



Department of **Agriculture and Food**



Christmas Island Fruit Fly and Scale Survey

June 2012.

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Recommendations

Eradication of Papaya fruit fly (PFF)

PFF is a known major pest of many crops. It is very responsive to male lures and male annihilation is an extremely effective technique in reducing numbers. It has been eradicated from several countries by using a combination of male annihilation and protein baiting. The eradication of PFF may inadvertently create a niche and lead to Mediterranean fruit fly (Medfly) establishing on the island because Medfly is outcompeted by the more aggressive *Bactrocera* species. PFF was caught at all trapping sites and an eradication program would require the whole island to be treated.

Eradication of White striped fruit fly (WSFF)

It needs to be determined whether WSFF has pest status on Christmas Island or if the large numbers trapped come from *Syzygium* and *Terminalia* trees in the forest. Little is known of its biology and a small population has been eradicated from California using baiting and male annihilation. WSFF is widely dispersed across the island in both disturbed and undisturbed areas. It breeds on the fruit of native trees and shrubs in inaccessible areas, in wetlands of international significance and in areas where birds nest and crabs forage. Any eradication program is likely to have some off-target impacts and this would impinge on approval for any eradication program.

Eradication of Melon fly

Numbers of this important pest species which primarily attacks cucurbits were lower than expected. Melon fly appears not be established in undisturbed areas and eradication using male annihilation, protein baiting and sterile insect technique (SIT) may be feasible. After eradication, quarantine would need to be improved to prevent reintroduction from Asia.

Area-wide management

A preferred option may be to use male annihilation and protein foliar baiting for area-wide management of all species within and around the horticultural precinct. Lure blocks containing cuelure and insecticide would target male WSFF and Melon fly whilst lure blocks with methyl eugenol and insecticide would target male PFF. As fipronil has been used against ants on Christmas Island and in male annihilation against fruit flies in Nauru its use should be investigated. Protein baiting is a simple technology that targets the females of all species. Effective organic products are now widely used.

Biological control of scale insects

Before importing biological control agents there is a need to know what parasites and predators are already present on the island. Although this has been carried out to some degree for the scale insects in the national park more surveys are required in the town and horticultural area. In addition to parasitic wasps there are predatory ladybirds available from commercial insectaries in Australia that could be imported and released against various scale insects and mealy bugs.

Biological control of fruit flies

A similar situation exists for fruit flies. Biological control of fruit flies has been particularly successful in Hawaii and in some islands of the South Pacific where a number of *Bactrocera* species coexist. This gives potential for the parasitoids to breed up on a number of hosts. Some of the most effective parasitoids are either native to or already established in Australia and there should be no barrier to importing them into Christmas Island. In the first instance fruit should be collected and held to determine which fruit flies are causing the damage and if any parasites are already established on Christmas Island.

Trapping

A small grid of traps should be checked monthly to determine fruit fly abundance throughout the year. These should target the proposed horticultural precinct and areas where Melon fly has been found.

Threat to Northern Australia

As with tropical fruit flies in the Torres Strait, the presence of PFF, Melon fly and WSFF on Christmas Island pose a threat to mainland Australia, especially the tropical North. Therefore any action taken to reduce their abundance will reduce the threat of establishment on the mainland.

Introduction

Christmas Island is located in the Indian Ocean, almost 400 km south of Java and 2,600 km north-west of Perth and has an area of 135 square km. It became an Australian Territory in 1958 and is administered by the Department of Regional Australia, Local Government, Arts and Sport. State-level Government is replicated by the Australian Government and the Minister responsible for Territories. An Administrator, appointed by the Governor-General, represents the Minister in the Indian Ocean Territories and resides on Christmas Island.

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The Department of Regional Australia has overall responsibility for the Territories, including the provision of State type services. However, additional Government services, such as those involving quarantine and customs, are the responsibility of the relevant Australian Government agencies. All Service Delivery Arrangements are undertaken by the Western Australian Government. The Department of Agriculture and Food (DAFWA) provides services to minimise the impact of invasive animals and plants on the economy, environment and lifestyle.

Christmas Island has a monsoonal climate with a distinct wet and dry season (BOM 2012). The wet season normally falls between November and May with heavy rainfall alternating with periods of humid, calm weather. The dry season lasts from June to November and has long dry periods with steady southeast trade winds and occasional showers. Temperatures vary little from month to month. The average daily maximum is 28° C in April and the average daily minimum falls to 22° C in August.

