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The use of *Leptomastix dactylopii* Howard (Hymenoptera: Encyrtidae) to control *Planococcus citri* (Risso) (Hemiptera:Pseudococcidae) in Queensland citrus orchards

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Abstract

In October 1980 the parasitoid *Leptomastix dactylopii* Howard (Hymenoptera:Encyrtidae) was introduced into Queensland from California to control citrus mealybug *Planococcus citri* (Risso) (Hemiptera: Pseudococcidae) in citrus and custard apple *Anoma spp. hybrid*. Previously its most common natural enemies in citrus were *Cryptolaemus montrouzieri* Mulsant (Coleoptera:Coccinellidae), *Leptomastidea abnormis* Girault (Hymenoptera:Encyrtidae) and *Oligochrysa lutea* (Walker) (Neuroptera:Chrysopidae) but these were unable to consistently keep infestations at acceptable commercial levels.

Following its introduction, *L. dactylopii* became the most common natural enemy of *P. citri* throughout south-east Queensland. Parasitoid numbers were lowest during winter and spring indicating that augmentative spring – early summer releases may increase its effect. This was confirmed by widespread releases of 5 to 10 000 parasitoids per hectare during the period November to January of each year from 1984 to 1987. Releasing advanced the parasitoid's activity by six weeks and by late March, an average 50% of mealybug infested fruit had *L. dactylopii* present. Mealybug infestations averaging 38% of fruit infested in early December were reduced to within an acceptable 5% level by harvest in April. Where orchardists had used sprays for the control of scales or mealybug in November, a summer augmentative release was also beneficial and resulted in acceptable mealybug levels at harvest in contrast to sprayed areas receiving no releases. Without augmentative releases, parasitism by *L. dactylopii* increased naturally from late summer but usually too late to reduce the mealybug infestation to 5% or less at harvest.

The parasitoid is now commercially mass reared and released annually in 170 ha of Queensland citrus.

INTRODUCTION

Citrus mealybug *Planococcus citri* (Risso) (Hemiptera:Coccidae) is a serious pest of citrus and custard apple, *Anoma spp.* hybrid in Queensland. Washington navel oranges (*Citrus sinensis* (L.) Osbeck and Marsh grapefruit *Citrus paradisi* Macfedyen are the most susceptible varieties of citrus (Smith and Papacek 1985). Mealybug crawlers infest young citrus fruit in early November and settle under the calyx. Later they move to either the navel of the navel oranges or between adjoining surfaces of clustered fruit. Fruit become unsightly due to growth of sooty mould on the honeydew produced by the mealybug and heavy infestations in navels can cause end rot and fruit drop. Infestation levels up to about 5% in harvested fruit are acceptable for local fresh fruit markets. Methidathion sprays may control the pest if applied thoroughly before infestations build up, but spray efficacy is reduced by the preference of *P. citri* for crevices and protected sites. In the absence of natural enemies, infestations tend to redevelop after two to three months. Methidathion kills a wide range of natural enemies and its use must be minimised in orchards practising integrated pest management (Smith and Papacek 1985).

Cryptolaemus montrouzieri Mulsant (Coleoptera:Coccinellidae), *Leptomastidea abnormis* Girault (Hymenoptera: Encyrtidae) and *Oligochrysa lutea* (Walker) (Neuroptera:Chrysopidae) were the most common natural enemies of *P. citri* on citrus in Queensland prior to the release of *L. dactylopii* (Smith and Papacek 1985). *Pauridia peregrina* Timberlake (Hymenoptera:Encyrtidae) is less common. Both adults and larvae of *C. montrouzieri* and larvae of *O. lutea* feed on all stages of *P. citri*. *L. abnormis* parasitises mainly second instar nymphs and *P. peregrina* first instar nymphs. *C. montrouzieri* and *O. lutea* are native to Australia, *L. abnormis* possibly Mediterranean in origin and *P. peregrina* oriental (Flanders 1953).

