and lower leaf surfaces, fruit, twigs, branches, insides and outsides of trees.
• The residual activity of oils (how long they last) is less under hotter tropical conditions than in the cooler temperate climates. This is largely because the oil molecules evaporate and move within the plant more quickly in warmer climates.

7.7.3.8 Controlling soft scales and mealybugs

Soft scales and mealybugs can be more difficult to control than hard scales. Soft scales have one annual generation in southern states and two generations in northern NSW and Queensland. Control should be achieved with high grade parafinnic oil, as long as you apply the spray thoroughly to all infested plant surfaces. Timing of the oil spray is critical, and needs to coincide with the presence of the young, recently hatched stages (crawlers) which generally occur on the upper leaf surfaces. The other soft scales such as black scale and soft brown scale are more difficult to control because they have overlapping generations.

To achieve the best control, time your oil spray to coincide with the greatest number of young stages. Spot spraying heavily infested trees, rather than whole blocks, is also an option for these scales.

Ants promote soft scale infestations and must also be controlled. In fact controlling soft scale infestations is pointless if you do not also control the ants.

7.7.3.9 Controlling armoured (hard) scales

Light infestations of armoured scales such as red and purple scale are easily controlled using oil sprays. Moderate to heavy infestations are more difficult to control, largely as a result of the very large numbers of scale insects present. A 1% oil spray applied at high volumes should be used. Good coverage of all the above-ground parts of the tree is necessary. Manipulate your sprayer to direct more spray into the tops of trees so that the spray drips down inside the canopy. Good coverage of the inside of trees is essential and high volume sprays are necessary.

7.7.3.10 Spray volumes

HMOs and AMOs generally need to be applied at high volumes so that the oil forms an effective film over the plant or fruit surface. The volume of oil sprays needed depends on the type of pest; the level of infestation; tree height; canopy density; and planting density. For large custard apple trees, this may mean rates as high as 2 000L/ha or even higher up to 5 000L/ha. Thorough coverage to the tops and insides of trees is important, especially for control of armoured scales. Oils are not poisons, and have limited residual activity, but the benefits of a single effective spray can last more than one season. Some sprayers are better at applying high volumes of spray than others. The best high volume sprayer is the oscillating boom with a horizontal outrigger. If you are using an airblast sprayer, then a tower is recommended in trees higher than 2 m.

7.7.3.11 Phytotoxicity

Oil sprays can sometimes damage plants – this is referred to as phytotoxicity. Instances of phytotoxicity are less common these days than in the past, largely due to the availability of better quality high grade products.

We recommend that with custard apples avoid spraying trees on hot days where temperatures are likely to exceed 28°C. Petroleum oils, such as Summer oil, should only be used during the dormancy period. Spraying on days when humidity exceeds 70% should also be avoided as this can slow the rate of drying.

For cooler subtropical regions, high grade parafinnic oils such as Biopest® and Bioclear® can be sprayed throughout the season except during the hottest summer months when temperatures exceed 28°C. The most commonly used oil spray used throughout the season is Biopest oil®. It is a highly refined food-grade iso-paraffinic oil formulation. It is applied at rates from 1-2L/100L. Lower rates are used under warmer conditions. These parafinnic oils have minimal impact on beneficial insects, are not persistent in the environment and have low toxicity to animals & grower.

The manufacturers recommend that trees be sprayed with Biopest oil® no more than four times during the growing season with two weeks minimum application interval. Biopest oil® also has anti-fungal activity. They recommend that sprays should not be applied when buds are fully opened and shoot elongation is occurring. Stressed trees should not be sprayed. Avoid spraying when temperatures exceed 28°C and when humidities exceed 80%.

Plate 2. High grade parafiinic oils are useful in IPDM programs. These oils can control a range of scales and mealybuds and have some anti-fungal activity.

7.7.4 COPPER SPRAYS

The following article is extracted with permission from a factnote provided by the NSW Department of Primary Industries (Hardy *et al*., 2007) on the use of copper in citrus. It contains information relevant to custard apple. See references for further details.

Note: the only formulation of copper currently registered for use on custard apple is copper oxychloride. ACAGA is in the process of obtaining minor use permits for other formulations which may be more efficacious.

7.7.4.1 Mode of action

Copper sprays are protectant fungicides that must be applied evenly to the plant or fruit surface before the disease develops to prevent infection. Copper is not a systemic chemical and cannot be carried internally through the plant to kill the pathogen. Once the copper is applied it sticks only where it hits and does not spread to a large extent across the fruit or leaf surface. It's no coincidence that copper is most effective on those diseases that need free water present to develop. On the plant surface, when there is water present (from rain, dew or irrigation) exudates from the plant or spores form weak acids, which lower the pH of this surface water.
The solubility of copper products increases as the pH drops, slowly dissolving to release a small and constant supply of cupric ions (Cu^{+2}) as long as the water remains. Only one copper formulation (cuprous oxide) also releases cuprous (Cu^{+1}) ions, which also have fungicidal and bactericidal activity. These copper ions are picked up by spores or bacteria that come in contact with this surface water, travelling through the cell walls to eventually disrupt cellular enzyme activity.

Over time, the coverage of copper over the plant or fruit surface deteriorates due to fruit growth, and the action of rain and wind. The surface area of fruit can increase substantially from fruit set to harvest (about 14 times) whereas the surface area of fully-expanded leaves only increases slightly. In areas of high rainfall or wet conditions copper fungicides would tend to offer a shorter period of protection than if conditions were dry. Depending on the retention characteristics of the copper formulation, re-application of the protective copper layer may be needed in certain areas.

7.7.4.2 Copper formulations

There are five basic types of copper compounds: copper oxychloride, copper hydroxide, tribasic copper sulphate (green and blue coppers), copper ammonium complexes (dark blue aqueous complex of copper and ammonia) and cuprous oxide (red copper). In the past, most copper products were wettable powders and contained around 50% copper as the active ingredient (a.i.). However, today's formulations contain from 8% to 75% copper and application rates vary accordingly. Products are formulated as wettable powders, wettable granules, liquid flowable suspensions or aqueous liquids. Copper products may also contain small amounts of impurities (lead, cadmium etc.) and some cheaper products may contain higher levels.

7.7.4.3 Particle size and retention

Research has demonstrated that the efficacy of a copper fungicide can be considerably improved by reducing the particle size. The smaller the particle size the greater the number of particles per gram and therefore the greater the fungicidal or bacterial activity. With smaller particles, coverage is improved and there is significantly more surface area available per gram of product to release copper ions when moisture is present (Plate 3).

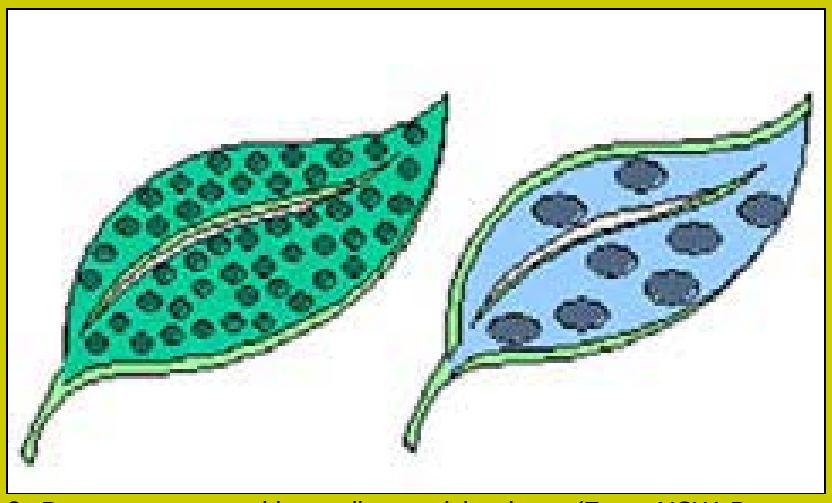

Plate 3. Better coverage with smaller particle sizes. (From NSW Department of Primary Industries Factnote; Hardy *et al*., 2007; with permission).

The median particle size of the copper oxychloride and copper hydroxide products are around 3 microns and for cuprous oxide products around 1 micron. The main factors influencing product retention on plants are:

- rainfall (from direct rainfall dislodgement or from rain solubilisation)
- wind events (particles over 3–4 microns can be blown off plant surfaces)
- physical dislodgement of the copper particles due to plant surface growth underneath the deposits (e.g. fruit expansion).

Smaller particles resist dislodgement better as they are lighter and have a larger surface area relative to their weight (hence a greater area of contact with the plant surface) and this results in an increase in the total force of adhesion. The high initial losses experienced from weathering arise from a rapid and complete loss of large particles while remaining residue consists of small particles. Formulations with smaller particles produce improvements in disease control through better coverage, rain-fastness, and longevity of the product and release of copper ions on the plant surface.

Research by Professor Pete Timmer in Florida found that:

- whether it is a liquid, liquid flowable or dry formulation there is little difference in the level of control per unit of metallic copper
- the most important factor affecting product effectiveness is the particle size of the formulation and how well it sticks (rain-fast) to the plant surface
- products with a smaller particle size tend to have better coverage, rain-fastness and longevity
- more frequent applications of copper at lower rates are more effective than the same amount of copper applied in fewer applications.

A range of formulations is presented in Table 8.

TABLE 8.

Some formulations of copper and their median particle size. Note: only the copper oxychloride formulation is registered for use on custard apple. (Hardy et al., 2007, with permission).

Some product names	Active ingredient	Concentration of copper (%)	Some distributors	Median particle size (microns)
Oxydul	Copper oxychloride	52	Nufarm	3.1
Coppox	Copper oxychloride	50	Melpat International	1.8
Kocide WP	Copper hydroxide	50	Dupont	3.1
Kocide Blue	Copper hydroxide	35	Dupont	2.5
Tribase Blue*	Tribasic copper sulphate	19	Nufarm	0.7
Nordox	Cuprous oxide	75	Gro-chem NZ Ltd	1.2
Norshield WG	Cuprous oxide	75	Nufarm	1.0

7.7.4.4 The impact of water pH

Most copper products are formulated to be almost insoluble in water at pH 7.0. As the pH of water decreases the solubility of the copper fungicides increases and more copper ions are released. If the water used is too acidic (below pH 6.0-7.0 - depending on the copper formulation) excessive amounts of copper ions could be produced which may cause damage to fruit and foliage. Formulations vary in solubility - hydroxides are more soluble than oxychlorides which are more soluble than tribasic copper sulphates and cuprous oxide. Less soluble formulations are usually more persistent.

