# GUAVA MOTH IN NEW ZEALAND – DISTRIBUTION, HOSTS, LIFE CYCLE OBSERVATIONS AND DISCUSSION OF PEST MANAGEMENT OPTIONS

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## ABSTRACT

Guava moth was first observed in New Zealand in 1997. Little is known of this species in its native Australia, where it is not considered a pest. In New Zealand guava moths laid their eggs at the stem and style end and in cracks and crevices on fruit, and the resulting larvae fed internally on fruits. Pupation occurred in loose soil and debris in the orchard, and in sawdust beneath fruits in the laboratory. In July 2003 guava moth distribution, as determined by pheromone trap catches, was limited to Northland, where adult males were found north of and including Whangarei Heads. No moths were trapped in Auckland, Waikato or Bay of Plenty. Larvae were collected from a range of introduced fruits in Northland during all months of the year. However, no larvae were found in samples of nearly ripe native berries. Control options for guava moth are discussed.

**Keywords:** Guava moth, *Coscinoptycha improbana*, biology, distribution, hosts.

## INTRODUCTION

Guava moth, *Coscinoptycha improbana* Meyrick (Lepidoptera: Carposinidae), was first observed in New Zealand in 1997 on citrus fruits in Ahipara (G. Messenger, pers. comm.), and has become a serious pest of macadamias and feijoas in Northland. Like many unwanted biosecurity incursions, the exact pathway and time of the arrival of guava moth to New Zealand remains unknown. Prior to 1997 guava moth had only been found along the eastern seaboard of its native Australia, from Queensland to Tasmania, and on Norfolk Island. In Australia, larvae bore into and feed internally on the flesh of ripening fruit of both native and introduced plants (Common 1990), but it is not considered to be a pest of commercial significance.

By 2000 in New Zealand, preliminary surveys indicated that guava moth infested home garden fruits, such as feijoa (*Acca sellowiana*), loquat (*Eriobotyra japonica*), guava (*Psidium* sp.), macadamia (*Macadamia integrifolia*), plum (*Prunus domestica*), peach (*Prunus persicae*), nashi pear (*Pyrus pyrifolia*) and citrus (*Citrus* sp.), in Kaitaia, Ahipara, Sweetwater, Mangonui (Doubtless Bay) and Kerikeri. However, guava moth larvae were not found during targeted searches of feijoa fruits at 49 sites in Whangarei in 2000 (J.J. Dymock, unpubl. data), indicating that guava moth had not spread south to Whangarei at that time.

In 2001 MAF decided not to initiate any official control action against, or conduct any research on the guava moth (Stephenson 2001). Reasons included the large known

area of establishment in Northland, its low international profile and the on-going chance of natural (wind-blown) re-establishment from Australia. HortResearch developed a synthesized sex pheromone for guava moth in 2001 (A.R. Gibb, unpubl. data). This enables a large survey of guava moth to be undertaken in the north half of the North Island to determine its natural spread and whether it had been transported to other regions.

Due to its non-pest status in Australia, minimal research has been carried out on guava moth and little is known of its host plants and life cycle. The only host records of guava moth in Australia are guava, feijoa, citrus, white cherry (*Schizomeria* ovata) and red olive plum (*Cassine australis*). Adults of the Carposinidae are nocturnal and rest on tree trucks during the day (Common 1990). All known larval stages feed internally, boring into soft and woody fruits, flower buds and spikes, bark and galls. Pupation occurs in or near the larval gallery or in a cocoon among the litter and soil on the ground. Of the 200 described species of Carposinidae only two (peach fruit moth (*Carposina sasakii* (*C. niponensis*)) and raspberry bud moth (*Heterocrossa rubophaga*)) are considered to be serious pests. Peach fruit moth is a pest in Asia on a range of fruit (Kang 1995). Integrated control measures recommended for peach fruit moth are insecticide applications targeting the exposed egg stage in the canopy (Huan et al. 1987), removal of fallen fruit targeting the late larval stage, soil compaction targeting the ground dwelling pupal stage and the use of sex attractants targeting the adult stage (Liu et al. 2002). Knowledge of the guava moth's life cycle enables selection of the most appropriate control measures and is essential to the development of an IPM programme.