Much of the island is degraded as phosphate mining has removed the vegetation and topsoil. Sixty three percent of the island (8500ha) is national park which includes a diversity of habitats including rainforest and the internationally recognized Ramsar wetlands. Christmas Island supports thousands of seabirds including endangered species which nest on the island and 20 land crab species, including 50 million red crabs which shape and maintain the health of the island's unique rainforests (Parks Australia 2012).

The herbivorous red crabs maintain the openness of the Christmas Island forest by consuming seeds and seedlings before they have a chance to establish. Their numbers have been impacted in recent years by yellow crazy ant (*Anoplolepis gracilepes*). This species forms super colonies and their activities blind the crabs and indirectly causing death. Aerial baiting has been used with some success to reduce ant numbers but has off target impacts and ant numbers ultimately rebound. Ants also encourage scale insects in particular lac scales and the sooty mould which grows on exuded sap affects plant growth.

The entomological fauna of Christmas Island was surveyed in October 1964, April 1989 and in May 2000 (Campbell 1968, CSIRO 1989, Bellis et al 2004). The 1964 survey found cottony cushion scale *Icerya purchasi*, lac scale *Tachardina aurantiaca*, coconut scale *Aspidiotus destructor*, white peach scale *Pseudaulacaspis pentagona* and Melon fly *Bactrocera cucurbitae*. Melon fly numbers were low with only 3 specimens collected from gardens at South Point the only locality where it was found.

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The 1989 survey collected lac scales *Tachardina spp*, longtailed mealy bug *Pseudococcus longispinus*, numerous Psyllids, and 3 species of *Dacus* (now *Bactrocera*) fruit flies.

No fruit fly traps were used in either the 1964 or 1989 survey. The 2000 survey used Steiner traps baited with cuelure, trimedlure and methyl eugenol at the Pink House, Drumsite, Grants Well, the Dales and the market garden. They collected White striped fruit fly *Bactrocera albistrigata* and Melon fly *Bactrocera cucurbitae* from cuelure traps, Papaya fruit fly *Bactrocera papayae* and Breadfruit fly *Bactrocera umbrosa* from methyl eugenol traps. Betel nut fruit fly *Bactrocera arecae* was collected by sweep netting a lime tree. No Mediterranean fruit fly *Ceratitidis capitata* were collected. Bellis *et al* 2004 commented "Fruit-infesting species such as Tephritid fruit flies are commonly transported as larvae in fruit. All of the fruit fly species found on Christmas Island are known to breed in fruit likely to have been imported from southeast Asia.

Of the sedentary sap sucking insects once again lac scale, cottony cushion scale and longtailed mealybug were collected. Two Whiteflies, Citrus black fly *Aleurocanthus woglumi* and Sugarcane white fly *Neomaskellia bergii* were found on lime and sugarcane respectively. Spherical mealybug *Nipaecoccus viridus* was collected from lime and asparagus and a Mealybug *Dysmicoccus* sp from guava. Two species of unidentified soft scales in the genera *Coccus* and *Saissetia* were also found. Of the hard scales *Aspidiotus destructor* and White peach scale were once again found and a species of *Lepidosaphes* and *Lindingaspis* on lime.

Seventeen species of ants were collected including Crazy ant, Pharaoh's ant, Black house ant, Hairy ant, Coastal brown ant, Tropical fire ant, Ghost ant and White footed house ant. Soft scales, Mealybug and White flies excrete honeydew, a waste product derived from the plant sap on which they feed. This is a favoured food for many common ant species. Ants in the canopy in search of honeydew will disrupt predators and parasites of the scale insects significantly reducing their impact (Smith *et al* 1997). They also remove excess honeydew from the scale preventing asphyxiation and transport crawlers around the plants (Abbott & Green 2007).