7.7.4.5 Phytotoxicity

Copper sprays can cause marking on fruit. If too many copper ions are released at one time, damage to the fruit and foliage can result. This can happen if the spray solution is too acidic (i.e. below pH 6.0–7.0), by some aqueous liquid copper formulations, by copper formulations that have high amounts of soluble copper or by formulations that are very soluble and release too many copper ions.

Some copper-based fungicides may cause a small reduction in plant vigour. This reduction is caused by too many copper ions passing into the leaf and/or by other impurities in the product. Copper salts such as copper chloride (used in the production of copper hydroxide and oxychloride), if not completely oxidised during manufacturing, can remain (up to 2%) in some low quality copper formulations. This copper salt rapidly dissolves and could increase copper ions to excess levels as soon as the product is added to the spray tank. Other heavy metal impurities such as lead and cadmium have also been implicated in increased levels of blemish. This partially explains some of the crop safety differences between copper formulations — low quality copper formulations with higher levels of impurities may reduce plant growth and cause more fruit blemish.

Timing, frequency of application and the rate of copper applied is also very important, particularly with spring and summer applications. Although the current label for copper

oxychloride indicates applying copper every two weeks when disease is present, or at the start of the wet weather, some custard apple growers have observed phytotoxicity particularly when copper was applied in summer (December–January) and where 3–4 successive applications of copper were used.

In some soils, copper levels can also increase and become toxic to roots. High copper levels may also interfere with the uptake of other plant nutrients. It is also generally recommended that no other products, such as fungicides, insecticides or nutrient sprays be mixed with copper sprays.

The phytotoxic effects of copper are more common when:

- Copper is applied with other products (especially acidic ones) in the one tank mix
- High rates of copper are applied mid-summer
- 3–4 successive applications of copper are used at high rates
- Copper is applied to wet fruit, when the cells are turgid (e.g. early morning before the dew has lifted or spraying immediately after rain)
- Copper is applied at high temperatures (especially when fruit and plant surface temperatures are above 25°C)
- There is cool and slow drying weather or when humidity is low and cloud cover is close to zero
- Using some aqueous liquid formulations (i.e. copper and ammonia complexes)

7.7.4.6 Best practice tips

- Copper sprays are protectant fungicides and need to be applied prior to disease infection
- Apply a good even coverage of copper to plant and fruit surfaces
- The protective layer of copper diminishes over time and only offers short-term protection under certain conditions (i.e. in wet or humid climates). If infection is likely over longer periods then re-application may be necessary
- Smaller particle size results in better rain-fastness and retention of the copper product.
- Always apply copper sprays alone
- pH of the water used to apply copper should be >6.0
- Choose a product and rate that minimises the amount of copper
- More frequent applications using lower rates of copper are just as effective and cause less phytotoxicity than applying high rates in fewer applications
- Don't over-apply copper
- Don't apply copper when fruit or leaf temperatures are high, humidity is low or the fruit is wet

7.7.5 Buprofezin (Applaud®) insecticide

Buprofezin (Applaud®) is an insect growth regulator discovered by Nihon Nohyaku Co. Ltd, Japan. Applaud® shows activity against Hemiptera including some scales, mealybugs, planthoppers, leafhoppers and whiteflies. It controls nymphal stages through the moulting process. It may suppress oviposition of adult females and reduce the viability of eggs. Applaud® is highly selective to most families of beneficial insects, including the parasitoid wasps, although it may affect early instars of some predatory ladybirds. Applaud® is registered

in over 40 countries around the world. Registrations include scales on citrus in the United States and Europe and scales and mealybugs in kiwi fruit and grapes in New Zealand.

Applaud® works more effectively if used in combination with predators and parasitoids. Applaud® inhibits the synthesis of chitin by suppressing the hormone that regulates the synthesis process. For insecticide resistance management, Applaud® is a Group 17A insecticide. This group is known as the Homopteran chitin biosynthesis inhibitors and are specific to that group of insects. To minimise the risk of resistance developing, a total of number of no more than two applications be made on a crop per season. Some naturally occurring insect biotypes resistant to Applaud® and other Group 17A insecticides may exist through normal genetic variability in any insect population. If Applaud® or other Group 17A insecticides are used repeatedly; the effectiveness of Applaud® on resistant individuals could be significantly reduced.

There are few insect management products available which offer both effective control of key pests (scales and mealybugs) and selectivity to many of the beneficial insects important in integrated pest management in tree crops. Applaud® has no significant effect on adult ladybirds but is known to be toxic to early instars of Crytolaemus ladybird. Applaud® may also affect egg hatch of these species for two to three weeks after application

7.7.6 Pyraclostrobin

Pyraclostrobin (Cabrio®) is a highly active, new generation strobilurin fungicide. While other products may only suppress disease, Cabrio® provides fast and long-lasting results that help to protect the quality of the custard apple crop. When Cabrio® is applied to the plant, some of the product penetrates the leaf surface within a short period of time (Plate 4). This quantity then diffuses within the leaf and starts to build a protective barrier against disease. Cabrio® remaining on the leaf surface then binds to form deposits on and within the waxy cuticle as a result of its lipophilic nature. These deposits act as reservoirs to release the product over time for ongoing protection.

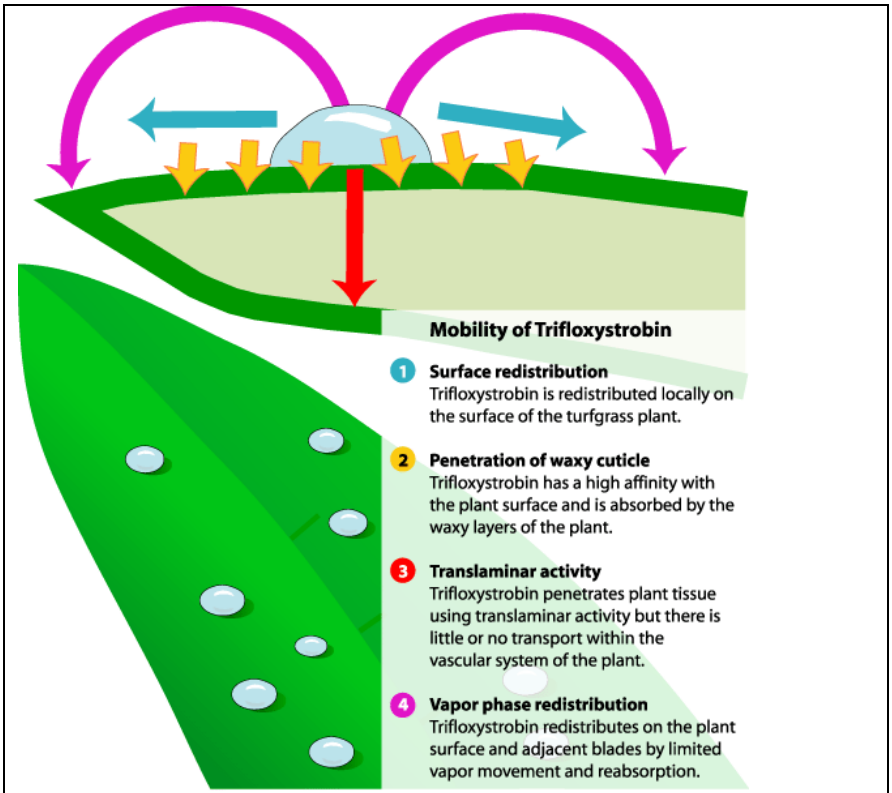

Plate 4. Mobility of a strobin fungicide. Photo courtesy of Prof. Paul Vincelli and Dennis Duross, University of Kentucky.

Cabrio® is ideal for use over the critical flowering and fruit development period when frequent rainfall may occur. This is due to Cabrio® being highly rain-fast once it has dried on the plant, with the product binding tightly to the waxy cuticle and having a high level of resistance to subsequent rainfall events. Field trials have shown that dew or light rainfall following application of Cabrio® will reactivate leaf deposits of the product, hence the period of protection against disease is optimised.

Optimum disease control is achieved when Cabrio® is applied evenly to the plant surface. In addition, translaminar activity means that Cabrio® will move between the leaf surfaces to provide a level of disease control on the unsprayed surface. Cabrio® is recommended for application from fruit set and for optimum results, should be applied in a preventive program of three sprays.
While a range of spray intervals is specified on the label, the shorter interval should be used when conditions favour disease development or during periods of rapid growth.

Cabrio® is a Group K Fungicide and is subject to an AVCARE fungicide resistance management strategy. A maximum of three applications of Cabrio® or any other Group K Fungicide should be applied in any one season. Cabrio® has a withholding period of 21 days.

7.8 WEATHER EFFECTS ON SPRAY EFFICACY AND PHYTOTOXICITY

Weather conditions at the time of pesticide application can greatly affect efficacy. Some considerations for effective application are presented below.

- Do not spray during high winds due to drift. Spray when conditions are calm or when there are very light winds which will increase spray turbulence and penetration.
- Do not spray when rain is eminent. Rainfall greater than 2 mm will reduce leaf retention. Most pesticides need at least 3-4 hours of drying to be effective.
- If the foliage is wet, or if water can be shaken from it, spraying should be delayed until conditions are drier.
- Do not spray when air temperatures are greater than 28°C. High temperatures favour rapid pesticide evaporation and drift and can greatly increase leaf and fruit burn particularly for pesticides such as oils and copper.
- Excessively low humidities, less than 60%, may increase rate of droplet evaporation and reduce efficacy. In contrast, do not spray under excessively high humidity (>80%) conditions as this can reduce the rate of pesticide drying and increase leaf and fruit burn.
- Spray either in the morning or afternoon but not too early or too late due to dew or condensation forming on leaves. Most custard apple growers suggest before 7.0 am and after 5.0 pm.
- Do not apply copper to wet fruit.
- Do not apply pesticides to stressed trees. Make sure trees are well irrigated.

7.9 PESTICIDE SAFETY

Most pesticides should be considered potentially hazardous. However, simple safety precautions can eliminate these hazards.

- Always read the label before handling
- Obtain, study and have on hand for emergencies the Material Safety Data Sheet for each chemical you use (suppliers of chemicals are legally required to supply these)
- Use chemicals only as directed
- Follow the label safety directions, including the use of safety equipment
- Be aware of how poisons can enter the body.
- Keep all chemicals in a secure location
- Store chemicals in original containers only
- Dispose of empty containers immediately and correctly

7.10 MATERIAL SAFETY DATA SHEETS

Material safety data sheets (MSDS) provide product safety information. Product suppliers are required to make these sheets available at the point of sale. If a sheet is not available, notify the product manufacturer and the state authority responsible for occupational health and safety.