This paper summarises the findings of a distribution survey, host survey and observations of the guava moth's life cycle.

## METHODS

### Distribution survey

A survey was conducted from April to July 2003 using delta pheromone traps (Clare et al. 2000) suspended in feijoa trees at ca 1.5 m above ground. A rubber cap impregnated with a synthesised sex pheromone (950 µg of (*Z*)7-octadecen-11-one and 50 µg of (*Z*)7-nonadecen-11-one) was placed on a sticky base, which was inserted into each trap. The sticky trap bases were replaced every two weeks and pheromone caps were replaced every six weeks. The survey was carried out in the Northland, Auckland, Waikato and Bay of Plenty regions. Mainly backyard feijoa trees in and around small towns were used to hang pheromone traps, as it was unlikely that these had been treated with an insecticide. In Northland, within four of the known guava moth towns, five pheromone traps were set-up to confirm that these traps were a suitable tool to survey for guava moths. Within the remainder of the Northland region and the other three regions, pheromone traps were set-up in feijoa trees in and/or around towns to give a good spread throughout the regions (Fig. 1). Between 49 and 67 traps were placed in each region.

### Host survey on introduced plants

Macadamia, plum, peach, nectarine (*Prunus persica*), feijoa, guava, loquat, nashi (*Pyrus pyrifolia*) and mandarins (*Citrus unshiu*) were surveyed in the field for the presence of guava moth larvae at 12 orchards (Table 1). At each site, when fruit were present, fruit were sampled every two weeks by examining fruit with a hand lens and any holes were investigated by cutting open the fruit. Sampling stopped when a larva was found or 10 fruits had been examined on each of 10 randomly selected trees. Suspected guava moth larvae were placed in diet tubes and reared through to adult for identification. Adult guava moths are similar to some endemic carposinids of the genus *Heterocrossa*. The male can be distinguished from these by the raised tuft of silky white scales towards the base of the forewing. The female may be distinguished from similar pale species, such as *Heterocrossa philpotti* (Dugdale) and *H. gonosemana* (Meyrick), by the dark marking that runs across the forewing about 1/3 of the distance from the top. This marking is almost vertical in *C. improbana*, but oblique to L-shaped in the *Heterocrossa* species (Hoare 2001).

**TABLE 1: Description of orchard sites where fruit were surveyed every fortnight for the presence or absence of guava moth larvae.**

| Orchard | Host fruit | No. of trees | Pest management | Survey duration |
|---|---|---|---|---|
| 1 | Macadamia | 50 trees | Organic | Dec 01–Nov 03 |
| 2 | Macadamia | 60 trees | Unsprayed | Dec 01–Nov 03 |
| 3 | Plum | 20 trees | Organic | Sept 02–Nov 03 |
| 4 | Feijoa | 2000 trees | Unsprayed | April 03–Nov 03 |
| 5 | Feijoa | 10 trees | Organic | Sept 02–Nov 03 |
| 6 | Peach | 10 trees | Organic | Sept 02–Nov 03 |
| 7 | Satsuma mandarin | 20 trees | Unsprayed | Sept 02–Nov 03 |
| 8 | Guava | 5 trees | Organic | Dec 01–Nov 03 |
| 9 | Guava | 1500 trees | Unsprayed | July 03–Nov 03 |
| 10 | Loquat | 15 trees | Organic | Dec 01–Nov 03 |
| 11 | Encore mandarin | 200 trees | Unsprayed | Oct 03–Nov 03 |
| 12 | Nashi | 1200 trees | Unsprayed | Dec 03 |

**Host survey on native plants**

In November 2002 delta pheromone traps were placed in the canopy of native trees of puriri (*Vitex lucens*), karaka (*Corynocarpus laevigatus*), titoki (*Alectryon excelsa*), poroporo (*Solanum aviculare*), supplejack (*Rhipogonum scandens*), tawa (*Beilschmiedia tawa*) and taraire (*Beilschmiedia taraire*) at eight native bush sites located in a transect from Kerikeri to Ahipara. Four traps were set up at each site, each in an individual tree. Traps were checked every six weeks for the presence of male guava moths. Pheromone caps and sticky bases were replaced at each assessment. When present, up to 50 ripe berries and drupes from around each trap location were inspected at either two or six weekly intervals for the presence of guava moth larvae. Berries and drupes were unable to be removed from the native bush, therefore any lepidopteran larvae were removed, placed in a diet tube and sent to Dr R.J.B. Hoare (Landcare Research) for larval identification.