These authors state there were nine species of scale insects occurring in rainforest on Christmas Island including the soft scales: Soft brown scale *Coccus hesperidum* a pest of citrus in Australia, *Coccus celatus* Green coffee scale, *Milviscutulus mangiferae* Mango shield scale, *Ceroplastes ceriferus* Indian white wax scale, *Ceroplastes destructor* White wax scale an important pest of citrus and ornamentals in Australia, *Saissetia oleae* Black scale and *Saissetia coffeae* Hemispherical scale. The lac scales *Paratachardina lobata* and *Tachardina*

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aurantiaca also exude honeydew. These scales normally occur at relatively low densities but in yellow crazy ant supercolonies numbers are an order of magnitude greater.

The main industries on Christmas Islands are phosphate mining, the detention centre and tourism. It is serviced by regular flights from Perth and occasional flights from Asia. There is a small horticultural industry on Christmas Island but most fruit and vegetables are imported from Australia or Asia and are often very expensive. There is potential to expand the horticultural industry on CI to provide a local source of fruits and vegetables but pests such as fruit flies and scale insects are barriers to this. DAFWA was asked to investigate the potential to eradicate pest fruit flies from Christmas Island thus removing one barrier to the development of a horticultural industry there. We were also asked to investigate control of scale insects especially in the urban areas. Much work has been done already and is continuing on control of ants and scales in the national park.

Methods

Fruit flies

Traps, lures and other equipment were sent to Christmas Island in advance. On arrival this equipment was collected and traps assembled. Four types of traps were used

1. Lynfield trap with four dental wicks containing cuelure and maldison and dichlorvos (DDVP) killing strip in the base of the trap



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2. Lynfield trap with three dental wicks containing methyl eugenol and maldison and dichlorvos killing strip in the base of the trap



3. McPhail type traps with 3 part Biolure and dichlorvos killing strip
4. Ceratraps with protein lure



At most sites all four types of traps were set out. Traps were hung at head height in shady trees. Traps were collected after 2-5 days in the field. Some traps were sampled multiple times e.g. at Territory Day Park. Traps were removed cleaned and left for future use. The flies caught were placed in 70% alcohol. Scale insects were also placed in 70% alcohol. Most of the alcohol was decanted and a cotton wool wick placed in the samples before shipment to

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Australia as per AQIS shipping guidelines and International Civil Aviation Organization (ICAO) Technical Instructions for the Safe Carriage of Dangerous Goods by Air (Special Provision A180).



Packed for shipment

When fruit was found it was cut open to inspect for larvae. One heavily infested sample of avocados was collected and held for the emergence of adults. Trap sites are listed in Table1

Site	Description	GPS	Elevation(m)
Territory Day Park	Recreation area next to rainforest	S10.43224° E105.66924°	199.4
Pink house	Clearing in rainforest	S10.49169° E105.64680°	237.4
Lookout LB4	Elevated rainforest	S10.47803° E105.60158°	312.7
Hugh's Dales	Rainforest, streams	S10.47576° E105.56082°	57.6
Chinese cemetery	Coastal	S10.41733° E105.68359°	43.6
The Grotto	Coastal	S10.42353° E105.70143°	39.9
Lily-Ethel Beach	Coastal	S10.46546° E105.70979°	39.9

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Irvine Hill Road	Track off main road, rainforest	S10.44254° E105.68393°	302.7
Triadic Way	Urban coastal	S10.41662° E105.68144°	104.5
Lower Poon Saan Road	Urban coastal, elevated	S10.42396° E105.67833°	137.8
Rubbish Tip	Clearing in rainforest	S10.43779° E105.68670°	296.6
Old Club	Urban coastal	S10.42706° E105.67370°	76.2
Pai Chin Lu St	Urban coastal, elevated	S10.42160° E105.67911°	152.7
Market garden	Downhill from rainforest	S10.44986° E105.66028°	213.4
Blowholes turnoff	Near old mine site	S10.50807° E105.64706°	204.5
Pumpkin Patch near south point	Near old mine site	S10.52406° E105.65713°	285.3
South point	Rainforest	S10.55808° E105.65522°	249.3
Greta Beach	Coastal	S10.49309° E105.67875°	107.9
VQ3 Lodge	Urban coastal	S10.41670 E105.67497	25.0

Table1; fruit fly trapping sites

Where possible we tried to sample the locations which had been sampled in the 1989 survey. The sites chosen gave coverage of virgin rainforest, regrowth vegetation, coastal fringe, pumpkin patches and urban areas. Altitudes ranged from 25 to 312 metres.