7.11 MAXIMUM RESIDUE LIMITS (MRLS)

The Australian Pesticides and Veterinary Medicines Authority (APVMA) sets maximum residue limits (MRLs) for agricultural and veterinary chemicals in agricultural produce, particularly produce entering the food chain. These MRLs are set at levels which are not likely to be exceeded if the agricultural or veterinary chemicals are used in accordance with approved label instructions. At the time that the MRLs are set, the APVMA undertakes a dietary exposure evaluation to ensure that the levels do not pose an undue hazard to human health. The MRL Standard lists MRLs of substances which may arise from the approved use of those substances or other substances, and provides the relevant residue definitions to which these MRLs apply.

7.12 HOW PESTICIDES ENTER THE BODY

Dermal exposure (direct contact with the skin and absorption). Liquids are particularly hazardous and can lead to acute poisoning, especially when pesticide concentrate is handled (i.e. when mixing). Long-term exposure to chemicals as a result of spray drift or contact with recently sprayed plants can also lead to chronic poisoning. Dermal poisoning occurs when inadequate protective clothing is worn.

Inhalation. Inhaling chemicals, particularly dusts and fumigation vapours, can lead to acute (short-term and severe) poisoning and chronic (continuing over a long time) poisoning. Inhalation poisoning occurs when a suitable, properly maintained respirator is not worn.

Swallowing. Children under the age of five are most at risk of swallowing poisons, usually as a result of inadequate storage security or improper disposal of empty containers. Another often forgotten way that poison is ingested is by eating fruit too soon after pesticide application, which over time can lead to chronic poisoning. This is a result of not reading or following the label safety directions, in particular the withholding period.

7.13 COMMON SYMPTOMS OF POISONING

Acute poisoning symptoms often start within a few hours of exposure. Mild symptoms can include nausea, anxiety, sweating, and salivation; more severe symptoms can include vomiting, abdominal cramps, diarrhoea, urinary incontinence, vision impairments and respiratory difficulty. Chronic poisoning is much more insidious as symptoms often do not show up until some time after exposure.

7.14 FIRST AID INSTRUCTION AND SAFETY DIRECTIONS (FAISD) HANDBOOK

The First Aid Instruction and Safety Directions (FAISD) Handbook is a consolidation of the advice provided to the Australian Pesticides and Veterinary Medicines Authority (APVMA) by the Office of Chemical Safety (OCS) in the Office of Health Protection (OHP) of the Australian Government Department of Health and Ageing (DoHA), up to the date of amendment. The data on which these recommendations are based has been supplied largely by companies and persons seeking approval and registration of products from the APVMA. The

recommendations are intended to provide guidance to these parties in the approval of labels for agricultural and veterinary chemical products.

7.15 SPRAY ACCREDITATION

Spray accreditation can be obtained by attending a course provided by an accredited trainer. Accreditation is given to people with a valid ChemCert Australia certificate. At present, no other certification is recognised by the Australian Pesticides and Veterinary Medicines Authority (APVMA).

An authorised person is one who conducts the business of selling or supplying agricultural chemical products, or is a state-licensed spray contractor, or is Farmcare Australia certified. In current Queensland law, you only need training in safe use of chemicals if you are a contractor spraying on other people's land or if you want to buy restricted chemicals. However, most customers now see it as highly desirable for their growers to be able to demonstrate a safe, responsible use of chemicals. Spray accreditation must be renewed every five years.
Many rural training organisations offer courses in using farm chemicals. ChemCert is a national body that arranges training. Contact 02 6933 2177 or visit the ChemCert Australia web page: http://farrer.riv.csu.edu.au/chemcert

7.16 PESTICIDES AND THE ENVIRONMENT

Always consider the environment when you are applying pesticides. There are four main ways in which pesticides can pose a threat to the environment:

- Spray drift. This is usually the result of incorrect sprayer set-up or calibration (or sprayer type), or of spraying during inappropriate weather conditions. Calibrate your sprayer regularly.
- Excessive spray runoff. This is also usually the result of incorrect sprayer set-up or calibration (or sprayer type), or of spraying during inappropriate weather conditions. Inappropriate disposal of excess chemical (both concentrate and diluted) or empty containers. There are documented methods for safely disposing of pesticides and their containers. These can vary from state to state and some are legal requirements. All growers should be aware of their own local disposal regulations. Do not use empty pesticide containers for any other purpose.
- Inappropriate location of pesticide storage sheds, and fill-up and wash-down areas. The possibility of a spill occurring should be considered when locating these areas. An example of a potential hazard is locating these areas next to your water source, which could become contaminated in the event of a spill. If you must store chemicals close to a water source then ensure precautions are in place to contain and handle any spill.

7.17 DRUMMUSTER AND CHEMCLEAR®

DrumMUSTER is the national program for the collection and recycling of empty, cleaned, non-returnable metal and plastic farm chemical containers. Chemical users throughout Australia are encouraged to deliver their empty, cleaned containers to their local *DrumMUSTER* collection site on designated collection days at one of the 708 *DrumMUSTER* collection sites nationally.

Trained inspectors receive and inspect each drum on site ensuring that every drum delivered is clean and free of chemical residue and therefore safe to transport and suitable for recycling. Metal drums should be punctured from the top through the bottom and lids should be removed from all containers. Each container delivered to *DrumMUSTER* is recycled into useful everyday products such as street signs, irrigation piping, plant stakes and outdoor furniture.

DrumMUSTER provides:

- an environmentally responsible solution for chemical users to the problem of disposing their empty chemical containers
- helps property owners to keep their property clean of potential contamination
- encourages good farming practice and meets Quality Assurance obligations
- supports the preservation of the wider environment

DrumMUSTER is funded by a levy of 4 cents per litre or kilogram on drumMUSTER eligible non-returnable farm chemical containers over 1 litre or kilogram in content. For more information contact:

DrumMUSTER
GPO Box 816
CANBERRA ACT 2601
Tel: (02) 6230 6712
Fax: (02) 6230 6713
Email: drummuster@drummuster.com.au
Website: www.drummuster.com.au

ChemClear® is the national program for the collection and disposal of unwanted currently registered rural chemicals. The objective of the program is to minimise the accumulation of unwanted rural chemicals on farm which may create potential risks to the environment, public health and trade. There are two categories of ag and vet chemicals.

ChemClear® collects Group 1 chemicals which are currently registered products manufactured by participating companies signed to the Industry Waste Reduction Agreement. These products are collected free of charge. Group 2 chemicals are products manufactured by non-participating companies, or, deregistered, unknown, mixed or out of date products. A fee for disposal applies. The service is easy to use:

- The waste holder is required to take an inventory of their unwanted chemicals and register them for collection by free call 1800 008 182 or online at www.chemclear.com.au
- Once the booking is lodged and confirmed the waste holder is required to continue to store their products until a collection in their area is scheduled.
- Collections are organised by State or, by planned routes when registered bookings reach a quantity threshold.
- Collections are undertaken in the registered waste holder's Shire Council area.
- Prior to a collection the registered waste holder is contacted and advised of the retrieval location and date, an appointment time is also negotiated.
- Waste holders are required to transport their chemicals to their nominated collection site and meet the ChemClear® retrieval vehicle.

For more information on the program contact:

ChemClear®
Agsafe Limited
GPO Box 816
CANBERRA CITY ACT 2601
Tel: (02) 6230 4799
Fax: (02) 6230 4799
Freecall: 1800 008 182
Email: chemclear@agsafe.com.au
Website: www.chemclear.com.au

Both of these important industry stewardship programs are part of the Industry Waste Reduction Scheme (IWRS) which is managed by Agsafe Limited. The signatories to this agreement are CropLife Australia Limited, Animal Health Alliance, Veterinary Manufacturers and Distributors Association (VMDA), National Farmers' Federation (NFF) and Australian Local Government Association (ALGA).

CHAPTER 8

Pest and disease management programs

8.1 PEST AND DISEASE MANAGEMENT PROGRAMS

8.1.1 Introduction

This section outlines our current strategies and programs for controlling custard apple 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.

8.1.2 Weather conditions

We have observed an increase in fruit diseases on custard apples over the past 5 years. This is probably due to a build up of inoculum within orchards, an increase in neglected orchards or buid-up on host species growing nearby.

Disease activity will increase during years of above average rainfall (Figure 1) so spraying intensity will increase significantly. Rainfall can vary as much as from 1000 to 3000mm per season.

In addition, under warmer conditions, activity of insect pests can occur 2-3 months earlier than in cooler regions and the number of life cyles may also increase.

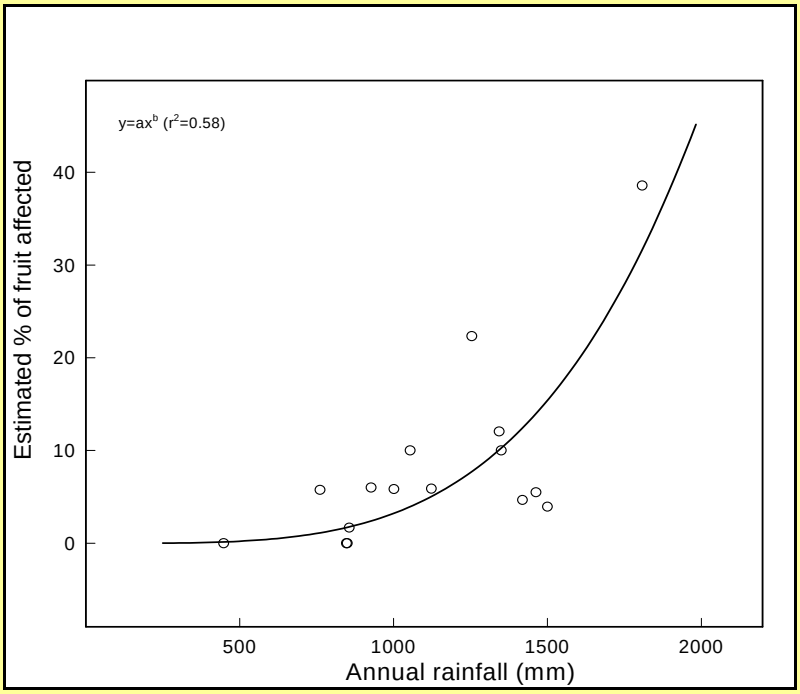

Figure 1. Relationship between annual rainfall for different districts/regions and incidence of anthracnose in custard apple (George and Redpath, 2009).