**Oviposition**

Guava moth adults were reared from infested macadamia nuts collected from the HortResearch orchard in Kerikeri. Infested nuts were placed on a bed of untreated sawdust 4 cm deep in 15 litre containers (30 cm x 20 cm x 20 cm deep) to allow larvae to pupate in the sawdust if necessary. Guava moth pupae were periodically retrieved from the sawdust and placed in 2-litre containers until the moths emerged.

To determine where guava moths lay their eggs, 10 guava moth adults (<1 day old, five of each sex) were transferred to a vented container containing 15-30 ripening host fruits of guavas, oranges, mandarins or loquats. There was one container for each fruit species. Approximately 5 cm of stalk remained attached to the fruits because eggs had previously been observed on stalks of macadamias in the field. In another experiment, ca 20 guava moth adults (<3 days old, ca 10 of each sex) were transferred to a single vented container containing one raceme of 20 macadamia nuts.

For both experiments, the fruit and moths were left at ambient temperature for at least 2 weeks. The moths were provided with honey/water syrup. At the end of the period, the fruit and attached stalks were examined under the microscope for the presence of eggs and larvae.

**Pupation**

Four observational experiments were undertaken to determine whether guava moths leave fallen fruit to pupate in/on the ground, how far they travel to pupate and the length of the pupal period.

In the ground collection experiment, debris, leaf litter and loose soil (to a depth of 3 cm) associated with, but not including, fallen macadamia nuts were collected from the HortResearch orchard in Kerikeri over a 5-week period. The litter, loose soil and debris

were placed in five 2-litre containers, covered in mesh, and left at ambient temperature. The number of moths that emerged was recorded.

In the dispersal experiment, three aluminium trays (85 cm x 40 cm x 6 cm deep) were filled to a depth of 5 cm with untreated sawdust moistened when required with water applied with a garden sprayer. Approximately 50 infested macadamia nuts collected from the HortResearch orchard in Kerikeri were placed in a circular pile (30 cm in diameter) at one end of each tray. Insect adhesive (Insect Arrest™) was pasted around the rim of the trays to prevent escape by larvae. The trays were oriented at 90° and 180° angles to each other. The trays were left for at least two weeks at ambient temperature and then the location of the pupae found in the trays was recorded.

In the depth experiment, fifty infested macadamia nuts collected from the HortResearch orchard in Kerikeri were placed on 10 cm depth of untreated sawdust, moistened as previously described, in two 15 litre containers (30 cm x 20 cm x 20 cm deep). The depth that pupae were found was recorded. In all pupation studies adult moths were allowed to emerge from the pupae so that their identity could be validated.

For the pupal period experiment, field collected larvae were individually reared though to pupation in test tubes containing Brinton's artificial diet (Brinton et al. 1969), which was modified by reducing the amount of water and sawdust and adding agar. Pupae were weighed and then buried in damp vermiculite in individual small pottles at 21°C. Pupae were observed daily and the length of the pupal period was recorded.

## RESULTS

### Distribution survey

Adults were only recorded in pheromone traps located in Northland (Fig. 1). No guava moths were trapped in Auckland, Waikato or Bay of Plenty.

Guava moths were caught in large numbers (average of 83 moths per trap over 12 weeks) in traps in and around towns previously reported to have the moth (Kaitaia, Ahipara, Mangonui and Kerikeri). In addition to its known distribution in and north of Kerikeri, guava moth was found along eastern Northland in Towai, Kawakawa, Moerewa, Pakaraka and Ohaeawai. It was found on the west coast of Northland on the Hokianga Harbour and as far south along the west coast as Waimamaku. In the Whangarei City/ Kamo area, guava moth was trapped in four of seven sites. It was also found 12 km west of Whangarei City in Maungatapere and southeast of Whangarei City at Parua Bay. The most southern site that guava moth was caught was at Whangarei Heads.