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Trap on Jackfruit in Silver City



Trap in feral Papaya

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Trap near the Dales World Heritage area

Fruit flies were initially identified by Mr Woods and confirmed by Mr Ian Lacey (DAFWA). Doubtful or unknown specimens were sent to DAFWA taxonomist Mr Andras Szito for identification.

Scale insects

The scale insect problem in the forest especially with the lac scales *Paratachardina lobata* and *Tachardina aurantiaca* and the interaction with yellow crazy ants has been well studied (Abbott & Green 2007) and is subject to ongoing research by Parks and Wildlife. We therefore concentrated collection in gardens in the town area. In the limited amount of time available for collection it was obvious that scale are an issue on a number of ornamental plants and fruit trees and that ant species other than yellow crazy ants are involved.

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Collecting scale and fruit flies at Silver City

Scale insects were sent to Mr Cameron Brumley (DAFWA) for slide mounting and identification. This is a time consuming process and ID's were not available at the time of this report. Unfortunately the necessity to hold specimens in alcohol for import into Australia makes the process of identification more difficult and less precise.

Results

Fruit flies

Fruit flies caught in traps are listed in Table2. White striped and Melon fly were caught in cue lure traps and papaya fruit fly in traps with methyl eugenol. The McPhail and Ceratraps caught very few flies.

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Site	White striped fruit fly	Melon fly	Papaya fruit fly	Breadfruit fly
Territory Day Park	1603	1	784	18
Pink house	946	0	1053	0
Lookout LB4	1149	0	618	0
Hugh's Dales	1218	0	97	0
Chinese cemetery	1004	0	133	0
The Grotto	986	0	133	0
Lily-Ethel Beach	574	0	81	0
Irvine Hill	165	0	302	0
Triadic Way	204	0	663	0
Lower Poon Saan Road	75	3	255	0
Rubbish Tip	0	0	75	0
Old Club	1540	0	246	0
Pai Chin Lu St	122	0	100	0
Market garden	1529	0	418	0
Blowholes turnoff	238	0	505	0
Pumpkin patch near South Point	380	90	318	0
South point	107	0	268	0
Greta Beach	1708	0	183	0
VQ3 Lodge	500		179	0
Total	14048	94	6411	18

Table 2: Fruit flies caught in traps on Christmas Island

Over 20,000 fruit flies were caught in a short period of time. Sixty nine percent were caught in cuelure traps and 31% in methyl eugenol traps. Only 60 flies were caught in the McPhail type traps with Biolure and only 8 in the liquid protein based Ceratraps. Additionally 33 Papaya fruit flies emerged from avocados collected from the ground at the market garden. The highest number of White striped fruit flies was caught at Greta beach, the highest papaya fruit fly at Pink House and the highest Melon fly at Pumpkin patch. No Medflies were caught in any of the traps.

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Trap in market garden

Discussion

Scale insects

Many of the scale insects already identified from Christmas Island are pests in Australia. Soft brown scale *Coccus hesperidum* is a pest of citrus across Australia. It is controlled with sprays of petroleum oil which do not disrupt wasp parasites that attack it. At least seven wasp parasitoids have been imported to control it (Smith et al 2007). Two species *Microterys flavus* and *Diverinervus elegans* are important control agents in Queensland.

Wax scales exude an outer waxy covering that protects them against predators and desiccation. White wax scale *Ceroplastes destructor* is an important pest of citrus and ornamentals in Australia. In Perth its population fluctuates possibly because of the effect of climate on natural enemies. It is difficult to kill with insecticides and is a bane of many gardeners especially on hedges. Three wasp

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parasitoids have been imported and released in Australia. *Paraceraptocerus nyasicus* has been particularly successful in Queensland and white wax scale is now scarce there (Smith et al 2007). *Ceroplastes ceriferus* Indian white wax scale is only a minor pest in Queensland.

Milviscutulus mangiferae Mango shield scale is a cosmopolitan species with a wide distribution in the Pacific area, but in Australia is only found in north Queensland. Sooty mould grows on honeydew it produces and in heavy infestations this can reduce tree vigour (Grimshaw and Donaldson 2007).

Black scale *Saissetia oleae* is a citrus pest in Australia but attacks a wide range of fruits such as Custard apple. *Saissetia coffeae* Hemispherical scale also attacks citrus and avocado, ferns and palms. Four parasitoids have been imported for control in Australia.