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, low 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 on 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.

Copper products generally show longer residual activity on fruit and higher rain fastness than fungicides such as mancozeb and pyraclostrobin e.g. Cabrio®. Currently copper oxychloride is the only formulation of copper registered for use on custard apple. Rain-fastness of some commonly used pesticides on custard apple is presented in Table 1.

TABLE 1.

Rain-fastness of some commonly used pesticides for custard apple. 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
Prodigy®	Do not apply if rainfall is expected within 6 hours

8.1.3 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.

8.1.3.1 Dormancy

- A key strategy in this period is to eliminate carry-over diseases and pests from the previous growing season.
- 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, Section 7.4.2).

- 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 will be highly beneficial for disease and pest control. (These management strategies are discussed in more detail in Chapter 6).

8.1.3.2 Budbreak and early flowering

- Commence routine fungicide sprays after fruit set. Note that some varieties such as 'African Pride' are more susceptible to fruit disease such as *Pseudocercospora* and *Cylindrocladium,* than are 'Pinks Mammoth' types.
- Depending on weather, apply sprays every three to four weeks, commencing at fruit set. We suggest that different chemicals should be rotated, to reduce the incidence of fungal resistance.
- One suggested rotation is Mancozeb®, Cabrio® and Biopest oil®. Biopest oil® also has anti-fungal activity and could be included in the rotation. Mancozeb® is compatible with Biopest oil so these two chemicals can be applied together. Then start again. Check labels to ensure that mixtures are compatible or contact the chemical company. Biopest oil® is effective against young mealybug and scales.
- Should there be a disease event in the interval between sprays (at least two days of wet and cloudy weather), bring the next scheduled spray forward.

8.1.3.3 Late flowering and early fruit development

- The main pest threat in spring is spotting bug. Damaged flowers and fruit up to marble size generally drop off. Fruit is most susceptible up to about tennis ball 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% or more fruit (4 fruit out of the 200 inspected) have fresh bug damage.

8.1.3.4 Late fruit development

- 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 spot spraying of the trunk and the immediate surrounding soil surface with chlorpyrifos, completes the ant management strategy (also see Chapter 4, Section 4.3). 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. At present, only two beneficial species are available. These are Cryptolaemus ladybirds and lacewings. Leptomastix wasps are no longer commercially available from suppliers.
- 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, copper oxychloride and DC-Tron petroleum oil.
- In autumn, Yellow Peach Moth may become a problem in some orchards. We recommend that Prodigy® is applied on first appearance of frass on fruit. Prodigy® is not harmful to predatory insects such as ladybirds or parasitoid wasps.

8.1.3.5 Fruit maturation and harvest period

- Queensland Fruit Fly presents its biggest danger during the fruit maturation period of March to May, especially for cv. African Pride. The strategy with controlling fruit fly is to reduce populations to very low levels very early in the season (also see Chapter 4, Section 4.9). To achieve this, either bait sprays must be applied early in the season, at least two months before commencement of harvest, or one or two cover sprays of Trichlorfon (Lepidex®) closer to harvest.
- 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™. We also suggest that cover sprays of Trichlorfon (Lepidex®) be applied if more than 30 fruit flies per trap. Cover sprays of Trichlorfon (Lepidex®) are effective but are highly disruptive to natural enemies of scales and mealybug. They should only be used to reduce initially high populations of fruit fly or during periods of high infestation of fruit fly.
- Pseudocercospora 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® and Cabrio® fungicide sprays are the most suitable response when diseases get out of hand.
- However, Cabrio® is more efficacious against these diseases than the other fungicides but only three applications are recommended per season to prevent build up of disease resistance. Therefore, the timing of Cabrio® sprays will be critical to maximise its effects. We suggest that the first two applications be used early in the season to prevent build-up of inoculum. The third application may be reserved for an outbreak of Pseudocercospora spp. after a period of prolonged wet weather (4 -7 days or more) in autumn. Mulching under trees to reduce soil splash and the annual removal of dead twigs and mummified fruit are important cultural control measures.

8.2 PEST AND DISEASE CONTROL SCHEDULES

Pest and disease control schedules for the various regions - northern and central Queensland (8.2.1), South-east Queensland (8.2.2) and Northern NSW (8.2.3) are presented in Tables 2-4. These schedules are provided as a guide only. Read pesticide labels for information on useage.

TABLE 2.

(8.2.1) Guide only: Tentative pest and disease control schedule for custard apple in northern and central Queensland. Timing of application of pesticides should be based on monitoring and action levels and will vary with stage of growth and weather conditions (see foot notes).

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING AND RELEASE OF BENEFICIALS	COMMENTS
August	1	Dormancy	Scales, mealybug	1 x Petroleum oil	Carry over leaf &fruit diseases.	1 x Copper oxychloride	Monitor	The strategy here is to eliminate as much carry over disease and pests as possible by applying copper and oils. Remove and mulch prunings. Do not spray oils when temperatures exceed 30°C.
	2	Dormancy	Scales, mealybug	1 x methidathion e.g. Supracide® (optional)	Carry over leaf& fruit diseases.		Monitor	Apply methidathion only if scale pressure is high. Methidathion will kill beneficials.
	3	Dormancy	Scales, mealybug	1 x Petroleum oil	Carry over leaf& fruit diseases.	1 x Copper oxychloride	Monitor	Apply copper only during dormancy and early flowering only as it can leave residues on the fruit.
	4	Leaf drop+ early budbreak	Scales, mealybug	1 x methidathion e.g. Supracide® (optional)	Carry over leaf& fruit diseases.		Monitor	Apply methidathion only if scale pressure is high. Methidathion will kill beneficials.
September	1	Leaf drop+ early budbreak	Scales, mealybug, ants	Apply trunk bands for ant control	Carry over leaf &fruit diseases.	1 x Mancozeb®	Monitor	By controlling ants can greatly reduce mealybug and scale populations
	2	Leaf drop+ early budbreak	Scales, mealybug, ants		Carry over leaf &fruit diseases.		Monitor	
	3	Leaf drop+ early budbreak	Scales, mealybug, ants		Carry over leaf &fruit diseases.		Monitor	

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING AND RELEASE OF BENEFICIALS	COMMENTS
	4	Leaf drop+ early budbreak	Fruit spotting bugs, Scales, mealybug, ants	1 x methidathion e.g. Supracide®	Carry over leaf &fruit diseases.		Monitor for fruit spotting bug	Spray methidathion if more than 2% of fruit damaged with spotting bug. If possible, spray hot spots only.
October	1	Late budbreak	Fruit spotting bugs Scales, mealybug		Carry over of leaf and fruit diseases on new seasons growth		Monitor for fruit spotting bug	
	2	Late budbreak	Fruit spotting bugs Scales, mealybug			1 x Mancozeb®	Monitor for fruit spotting bug	
	3	Late budbreak	Fruit spotting bugs Scales, mealybug	1 x methidathion e.g. Supracide®			Monitor for fruit spotting bug	Methadathion will kill most beneficials.
	4	Late budbreak	Fruit spotting bugs Scales, mealybug				Monitor for fruit spotting bug	
November	1	Flowering	Fruit spotting bugs, scales, mealybug, mites	1 x Applaud® or if pressure high 1 x methidathion e.g Supracide® Set out fruit fly cue lure traps for monitoring	Pseudocercospora spp. Antracnose	1 x Octave®	Commence monitoring for fruit fly, Check for beneficials.	Applaud® is only effective on crawlers not adults. If scale or mealybugs are isolated to selected trees, use hot spot sprays of methidathion. If 25% of sampled fruit have one or more large mealybugs cover spray with methidathion . Use Cue lure traps to monitor fruit fly and to kill male fruit fly. The aim is to reduce early season fly populations.

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING AND RELEASE OF BENEFICIALS	COMMENTS
	2	Flowering	Fruit spotting bugs, scales, mealybug, mites	1 x methidathion e.g. Supracide®	Pseudocercospora spp.	1 x Mancozeb®	Commence monitoring for fruit fly and fruit spotting bug	If possible, alternate Mancozeb®, Cabrio® sprays to prevent build up of disease resistance but max. of 3 sprays of Cabrio® per season. Spray methidathion if more than 2% of fruit damaged with spotting bug. If possible, spray hot spots only.
	3	Flowering	Fruit spotting bugs, scales, mealybug, mites		Pseudocercospora spp.		Commence monitoring for fruit fly and fruit spotting bug	
	4	Flowering	Fruit spotting bugs, scales, mealybug, mites Mealybug	1 x methidathion e.g. Supracide® Samurai® (soil/trunk drench)	Pseudocercospora spp. Antracnose	1 x Cabrio® 1 x Octave®	Commence monitoring for fruit fly and fruit spotting bug	Start applying fungicides when fruit are pea size. If possible, alternate Mancozeb® and Cabrio® sprays to prevent build up of disease resistance but max. of 3 sprays of Cabrio® per season. Strategically apply first Cabrio® spray before start of wet season. Methidathion will kill most beneficials.
December	1	Flowering	Fruit spotting bugs, scales, mealybug, mites	1 x Applaud or if pressure high 1 x methidathion e.g Supracide®	Pseudocercospora spp.		Commence monitoring for fruit fly and fruit spotting bug	