### Host survey on introduced plants

Guava moth larvae were found in introduced fruits in orchards from around Kerikeri in fortnightly samples during every month of the year, mainly in maturing or mature fruit. Guava moth larvae were found in macadamia nuts from January until November but not in December in 2002 and 2003. This was due in part to mature nuts having been harvested and to the presence of only very small nutlets where infestation had not yet occurred. Larvae were found in plums from January until March; in feijoas from March until June; in loquats from September until December; and in peaches in March and April. Larvae were also found in an early maturing peach cultivar in December 2003. Larvae were found in guavas from July until November, depending on maturity patterns between cultivars. Larvae were found in satsuma mandarins from May until August depending on the maturity of the cultivars, and encore mandarins in October and November. A single inspection of nashi pears in December 2003 found larvae on immature nashi fruitlets. The nashi pear grower had observed larvae on fruit from mid-January until mid-March 2003.

### Host survey on native plants

Pheromone traps in eight native bush areas caught a single guava moth at one site close to a subtropical nursery in July 2003. No guava moth larvae were found in samples of near-ripe berries of puriri, karaka, titoki and poroporo.

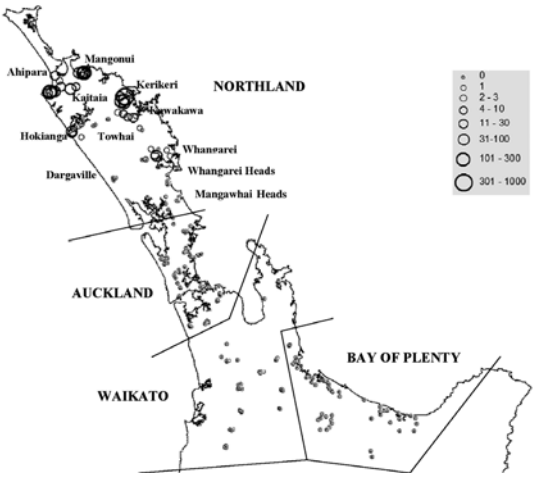


**FIGURE 1: The location of pheromone traps hung in feijoa trees throughout Northland, Auckland, Waikato and Bay of Plenty and the number of moths caught in each trap during the April–July 2003 distribution survey.**

**Oviposition**

On yellow guava fruits 1-2 eggs were laid at the stylar end of four out of 20 fruit caged with moths. Between three and five eggs were laid on loquats and six of the 30 fruit were infested. These eggs were laid among the hairs at the stylar end of loquats. Larvae from eggs laid on guavas and loquats emerged and burrowed directly into the fruit, as indicated by the larval entry hole being directly beneath the egg case. On oranges, eggs were laid under, and next to, the calyx at the stem end of the fruit. One to two eggs were laid per orange and four of the 20 oranges were infested. On the macadamia raceme 10 eggs were laid in cracks on the surface of a single nut, 1-2 eggs were laid in each of four cracks on the stem of the raceme and four eggs were laid at the stem end of a single nut. No larvae emerged from eggs laid on oranges and the macadamia raceme. No eggs were laid on mandarins.

**Pupation**

In the ground collection experiment, four guava moth adults emerged from 10 litres of debris, leaf litter and loose soil collected from beneath macadamia trees, indicating that pupation does occur in the soil.

In the dispersal experiment, a total of 99 pupae were collected. Eighty-one pupae were found directly under the infested macadamia nuts. A further 10 pupae were found within 3 cm of the infested macadamia nuts. The remaining eight pupae were found 7–41 cm away from the nearest macadamia nut in the pile.

In the depth experiment, thirty-one pupae were recovered. After two weeks, 81% had pupated less than 2 cm beneath the fallen fruit, with a further 16% pupating 2–4 cm beneath the fruit. One guava moth larva pupated at the depth range of 4–6 cm and no pupae were found >6 cm deep.