Leptomastix dactylopii Howard (Hymenoptera:Encyrtidae) occurs in North and South America and Europe and attacks third instar and young adult *P. citri*. It was introduced to California in 1935 from Brazil its probable centre of origin (Compere 1939). Flanders (1953) reported that although *L. dactyloptii* was released in California at the rate of over 10 million per year from 1938 to 1953, it did not become established. Similar difficulties were experienced in Israel (Rivnay 1960), on the island of Procida near Naples (Zinna 1960) and in the Campania region of Italy and in Sicily (Mineo and Viggiani 1976). Cold winters and/or hyperparasitism were blamed. However, it successfully established in Texas (Meyerdirk *et al.* 1978) and in Cyprus (Krambias and Kontzonis 1980). Doutt (1952) described the release of *L. dactylopii* and *C. montrouzieriu* against *P. citri* in a commercial greenhouse in California. Fisher (1963) described the mass culture of *L. dactylopii* for release annually in California orchards, but currently there appears to be little commercial rearing of the parasitoid and little data on its efficacy.

This paper reports studies evaluating the efficacy of *C. montrouzieri* and other native natural enemies against *P. citri* prior to 1980. It documents the introduction of *L. dactylopii* in 1980–81 and subsequent studies comparing its efficacy in both sprayed and unsprayed orchards when allowed to increase naturally or when augmented by releases of insectary reared parasitoids in spring and summer.

MATERIALS AND METHODS

Preliminary evaluation of existing natural enemies

To determine the efficacy of existing natural enemies, populations of *P. citri* and its natural enemies were assessed monthly from November 1979 to April 1980 in two 2 ha blocks of 12-year-old Washington navel oranges at Mundubbera. Fruit were assessed *in situ* and the effect of excluding natural enemies was studied using chemical disruption (0.1% DDT applied monthly for 7 months) and physical barriers (sleeve cages). In each block, one tree was treated with DDT, a closed branch cage was attached to each of four random trees and an open ended branch cage to each of four other random trees.

During this period, 11 000 *C. montrouzieri* adults (25 per tree) were released on one of the above blocks, 2500 adults in November and 2300 in December 1979, 3700 in January and 2500 in February 1980. The beetles were reared in the laboratory on *P. citri* on blanched potato sprouts *Solanum tuberosum L.* (Fisher 1963) or on butternut grammas *Cucubita moschata* Dushesne. Augmentative releases of *C. montrouzieri* were used in California (Fisher 1963) and this experiment was to assess the value of similar releases in Queensland.

Rearing, release and evaluation of *L. dactylopii*

Rearing and release

Adult *L. dactylopii* were received from Fillmore, California in March 1980 and mass reared in the laboratory on *P. citri* using the methods described above for *C. montrouzieri*.

The first releases of *L. dactylopii* were in November 1980 at a rate of 5 to 10 000 per ha and approximately 2.5 million adult parasitoids were released between then and April 1987, 88% on citrus and 12% on custard apple (Table 1). Data relating to custard apple are reported separately.

Table 1. *L. dactylopii* release sites in Queensland, Nambour 1980–May 1987

Date	Number released	Location	Number of sites	Crop	Total area (ha)
Nov 1980–May 1981	2 000	Nambour (27°S, 153°E)	1(1)*	citrus	0.2
	5 000	Palmwoods (27°S, 153°E)	1	custard apple	0.5
	40 000	Mundubbera (25°5'S, 151°5'E)	2(2)*	citrus	4.0
	10 000	Gayndah (25°5'S, 152°E)	1	citrus	1.0
	2 000	Glasshouse (27°S, 153°E)	1	custard apple	0.2
	5 000	Howard (25°5'S, 153°E)	1	citrus	0.5
	5 000	Rockhampton (23°5'S, 150°5'S)	3	citrus and ornamentals	0.5
	1 000	Cairns (17°S, 145°5'E)	1	ornamentals	0.1
Sept 1981–May 1982	40 000	Palmwoods and Glasshouse	9	citrus and custard apple	4.0
	10 000	Gayndah	1	citrus	1.0
Sept 1982–May 1983	250 000	Gayndah and Mundubbera	20(1)*	citrus	100.0
Sept 1983–May 1984	60 000	Palmwoods and Glasshouse	2	custard apple	6.0
Sept 1984–May 1985	840 000	Gayndah and Mundubbera	50(50)*	citrus	150.0
	60 000	Palmwoods and Glasshouse		custard apple	6.0
Sept 1985–May 1986	300 000	Gayndah and Mundubbera	30(19)*	citrus	100.0
	30 000	Palmwoods and Glasshouse		custard apple	3.0
Sept 1986–May 1987	760 000	Gayndah and Mundubbera	80(21)*	citrus	125.0
	90 000	Palmwoods and Glasshouse	10	custard apple	12.0
	30 000	Mareeba (17°S, 145°5'E)	1	custard apple	3.0

* Citrus sites monitored.