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING AND RELEASE OF BENEFICIALS	COMMENTS
	2	Flowering	Fruit spotting bugs, scales, mealybug, mites		Pseudocercospora spp.	1 x Mancozeb	Check beneficials, If not applying methidathion, release Leptomastixs 10000 wasps/ha Commence monitoring for fruit fly and fruit spotting bug	.
	3	Flowering	Fruit spotting bugs, scales, mealybug, mites		Pseudocercospora spp.			Avoid sprays of methidathion or Lebaycid® at time of release of Leptomastixs/lacewings.
	4	Flowering	Fruit spotting bugs, scales, mealybug, mites		Pseudocercospora spp.	1 x Mancozeb®	Commence monitoring for fruit fly and fruit spotting bug	
January	1	Fruit development	Fruit spotting bugs, mealy bugs, scale, fruit fly, yellow peach moth	1 x Prodigy® 1 x methidathion e.g Supracide® 1 x Fruit fly bait spray or	Pseudocercospora spp Anthracnose.	1 x Octave®	Monitor	The strategy to control fruit fly is to reduce populations early in the season. Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap. Summer prune if leaf density too great. Apply Prodigy® for control of yellow peach moth if frass is visible on fruit.
	2	Fruit development	Fruit spotting bugs, mealy bugs, scale, fruit fly,	1 x Fruit fly bait spray or	Pseudocercospora spp.	1 x Cabrio®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING AND RELEASE OF BENEFICIALS	COMMENTS
			yellow peach moth					fruit flies in lure trap.
	3	Fruit development	Fruit spotting bugs, mealy bugs, scale, fruit fly, yellow peach moth	1 x Fruit fly bait spray or	Pseudocercospora spp.		Release lacewings at 2 000 larvae per hectare Release 25 adult Crytolaemus ladybirds per tree	If possible, do not apply methidathion within 30 days after release of ladybirds. If necessary, spray hot spots only. Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	4	Fruit development	Fruit spotting bugs, mealy bugs, scale, fruit fly, yellow peach moth	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp.	1 x Mancozeb	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
February	1	Fruit development	Fruit spotting bug mealy bugs, scale, fruit fly, yellow peach moth	1 x or Prodigy®	Pseudocercospora spp., anthracnose, other fruit diseases		Monitor	Apply Prodigy® for control of yellow peach moth if frass is visible on fruit. Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	2	Fruit development	Fruit spotting bugs, mealy bugs, scale, fruit fly, yellow peach moth	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, other fruit diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	3	Fruit development	Fruit spotting bugs, mealy bugs, scale, fruit fly, yellow peach moth	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING AND RELEASE OF BENEFICIALS	COMMENTS
	4	Early harvest	Fruit spotting bugs, mealy bugs, scale, fruit fly, yellow peach moth	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, other fruit diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
March	1	Early harvest	Fruit fly, mealy bugs, scale, yellow peach moth	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	2	Early harvest	Fruit fly, mealy bugs, scale,	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, other fruit diseases	1 x Cabrio®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	3	Early harvest	Fruit fly, mealy bugs, scale,	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	4	Early harvest	Fruit fly, mealy bugs, scale,	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, other diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
April	1	Mid-harvest	Fruit fly, mealybugs	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING AND RELEASE OF BENEFICIALS	COMMENTS
	2	Mid-harvest	Fruit fly, mealybugs	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	3	Mid-harvest	Fruit fly, mealybugs	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	4	Mid-harvest	Fruit fly, mealybugs	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
May	1	Late-harvest	Fruit fly	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	2	Late-harvest	Fruit fly	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	3	Late-harvest	Fruit fly	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	4	Late-harvest	Fruit fly	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING AND RELEASE OF BENEFICIALS	COMMENTS
June	1	Late harvest	Fruit fly	1 x Fruit fly bait spray	Pseudocercospora spp., anthracnose black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	2	Dormancy	Fruit fly	1 x Fruit fly bait spray		1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	3	Dormancy	Fruit fly	1 x Fruit fly bait spray			Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	4	Dormancy	Fruit fly	1 x Fruit fly bait spray		1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
July	1	Dormancy	Scales, mealybug,		Carry over leaf &fruit diseases.		Monitor	
	2	Dormancy	Scales, mealybug,		Carry over leaf& fruit diseases.		Monitor	
	3	Dormancy	Scales, mealybug,		Carry over leaf& fruit diseases.		Monitor	
	4	Dormancy	Scales, mealybug,		Carry over leaf& fruit diseases.	1 x Copper oxychloride	Monitor	Remove diseased fruit and mulch prunings

Notes

Applaud®: Applaud® is only effective against crawlers. It will not be effective if adults are also present. Applaud should not be applied more than twice per season. 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

Biopest oil®: North Queensland growers suggest not to use Biopest oils under semi-tropical conditions due to the possibility of burn at temperatures greater than 28°C.

Cabrio®: Cabrio® should not be applied more than three times per season to prevent build up of disease resistance. Alternate Cabrio® and Mancozeb®.

Leptomastix wasps, Crytolaemus ladybirds and lacewings: These are available from Bugs for Bugs. info@bugsforbugs.com.au. Releases of Crytolaemus ladybirds too early or too late in the season will be ineffective. The optimum time to release is mid-January to mid-February. For lacewings, these should ideally be released in November at a rate of 2 000 larvae per hectare. A second release should be made 2 weeks later. Methidathion is toxic to beneficials. Release insects at least 1 week after last insecticidal spray and avoid spraying for at least 4 weeks if possible.

Fruit spotting bug: Spray methidathion if no. trees with live bugs >0.5% and no. trees with freshly stung fruit >2.5%. In north Queensland commence spraying in September.

Mealybug: 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).

Number of fungicide sprays: The number of fungicide sprays will vary from season to season. For dry seasons sprays may need to be applied every 4-6 weeks, in wet seasons, fortnightly.

Queensland fruit fly: In November comence monitoring for fruit fly using Cue lure traps to kill male flies. Aim to reduce fruit fly populations early in the season. For ICA 18 certification, apply bait sprays at a maximum interval of every seven days (or cover sprays every 14 days) from six weeks prior to commencing harvest to the completion of harvest. We also suggest that bait sprays should be applied if >15 flies in cue lure trays. Use either standard bait or Naturalure Fruit Fly Bait™. Apply cover sprays of Lebaycid® if more than 30 flies per trap or as per ICA 18 regulations.

Spray compatibilities: Always follow directions as per labels and check with manufacturers. Biopest oil is compatible with mancozeb.

Yellow Peach Moth: Apply Prodigy® on first appearance of frass on fruit – usually in February or March.

TABLE 3.

(8.2.2) Guide only: Tentative pest and disease control schedule for custard apple in south-east Queensland. Timing of application of pesticides should be based on monitoring and action levels and will vary with stage of growth and weather conditions (see foot notes).

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING AND RELEASE OF BENEFICIALS	COMMENTS
August	1	Dormancy	Scales, mealybug	1 x Petroleum oil	Carry over leaf &fruit diseases.	1 x Copper oxychloride	Monitor	The strategy here is to eliminate as much carry over disease and pests as possible by applying copper and oils. Remove or mulch prunings. Do not spray oils when temperatures exceed 30°C.
	2	Dormancy	Scales, mealybug	1 x methidathion e.g. Supracide® (optional)	Carry over leaf& fruit diseases.		Monitor	Apply methidation only if scale pressure is high. It will kill beneficials.
	3	Dormancy	Scales, mealybug	1 x Petroleum oil	Carry over leaf& fruit diseases.	1 x Copper oxychloride	Monitor	Apply copper during dormancy and early flowering only as it can leave residues on the fruit.
	4	Dormancy	Scales, mealybug	1 x methidathion e.g. Supracide® (optional)	Carry over leaf& fruit diseases.		Monitor	Apply methidation only if scale pressure is high. It will kill beneficials.
September	1	Leaf drop+ early budbreak	Scales, mealybug, ants	Apply trunk bands for ant control	Carry over leaf &fruit diseases.	1 x Mancozeb®	Check for beneficials	By controlling ants can greatly reduce mealybug and scale populations. In wet seasons, start application of fungiicdes early.
	2	Leaf drop+ early budbreak	Scales, mealybug, ants		Carry over leaf &fruit diseases.		Monitor	
	3	Leaf drop+ early budbreak	Scales, mealybug, ants		Carry over leaf &fruit diseases.		Monitor	

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING AND RELEASE OF BENEFICIALS	COMMENTS
	4	Leaf drop+ early budbreak	Scales, mealybug, ants		Carry over leaf &fruit diseases.		Monitor	
October	1	Late budbreak	Scales, mealybug		Carry over of leaf and fruit diseases on new seasons growth		Check for beneficials	
	2	Late budbreak	Scales, mealybug			1 x Mancozeb®	Monitor	If possible, alternate Mancozeb®, Biopest oil® and Cabrio® sprays to prevent build up of disease resistance but max. of 3 sprays of Cabrio® and 4 sprays of Biopest ® per season. Biopest oil also has anti-fungal activity.
	3	Late budbreak	Scales, mealybug				Monitor	
	4	Late budbreak	Scales, mealybug					
November	1	Flowering	Scales, mealybug, mites, fruit spotting bug	1 x Biopest oil 1 x Applaud® or if pressure high 1 x methidathion Set out fruit fly cue lure traps for monitoring.	Pseudocercospora spp. Anthracnose	Octave®	Commence monitoring for fruit spotting bug	Biopest oil also has anti-fungal activity. Do not apply Biopest oil if temperature >28°C. Use Cue lure traps to monitor fruit fly and to kill male fruit fly. The aim is to reduce early season fly populations. Applaud® is only effective on crawlers not adults. If scale or mealybugs are isolated to selected trees, use hot spot sprays of methidathion. If 25% of sampled fruit have one or more large mealybugs cover spray with methidathion.

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING AND RELEASE OF BENEFICIALS	COMMENTS
	2	Flowering	Fruit spotting bugs, scales, mealybug, mites		Pseudocercospora spp.	1 x Mancozeb®	Commence monitoring for fruit spotting bugs	
	3	Flowering	Fruit spotting bugs, scales, mealybug, mites	1 x methidathion e.g Supracide®	Pseudocercospora spp.		Commence monitoring for fruit spotting bugs	
	4	Flowering	Fruit spotting bugs, scales, mealybug, mites		Pseudocercospora spp.	1 x Cabrio®	Commence monitoring for fruit spotting bugs	
December	1	Flowering	Fruit spotting bugs, scales, mealybug, mites Mealybugs	1 x Applaud® or if needed 1 x methidathion e.g Supracide® 1 x Biopest oil® Samurai®	Pseudocercospora spp. Anthracnose	Octave®	Commence monitoring for fruit fly and spotting bugs. Check for beneficials.	Applaud® is only effective on crawlers not adults. If scale or mealybugs are isolated to selected trees, use hot spot sprays of methidathion. If 25% of sampled fruit have one or more large mealybugs cover spray with methidathion e.g. Supracide®. With fruit fly, the objective is to reduce populations to low levels early in the season. Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap. Apply Lebaycid fortnightly for ICA 18 or if >30 fruit flies per lure trap.