Cottony cushion scale *Icerya purchasi*, an Australian native, attacks citrus and a number of native and ornamental plants. Native ladybirds and lacewings are important predators. The ladybird *Rodolia cardinalis* is one of the early examples of effective bio-control being introduced from Australia to California to control Cottony cushion scale there.

White peach scale *Pseudaulacaspis pentagona* is a minor pest of peaches in NSW (Hely et al 1982) and deciduous fruit trees worldwide. Dormant oil sprays (with and without insecticide) are used for control on deciduous fruit.

White louse scale *Unapsis citri* is a major citrus pest in Queensland appears to be on Christmas Island. Although parasitic wasps have been imported and released in Australia they have not been successful in controlling this pest. Most effective controls are an introduced ladybird and a scale eating caterpillar. The ladybird *Chilocorus cicutatus* is available from Bugs for Bugs in Queensland.

Longtailed mealy bug *Pseudococcus longispinus* is a pest of many crops worldwide including grapes, citrus, mangoes, palms and ornamentals. It is difficult to kill with insecticides as it has a waxy outer covering and often shelters in crevices, between leaves or under the calyx of fruit. The mealybug ladybird *Cryptolaemus montrouzieri* has a larva that looks very similar to the adult mealybug themselves and is available from a number of commercial insectaries in Australia (www.goodbugs.org.au)

The first step is to thoroughly survey the scale population on Christmas Island, including the urban areas to identify which species are present. Collections should be made throughout the year and held for emergence of wasp

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parasitoids. Collection of predators such as ladybirds should also be made. After identification consideration should be given to importing the most effective natural enemies from an area with similar climate in Australia. Closest climate matches using CLIMEX[®] in Australia are in far north Queensland (Marc Poole pers.com.) and as Christmas Island is part of Australia there should be no barrier to these importations.

Climex climate match for Christmas Island in Australia

Fruit flies

All the species collected are exotic to Australia and two are major pests

Breadfruit fly *Bactrocera umbrosa*

This species is reported as a serious pest of bread fruit and jackfruit (White & Elson-Harris 1994). It is found in Malaysia, Indonesia, Philippines, Thailand, Papua New Guinea, Solomon Islands, New Caledonia and Vanuatu. Little is known of its biology and it is easily identified by the three large transverse bands on its wings (Walker 2005). High-value fruits can be protected by bagging with newspaper or paper bags before they mature.

White striped fruit fly (WSFF) *Bactrocera albistrigata*

This was the species most commonly caught in traps on Christmas Island and is also found in Indonesia, Malaysia and Thailand (White and Elson-Harris 1994). The name comes from the abdomen which has a dark stripe down the middle, flanked by two broader pale stripes at the sides. It is known to attack *Syzygium* species including the cultivated water apple *S. samarangense*. Wild plants of tropical almond *Terminalia catappa* are major hosts in Malaysia. Both *Syzygium* species and tropical almond grow throughout Christmas Island and probably account for the large numbers found. *Terminalia catappa* trees grow to larger than normal size on Christmas Island and *Syzygium nervosum* is one of the largest trees on the plateau and bears abundant round red fruit (Anon 1994). Mango, guava and carambola are also hosts (CDFA 2012) and WSFF is considered a threat to horticulture in California. In 2009 seven flies were trapped in Los Angeles and a successful eradication program was deployed using male annihilation and insecticide baiting. As this species was caught in large numbers throughout the island including the national park eradication would not be feasible. Its importance as a pest of cultivated crops on Christmas Island can only be determined by rearing out from host fruit.

Papaya fruit fly (PFF) *Bactrocera papayae*

Papaya fruit fly (*Bactrocera papayae*) is a major pest that attacks many commercial fruit including bananas, capsicums, chillies, citrus, guavas, mangoes, papaya and tomatoes. It is part of a species complex of closely related species (Clarke 2005) and is widespread in Thailand, Malaysia, Singapore and Indonesia, is established in Papua New Guinea and is occasionally trapped in the Torres Strait Islands

An outbreak around Cairns, North Queensland in 1995 was successfully eradicated in 1999 at a cost \$34 million against a predicted loss of more than \$100 million per year in damage and restrictions on market access. Protein baiting and male annihilation using Canite blocks containing methyl eugenol and maldison insecticide were used. Between 1998 and 2000 populations of Oriental fruit fly, *Bactrocera dorsalis* (part of the PFF species complex) and Melon fly were eradicated from Nauru using protein baiting and male annihilation blocks. Fipronil as used in yellow crazy ant control was the insecticide in the blocks (Allwood et al 2002).