For the pupal period experiment, field collected larvae reared on the modified Brinton's diet took 14.1 (± 0.3) days at 21°C from pupation to adult eclosion. There was no difference between the pupal development times and pupal weights of female and male guava moths (Table 2). Adults exhibited a 55:45 female:male sex ratio. No parasitoids were observed to emerge from a total of 426 larvae collected from the field.

**TABLE 2: Mean guava moth pupation times and pupal weight of individuals collected as larvae and reared on artificial diet.**

| | Females | Males |
|---|---|---|
| Time as pupa (days) | 13.9 ± 0.3 | 14.4 ± 0.4 |
| Pupal weight (g) | 0.0175 ± 0.0006 | 0.0174 ± 0.0006 |
| Number emerged as adults | 48 | 40 |

## DISCUSSION

The known distribution of guava moth in New Zealand has been extended in this study. Guava moth was absent in Whangarei during larval searches in 2000. However, it is now present north of and including Whangarei Heads, which is ca 20 km southeast of Whangarei City. This extension of the known guava moth areas could reflect the slow southward spread of the pest or the superior sensitivity of pheromone trapping when compared to the larval searches undertaken previously.

Compared to the host plant range recorded in Australia, guava moth has been found in two new plant families (Proteaceae and Rosaceae) in New Zealand. It is most likely that guava moth does occur on these families in Australia, but due to its non-pest status, no one has looked. A single adult guava moth was found in native bush areas in Northland. The moth was most probably blown in, due to the lack of corresponding larval and further adult findings. At this stage guava moth is not considered to be a pest of native plants.

In the laboratory, guava moth young larvae bore directly into fruit beneath their egg capsule. If this result was extrapolated to the field situation, it would mean that larvae would not be exposed to pesticides. Thus to control guava moth in the field, other IPM approaches may be needed, such as cultural control, pheromone-based control and biological control.

Field collections of loose soil and debris indicate that guava moths do pupate in the soil. In addition the laboratory observations have shown that the majority of guava moths pupate close to their host fruit, within the first 2 cm of sawdust beneath the fruit, and exist as pupae for 2 weeks at 21°C. Cultural control by removing fallen fruit and associated debris and leaf litter harbouring guava moth pupae every fortnight is a logical first step to an IPM programme, and is recommended overseas for the peach fruit moth (Huan et al. 1987). However, this may not be a practical option and has not yet been demonstrated to reduce guava moth populations. Grazing by chickens or even sheep may be a more efficient method of targeting or disturbing the ground-dwelling pupal stage. A soil application of insecticides is another option to reduce pupal numbers in the orchard.

Mating disruption has successfully been used in Japan to control a close relative of guava moth, *C. sasakii*, in apple orchards (Oku 1993). However, the small orchard block size and wide host range could be problematical for guava moth, since immigration of mated females is likely to lead to damage despite this treatment (Suckling 2000). The cost of the formulation could also prove prohibitive. Other pheromone-based technologies, such as mass trapping and "lure and kill", are possible control options, although similar immigration and expense problems are likely to arise.

The instigation of a biological control programme is a longer-term option for control of guava moth. While there have been no reports of predators or parasites of guava moth in New Zealand, it is possible that guava moth is not a pest in Australia due to the effects of one or several biological control agents. Developing a biological control programme for guava moth in New Zealand would involve identification of natural enemies in the native range of guava moth (Australia) and selecting one or more for detailed study. The costs of finding effective predators or parasites in Australia and assessing them in quarantine for risk to non-target species in New Zealand are high. When these costs are followed by the cost of an application to release a biological control agent required under environmental legislation, obtaining sufficient funding is a major hurdle for classical biological control of guava moth.

## ACKNOWLEDGEMENTS

This research was funded by New Zealand Citrus Growers Inc., Summerfruit New Zealand Inc., New Zealand Feijoa Growers Association Inc., New Zealand Macadamia Society Inc., Northland Regional Council, Auckland Regional Council, Environment Waikato, Environment Bay of Plenty and the Foundation for Research, Science and Technology. John Charles and Philippa Stevens made useful comments on a draft manuscript.

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