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING AND RELEASE OF BENEFICIALS	COMMENTS
	2	Flowering	Fruit spotting bugs, scales, mealybug, mites	1x Biopest oil or if needed 1 x methidathion e.g Supracide®	Pseudocercospora spp.	1 x Mancozeb®	Commence monitoring for fruit fly and spotting bugs. If grower is not sprayng methidathion release Leptomastixs 10000 wasps/ha	Spray methidathion if more than 2% of fruit damaged with spotting bug. If possible, spray hot spots only. Start applying fungicides when fruit are pea size. Apply no more than 3 Cabrio® sprays per season. Strategically apply first Cabrio® spray before wet season.
	3	Flowering	Fruit spotting bugs, scales, mealybug, mites		Pseudocercospora spp.		Monitor for fruit fly and spotting bugs	
	4	Flowering	Fruit spotting bugs, scales, mealybug, mites , yellow peach moth	1 x methidathion e.g Supracide® if needed	Pseudocercospora spp.	1 x Mancozeb®	Avoid spraying methidathion if released Leptomastixs	Methadation will kill beneficials.If possible do not apply within 30 days of release of Leptomastix.
January	1	Flowering + fruit development	Fruit spotting bugs, mealy bugs, scale, fruit fly, yellow peach moth		Pseudocercospora spp.			Summer prune if leaf density too great
	2	Flowering + fruit development	Fruit spotting bugs, mealy bugs, scale, fruit fly, yellow peach moth	1 x Prodigy®	Pseudocercospora spp.	1 x Cabrio®	Monitor	Apply Prodigy® for control of yellow peach moth if frass is visible on fruit.
	3	Flowering+ fruit development	Fruit spotting bugs, mealy bugs, scale, fruit fly, yellow peach moth		Pseudocercospora spp.		Release 25 adult Crytolaemus ladybirds per tree. Release lacewings at 2 000 larvae per hectare.	If possible, do not apply methidathion within 30 days after release of lacewings. If necessary, spray hot spots only.

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING AND RELEASE OF BENEFICIALS	COMMENTS
	4	Flowering + fruit development	Fruit spotting bugs, mealy bugs, scale, fruit fly, yellow peach moth	1 x Fruit fly bait spray or	Pseudocercospora spp.	1 x Mancozeb®		
February	1	Fruit development	Fruit spotting bug, mealy bugs, scale, fruit fly, yellow peach moth	1 x Biopest oil® 1 x Prodigy® 1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, other fruit diseases	Octave®	Monitor	Apply Prodigy® for peach moth if frass is visible. Do not apply Biopest oil® if temperature >28°C. Apply bait sprays weekly for ICA 18 or when more than 15 fruit flies in trap.
	2	Fruit development	Fruit spotting bugs, mealy bugs, scale, fruit fly, yellow peach moth	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, other fruit diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap..
	3	Fruit development	Fruit spotting bugs, mealy bugs, scale, fruit fly, yellow peach moth	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	4	Fruit development	Fruit spotting bugs, mealy bugs, scale, fruit fly, yellow peach moth	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, other fruit diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
March	1	Fruit development	Fruit fly, mealy bugs, scale, yellow peach moth	1 x Biopest oil® 1 x Fruit fly bait spray or 1 x Prodigy®	Pseudocercospora spp., anthracnose, other fruit diseases		Monitor	Do not apply Biopest oil if temperature >28°C. Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	2	Fruit development	Fruit fly, mealy bugs, scale,	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, other fruit diseases	1 x Cabrio®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING AND RELEASE OF BENEFICIALS	COMMENTS
	3	Fruit development	Fruit fly, mealy bugs, scale,	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	4	Fruit development	Fruit fly, mealy bugs, scale,	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp. anthracnose, other diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
April	1	Early harvest	Fruit fly, mealybugs	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	2	Early harvest	Fruit fly, mealybugs	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	3	Early harvest	Fruit fly, mealybugs	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	4	Early harvest	Fruit fly, mealybugs	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
May	1	Mid-harvest	Fruit fly, mealybugs	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING AND RELEASE OF BENEFICIALS	COMMENTS
	2	Mid-harvest	Fruit fly, mealybugs	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	3	Mid-harvest	Fruit fly, mealybugs	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	4	Mid-harvest	Fruit fly, mealybugs	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
				1 x Fruit fly bait spray or cover spray				Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
June	1	Late harvest	Fruit fly	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	2	Late harvest	Fruit fly	1 x Fruit fly bait spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	3		Fruit fly	1 x Fruit fly bait spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	4	Late harvest	Fruit fly	1 x Fruit fly bait spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING AND RELEASE OF BENEFICIALS	COMMENTS
							Monitor	
July	1	Completion of harvest - dormancy	Scales, mealybug,	1 x Fruit fly bait spray	Carry over leaf &fruit diseases.		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	2	Dormancy	Scales, mealybug,		Carry over leaf& fruit diseases.		Monitor	
	3	Dormancy	Scales, mealybug,		Carry over leaf& fruit diseases.		Monitor	
	4	Dormancy	Scales, mealybug,		Carry over leaf& fruit diseases.	1 x Copper oxychloride	Monitor	Remove diseased fruit and prunings.

Notes

Applaud®: Applaud® is only effective against crawlers. It will not be effective if adults are also present. It should not be applied more than twice per season. 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

Biopest oil®: Do not apply Biopest oils at temperatures greater than 28°C. Do not apply more than four Biopest oil sprays per season with two weeks minimum application interval.

Cabrio®: Cabrio® should not be applied more than three times per season to prevent build up of disease resistance. Alternate Mancozeb®, Cabrio® and Biopest oil®.

Leptomastix wasps, Crytolaemus ladybirds and lacewings: These are available from Bugs for Bugs. info@bugsforbugs.com.au. Releases of Crytolaemus ladybirds too early or too late in the season will be ineffective. The optimum time to release is mid-January to mid-February. For lacewings, these should ideally be released in November at a rate of 2 000 larvae per hectare. A second release should be made 2 weeks later. Methidathion is toxic to beneficials. Release insects at least 1 week after last insecticidal spray and avoid spraying for at least 4 weeks if possible.

Fruit spotting bug: Spray methidathion if no. trees with live bugs >0.5% and no. trees with freshly stung fruit >2.5%.

Mealybug: 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).

Number of fungicide sprays: The number of fungicide sprays will vary from season to season. For dry seasons sprays may need to be applied every 4-6 weeks, in wet seasons, fortnightly.

Queensland fruit fly: In November comence monitoring for fruit fly using Cue lure traps to kill male flies. Aim to reduce fruit fly populations early in the season. For ICA 18 certification, apply bait sprays at a maximum interval of every seven days (or cover sprays every 14 days) from six weeks prior to commencing harvest to the completion of harvest. We also suggest that bait sprays should be applied if >15 flies in cue lure trays. Use either standard bait or Naturalure Fruit Fly Bait™. Apply cover sprays of Lebaycid® if more than 30 flies per trap or as per ICA 18 regulations.

Spray compatibilities: Always follow directions as per labels and check with manufacturers. Biopest oil is compatible with mancozeb.

Yellow Peach Moth: Apply Prodigy® on first appearance of frass on fruit.

TABLE 4.

(8.2.3) Guide only: Tentative pest and disease control schedule for custard apple in northern NSW. Timing of application of pesticides should be based on monitoring and action levels and will vary with stage of growth and weather conditions (see foot notes).

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING	COMMENTS
October	1	Dormancy/leaf drop	Scales, mealybug,	1 x Petroleum oil	Carry over leaf &fruit diseases.	1 x Copper oxychloride	Monitor	The strategy here is to eliminate as much carry over disease and pests as possible by applying copper and oils. Remove and mulch prunings. Do not spray oils when temperatures exceed 28°C.
	2	Dormancy/leaf drop	Scales, mealybug, ants	1 x methidathion e.g. Supracide® (optional) Apply trunk bands for ant control	Carry over leaf& fruit diseases.		Monitor	By controlling ants can greatly reduce mealybug and scale populations. Apply methidathion only if scale pressure is high. It will kill beneficials.
	3	Dormancy/leaf drop	Scales, mealybug, ants	1 x Petroleum oil	Carry over leaf& fruit diseases.	1 x Copper oxychloride	Monitor	Apply copper during dormancy and early flowering only as it can leave residues on the fruit.
	4	Dormancy/leaf drop	Scales, mealybug, ants	1 x methidathion e.g. Supracide® (optional)	Carry over leaf& fruit diseases.		Monitor	Apply methidathion only if scale pressure is high.

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING	COMMENTS
November	1	Leaf drop+early budbreak	Scales, mealybug	1 x Biopest oil	Carry over leaf &fruit diseases.		Check for beneficials.	Don't spray Biopest oil® if temperature>28°C. Do not apply methidathion within 30 days after release of ladybirds. If possible, spray hot spots only.
	2	Leaf drop+early budbreak	Scales, mealybug		Carry over leaf &fruit diseases.	1 x Mancozeb®	Monitor	If possible, alternate Mancozeb®, Biopest oil® and Cabrio® sprays to prevent build up of disease resistance but max. of 3 sprays of Cabrio® per season. Biopest oil® also has anti-fungal activity.
	3	Leaf drop+early budbreak	Scales, mealybug		Carry over leaf &fruit diseases.		Monitor	Start applying fungicides when fruit are pea size.
	4	Leaf drop+early budbreak	Scales, mealybug		Carry over leaf &fruit diseases.		Monitor	
December	1	Late budbreak + flowering	Scales, mealybug, mites, fruit spotting bug		Carry over of leaf and fruit diseases on new seasons growth		Commence monitoring for fruit spotting bug.	
	2	Late budbreak+ flowering	Scales, mealybug, mites, fruit spotting bug	1 x Biopest oil® 1 x Applaud® or if pressure high 1 x methidathion e.g.Supracide®	Pseudocercospora spp. Anthracnose	1 x Mancozeb® Octave®	Commence monitoring for fruit spotting bug. Check for beneficials.	Applaud® is only effective on crawlers not adults. If scale or mealybugs are isolated to selected trees, use hot spot sprays of methidathion. If 25% of sampled fruit have one or more large mealybugs treat with methidathion.