Eradication of White striped fruit fly and Papaya fruit fly

Although eradication is technically feasible it is unlikely to be economically or environmentally viable. Large trees of the genus *Syzygium* and *Terminalia* would provide hosts in the forest for WSFF and Papaya fruit fly would attack a broad spectrum of wild fruits and berries. Treatments such as male annihilation if used in the national park could cause off target effects to birds and crabs. Problems of access to coastal and rainforest areas would require aerial application of treatments. Eradication of these species would leave an open niche that may be filled by Mediterranean fruit fly from Western Australia.

Melon fly *Bactrocera cucurbitae*

Originally from Asia it is a serious pest of cucurbit crops worldwide in tropical areas except in America and Australia. The adult Melon fly is approximately the size of a house fly, with an orange-brown body and clear wings with a large brown spot at the tip. It can attack flowers as well as fruits and is particularly damaging to melon and squash crops including zucchini and pumpkins. Papayas are considered an occasional host. It was eradicated from Okinawa and southern Japanese islands in the 1980s and 1990s using male annihilation and the sterile insect technique (Dyck et al 2005). In Hawaii it is controlled by planting border crops such as Sudax which are baited with insecticide/protein to kill roosting females. On Christmas Island numbers were lower than expected and it was only trapped at South Point, Silver City and Drumsite. The extent of breeding on wild

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hosts is unknown but it was not trapped in wilderness areas. Therefore eradication of this species from Christmas Island may be feasible. A male only strain has been developed and tested in Hawaii for use in SIT and trials on eradication of Melon fly from Mauritius will begin soon (Don McInnis pers com.)

Options for control

Pest	Option	Timeline	Cost	Outcome
	Do nothing	On going		High levels of damage to fruit persists
PFF	Eradication	5 years	Millions	Eradication difficult to achieve in forest areas
	Area wide management	3 years to develop then ongoing	Tens of thousands	Pest population reduced to manageable levels in horticultural precinct

Pest	Option	Timeline	Cost	Outcome
	Do nothing	On going		Pest status of WSFF needs to be determined
WSFF	Eradication	5-10 years	Millions	Very difficult to achieve
	Area wide management	5 years to develop then ongoing	Hundreds of thousands	Because it breeds in native fruits management may be difficult

Pest	Option	Timeline	Cost	Outcome
	Do nothing	On going		Melons and squash attacked heavily. Pumpkins relatively undamaged.
Melon fly	Eradication	5 years	Hundreds of thousands	Ongoing cost of preventing reintroduction of pest
	Area wide management	3 years to develop then ongoing	Tens of thousands	Outside cultivation of cucurbits and other vegetables possible in horticultural precinct

Quarantine

There is no point eradicating a pest unless quarantine is strengthened to prevent it being reintroduced. If Melon fly were eradicated it could easily re-establish from infested cucurbits brought in from Asia.

Area wide management (AWM)

A systems approach to the area wide management of fruit fly species may be the preferred option for the area that contains the new horticultural precinct. Management could include: removal of feral hosts, improved crop hygiene, import of biological control agents, use of male annihilation, protein baiting and release of sterile insects (if available). Such an approach used over a large enough area should achieve good levels of control of all pest species. The advantage of this approach is that it would be less expensive and is not reliant of a tightening of quarantine measures.

Impact of Yellow Crazy ant supercolonies on fruit flies

Yellow crazy ants impact on fruit flies in many ways. As red crabs consume fruit on the forest floor fruit fly larvae in the fruit would be killed. If ants kill crabs and prevent this fruit from being eaten there is potential for fruit fly larvae to leave the fruit and pupate in the soil to emerge as adults. Secondly the honey dew produced by scale insects may act as food for the fruit flies. Lastly crazy ants in the canopy may interfere and prevent any parasites attacking fruit fly larvae and eggs

Acknowledgements

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