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING	COMMENTS
	3	Late budbreak+ flowering	Fruit spotting bugs, scales, mealybug, mites				Commence monitoring for fruit spotting bug.	Spray methidathion if more than 2% of fruit damaged with spotting bug. If necessary, hot spot spraying only.
	4	Late budbreak+ flowering	Fruit spotting bugs, scales, mealybug, mites	Set out fruit fly cue lure traps for monitoring.		1 x Mancozeb®	Commence monitoring for fruit spotting bug.	Use Cue lure traps to monitor fruit fly and to kill male fruit fly. The aim is to reduce early season fly populations.
January	1	Flowering+ fruit development	Fruit spotting bugs, scales, mealybug, mites, yellow peach moth Samurai®	1 x Biopest oil® 1 x Prodigy® Mealybug	Pseudocercospora spp. Anthracnose	Octave®	Commence monitoring for fruit spotting bug. If not sprayng methidathion release Leptomastixs 10000 wasps/ha	Don't spray Biopest oil if temperature>28°C. Apply Prodigy® for control of yellow peach moth if frass is visible on fruit. Summer prune if leaf density too great
	2	Flowering+ fruit development	Fruit spotting bugs, scales, mealybug, mites, yellow peach moth	1 x Applaud® or if pressure high 1 x methidathion	Pseudocercospora spp.	1 x Cabrio®	Commence monitoring for fruit fly and fruit spotting bug .	Apply no more than 3 Cabrio® sprays per season. With fruit fly, the objective is to reduce populations to low levels early in the season. Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap. Apply Lebaycid® fortnightly for ICA 18 or if >30 fruit flies per lure trap.
	3	Flowering+ fruit development	Fruit spotting bugs, scales, mealybug, mites, yellow peach moth		Pseudocercospora spp.		Release lacewings at 2 000 larvae/ha. Release 25 adult Crytolaemus ladybirds per tree	If possible, do not apply methidathion within 30 days after release of lacewings Methidathion will kill beneficials.

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING	COMMENTS
	4	Flowering+ fruit development	Fruit spotting bugs, scales, mealybug, mites, yellow peach moth		Pseudocercospora spp. Anthracnose	1 x Mancozeb® Octave®		
February	1	Flowering+ fruit development	Fruit spotting bugs, fruit fly, yellow peach moth		Pseudocercospora spp.		Commence monitoring for fruit fly and spotting bug	
	2	Flowering+ fruit development	Fruit spotting bugs, fruit fly, yellow peach moth		Pseudocercospora spp.	1 x Mancozeb®	Commence monitoring for fruit fly and spotting bug	
	3	Flowering+ fruit development	Fruit spotting bugs, fruit fly	1 x Biopest oil® 1 x methidathion	Pseudocercospora spp.		Commence monitoring for fruit fly and spotting bug	Don't spray Biopest oil® if temperature>28°C.
	4	Flowering+ fruit development	Fruit spotting bugs, fruit fly, yellow peach moth		Pseudocercospora spp.	1 x Mancozeb®	Commence monitoring for fruit fly and spotting bug	
March	1	Fruit development	Mealy bugs, scale, fruit fly, yellow peach moth	1 x Prodigy®	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply Prodigy® for control of yellow peach moth if frass is visible on fruit. Summer prune if leaf density too great
	2	Fruit development	Mealy bugs, scale, fruit fly, yellow peach moth		Pseudocercospora spp., anthracnose, black canker, other fruit diseases	1 x Cabrio®	Monitor	

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING	COMMENTS
	3	Fruit development	Mealy bugs, scale, fruit fly, yellow peach moth	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	
	4	Fruit development	Mealy bugs, scale, fruit fly, yellow peach moth	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap. Apply Lebaycid® fortnightly for ICA 18 or if >30 fruit flies per lure trap.
April	1	Fruit development	Mealy bugs, scale, fruit fly, yellow peach moth	1 x Biopest oil® 1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Don't spray Biopest oil if temperature>28°C. Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap. Apply Lebaycid® fortnightly for ICA 18 or if >30 fruit flies per lure trap.
	2	Fruit development	Mealy bugs, scale, fruit fly, yellow peach moth	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap. Apply Lebaycid® fortnightly for ICA 18 or if >30 fruit flies per lure trap.

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING	COMMENTS
	3	Fruit development	Mealy bugs, scale, fruit fly, yellow peach moth	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap. Apply Lebaycid ® fortnightly for ICA 18 or if >30 fruit flies per lure trap.
	4	Fruit development	Mealy bugs, scale, fruit fly, yellow peach moth	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap. Apply Lebaycid® fortnightly for ICA 18 or if >30 fruit flies per lure trap.
May	1	Fruit development + early harvest	Fruit fly, mealy bugs, scale, yellow peach moth	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	2	Fruit development + early harvest	Fruit fly, mealy bugs, scale	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases	1 x Cabrio®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	3	Fruit development + early harvest	Fruit fly, mealy bugs, scale	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	4	Fruit development + early harvest	Fruit fly, mealy bugs, scale,	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp. anthracnose, black canker, other fruit diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
June	1	Early harvest	Fruit fly, mealybugs, scale	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker,		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING	COMMENTS
					other fruit diseases			more than 15 fruit flies in lure trap.
	2	Early harvest	Fruit fly, mealybugs	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	3	Early harvest	Fruit fly, mealybugs	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	4	Early harvest	Fruit fly, mealybugs	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp.,anthracnose, black canker, other fruit diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
July	1	Mid-harvest	Fruit fly	1 x Fruit fly bait spray or cover spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	2	Mid-harvest	Fruit fly	1 x Fruit fly bait spray	Pseudocercospora spp., anthracnose black canker, other fruit diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	3	Mid-harvest	Fruit fly	1 x Fruit fly bait spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	4	Mid-harvest	Fruit fly	1 x Fruit fly bait spray	Pseudocercospora spp., anthracnose black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.

MONTH	WEEK	STAGE OF GROWTH	PEST ACTIVITY	PESTICIDE	DISEASE ACTIVITY	FUNGICIDE	MONITORING	COMMENTS
August	1	Late harvest	Fruit fly	1 x Fruit fly bait spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	2	Late harvest	Fruit fly	1 x Fruit fly bait spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	3	Late harvest	Fruit fly	1 x Fruit fly bait spray	Pseudocercospora spp., anthracnose		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	4	Late harvest	Fruit fly	1 x Fruit fly bait spray	Pseudocercospora spp., anthracnose, black canker, other fruit diseases		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
September	1	Late harvest	Fruit fly, scales, mealybug,	1 x Fruit fly bait spray	Carry over leaf &fruit diseases.		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	2	Late harvest	Fruit fly, scales, mealybug,	1 x Fruit fly bait spray	Carry over leaf& fruit diseases.		Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap.
	3	Late harvest	Fruit fly, scales, mealybug,	1 x Fruit fly bait spray	Carry over leaf& fruit diseases.		Monitor	
	4	Late harvest	Fruit fly, scales, mealybug,	1 x Fruit fly bait spray	Carry over leaf& fruit diseases.	1 x Mancozeb®	Monitor	Apply fruit fly bait sprays weekly for ICA 18 or when more than 15 fruit flies in lure trap. remove diseased fruit.

Notes

Applaud®: Applaud® is only effective against crawlers. It will not be effective if adults are also present. Applaud® should not be applied more than twice per season. 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

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Cabrio®: Cabrio® should not be applied more than three times per season to prevent build up of resistance. Alternate Mancozeb®, Cabrio® and Biopest oil®.

Leptomastix wasps, Crytolaemus ladybirds and lacewings: These are available from Bugs for Bugs. info@bugsforbugs.com.au. Releases of Crytolaemus ladybirds too early or too late in the season will be ineffective. The optimum time to release is mid-January to mid-February. For lacewings, these should ideally be released in November at a rate of 2 000 larvae per hectare. A second release should be made 2 weeks later. Methidathion is toxic to beneficials. Release insects at least 1 week after last insecticidal spray and avoid spraying for at least 4 weeks if possible.

Fruit spotting bug: Spray methidathion if no. trees with live bugs >0.5% and no. trees with freshly stung fruit >2.5%.

Mealybug: 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).

Queensland fruit fly: In late December comence monitoring for fruit fly using Cue lure traps to kill male flies. Aim to reduce fruit fly populations early in the season. For ICA 18 certification, apply bait sprays at a maximum interval of every seven days (or cover sprays every 14 days) from six weeks prior to commencing harvest to the completion of harvest. We also suggest that bait sprays should be applied if >15 flies in cue lure trays. Use either standard bait or Naturalure Fruit Fly Bait™. Apply cover sprays of Lebaycid® if more than 30 flies per trap or as per ICA 18 regulations.

Number of fungicide sprays: The number of fungicide sprays will vary from season to season. For dry seasons sprays may need to be applied every 4-6 weeks, in wet seasons, fortnightly.

Spray compatibilities: Always follow directions as per labels and check with manufacturers. Biopest oil® is compatible with mancozeb.

Yellow Peach Moth: Apply Prodigy® on first appearance of frass on fruit.

CHAPTER 9

Pesticide application methods

9.1 INTRODUCTION

When IPDM is being implemented by custard apple 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.

9.2 SPRAY EFFICIENCY

9.2.1 General principles

Custard apple is one of the most difficult tree crops to spray efficiently because of the tree shape and the 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 custard apple 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.

9.2.2 Spray volumes

The majority of custard apple growers apply between 600-1 000 L of spray per hectare (George and Redpath, 2009) (Figure 1). 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. We would recommend that custard apple growers increase their spray volumes significantly. (Also see Section on spray calibration).

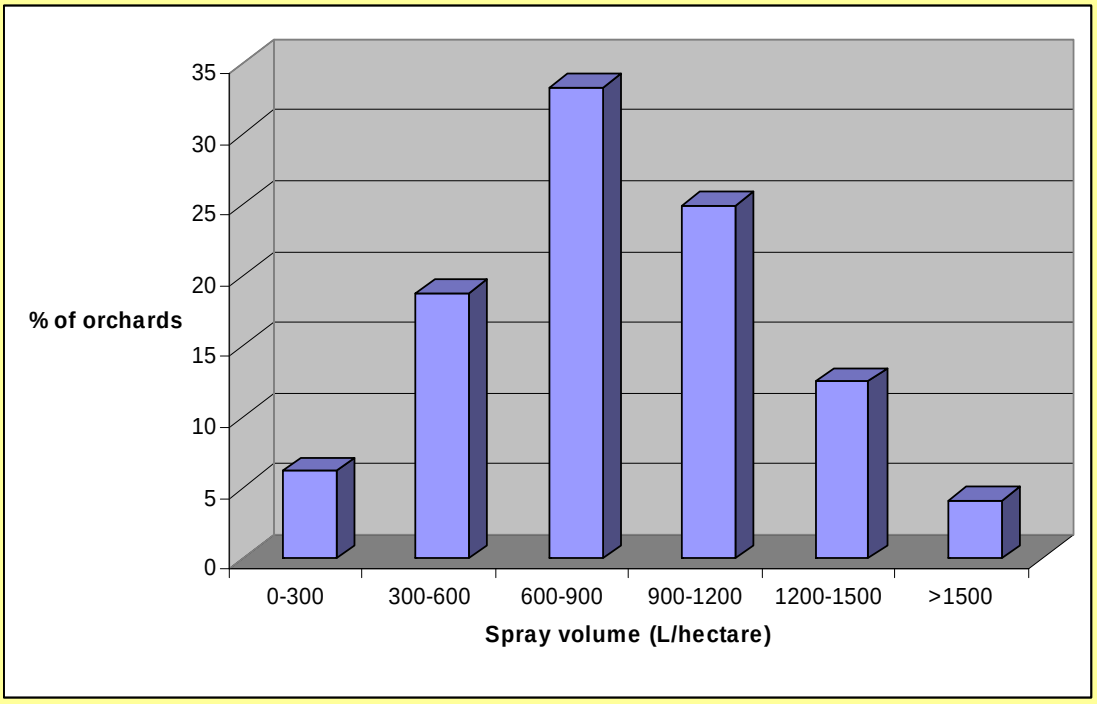


Figure 1. Range in spray volumes applied by custard apple growers using air-blast sprayers (George and Redpath, 2009).

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 custard apple 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

9.2.3 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

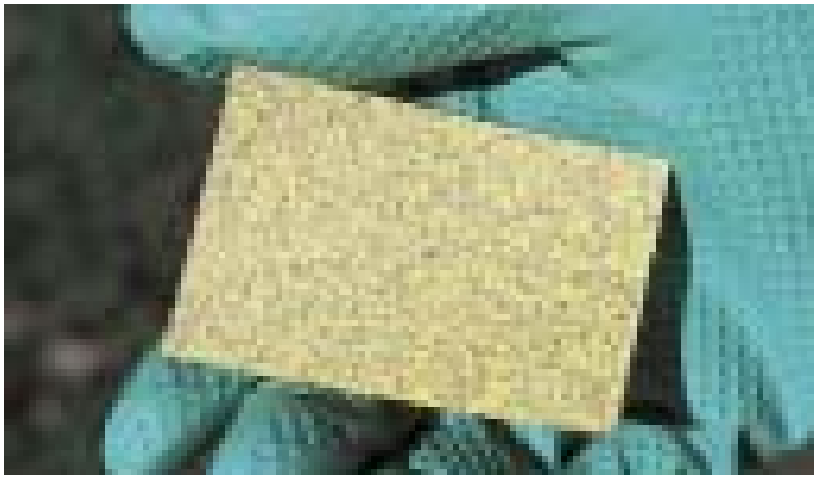


Plate 1. Water sensitive paper that show droplet distribution.

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.

9.3 TYPES OF SPRAYERS

About 80% of custard apple growers use air-blast sprayers (George and Redpath, 2009) (Figure 2). The second choice of sprayer is the mister.

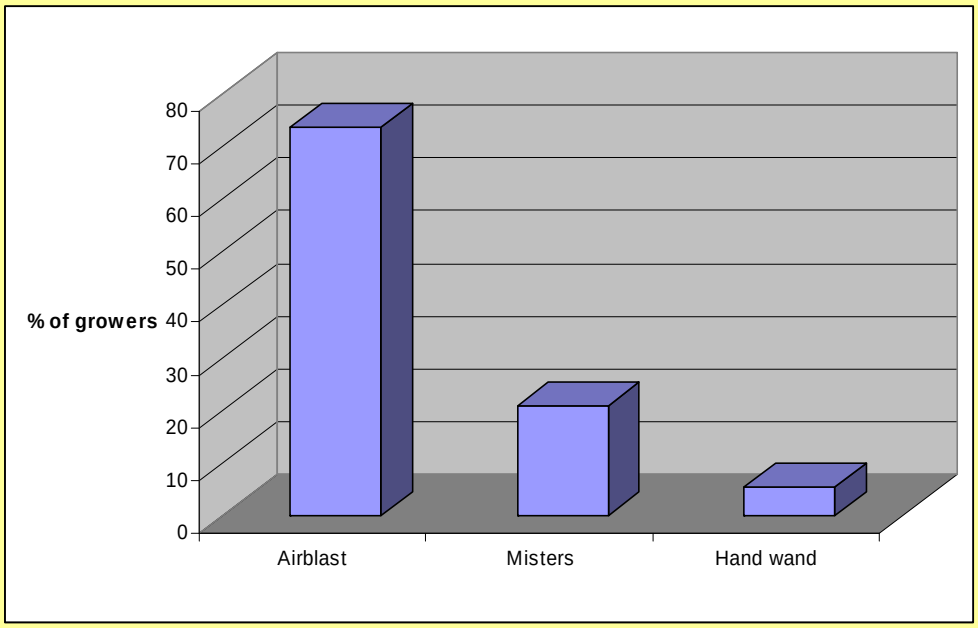


Figure 2. Percentage of growers using various types of spray equipment (George and Redpath, 2009).

Below we described some of the most commonly used sprayers in tree fruit orchards.

9.3.1 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 custard apple 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 custard apple. 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.

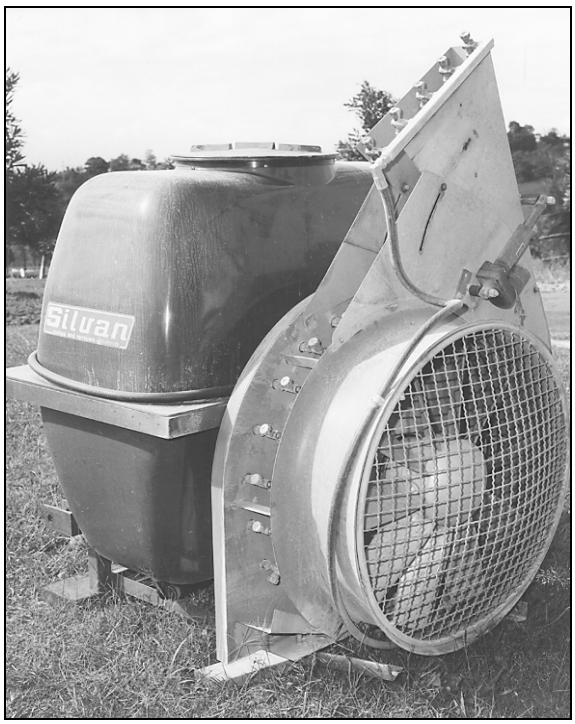
TABLE 3.
Set-up recommendations.

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.	

9.3.2 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 custard apple trees over 2 m in height. They are the main type of sprayer used by custard apple 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 custard apple 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.



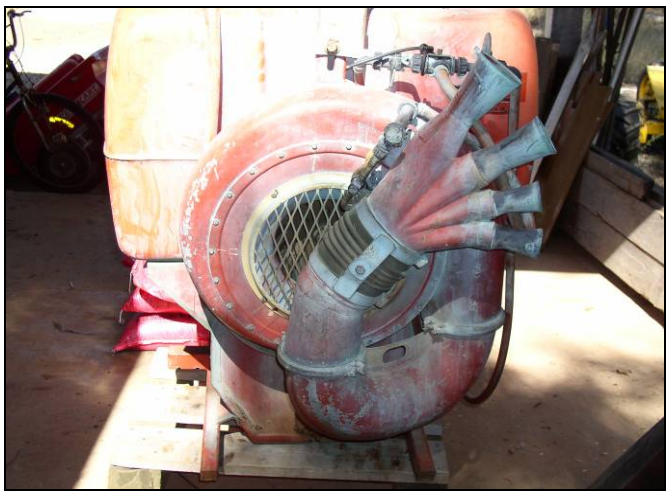


Plate 4. Different types of low-profile air-blast sprayers used by small growers.

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)

9.3.3 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

9.3.4 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

9.3.5 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.

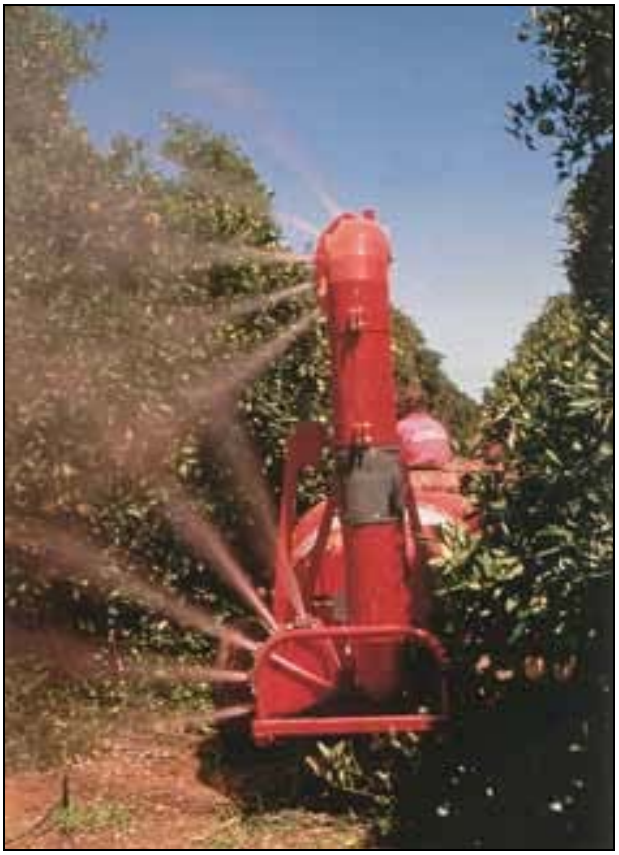


Plate 7. High-velocity air-shear sprayer with tower attachment.

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

9.3.6 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 custard apple 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

Component	Recommendations
	• 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

9.3.7 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.

9.3.8 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 presnted in Plate 10.

Plate 10. Small sprayer used to apply baits to trees.

9.4 Spray calibration

There are many options for calibrating sprayers. Howvever 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 growers 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).

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FURTHER INFORMATION

- For further information on the production of minor tropical fruit contact the QPI&F 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 DPI&F library provides a personalised information search service that may be useful for producers seeking information on minor and exotic crops. Contact QPI&F InfoSearch on 07 3239 6989.

- Visit the DPI&F website on www.dpi.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.
- Fruit Spotting bugs. Richard Llewellyn's Bioresources Pty Ltd. http://www.bioresources.com.au/FSBbiocontrol/Home.html

WEB SITES

- Australian Custard Apple Growers Association website- www.custardapple.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 Website: http://www.horticulture.com.au/industry/custardapple.asp
- 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 DPI: www.dpi.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/