Chemical treatments applied to orchards during studies

All study blocks received routine copper oxychloride sprays for disease control in the spring, and maldison-protein hydrolysate bait sprays to control Queensland fruit fly *Dacus tryoni* (Froggatt) (Diptera: Tephritidae) during February–April. Occasionally, the miticides mancozeb or fenbutatin oxide were applied in the summer for rust mites *Phyllocoptruta oleivora* (Ashmead) or *Tegolophus australis* Keifer (Acarina:Eriophyidae). Some study blocks were treated with 0.5 g a.i./L methidathion during 1985–87 (detailed later).

Monitoring techniques

Two techniques were used to monitor populations of mealybug and its natural enemies. Firstly, fruit were assessed monthly *in situ* (5–20 random fruit on 20 random trees per block) and the percentage with any stage of *P. citri* present recorded. The percentage of these infested fruit with mealybugs parasitised by *L. dactylopii* (pupae or adults) and/or *C. montrouzieri* (larvae, pupae or adults) present were also recorded. Secondly, 50 *P. citri* infested fruit (from at least 10 trees) were taken to the laboratory where the number of third instar plus adult mealybugs (the stages parasitised by *L. dactylopii*) were counted. Fruit were then individually confined in cages with sprouted potatoes to provide a continuing medium on which the mealybugs could complete their development at 25°C. Numbers of *L. dactylopii* and other emerging parasitoids during the next six weeks were recorded and percent parasitism recorded. The first technique reduced sampling time and avoided destructive sampling of the fruit. It was found to be a more practical measure when a large number of sites were surveyed and was the only one used during 1984–87.

Assessments

Initial establishment

L. dactylopii was first released and monitored in November 1980 in a 0.2 ha block of 5-year-old Marsh grapefruit at Nambour and in the two navel orange blocks at Mundubbera used in 1979–80 for the evaluation of existing natural enemies. Assessment in these and subsequent blocks continued until late April. In Queensland 70 to 80% of Washington navels and Marsh grapefruit are harvested by the end of April. The parasitoids were released at a rate of 10 000 per ha. Parasitism of mealybugs and predator abundance were assessed both *in situ* and (in the case of the parasitoids) in the laboratory using the methods described above. In each block four trees each had a closed branch cage attached, another four an open ended cage and another four an open ended cage from which predatory species; for example, *C. montrouzieri* were removed on inspection once a week.

Over wintering

During 1981–82 and 1983–83 *L. dactylopii* was not re-released at any of the 1980–81 study sites at Mundubbera or Nambour. The over wintering ability of *L. dactylopii* was determined at the three sites by picking fruit monthly from October to March and assessing parasitism in the laboratory using the methods described.

Augmentative release in orchards not sprayed with methidathion

Releases up to 1983 (particularly 250 000 in spring 1982) established *L. dactylopii* throughout the 1500 ha of citrus in the Gayndah–Mundubbera area. The first augmentative release monitored was in a one hectare block of six-year-old Washington navel oranges at Gayndah in 1982–83. *L. dactylopii* was established in this block in late 1980 and an augmentative release of 10 000 parasitoids per ha was made in mid October 1982. Parasitism in this block, and in all subsequent experimental blocks was measured using the first technique. *L. dactylopii* was not released at Gayndah-Mundubbera during the 1983–84 season but from 1984–85 on, an annual release programme was commenced.

In 1984–85, levels of *P. citri* and *L. dactylopii* were monitored *in situ* on 50 citrus blocks of one to five hectares in the Gayndah–Mundubbera area. Each received an augmentative release in October–December 1984 of 5 to 10 000 *L. dactylopii* per ha.

In 1985–86 similar data were collected from Gayndah–Mundubbera at 15 sites where augmentative releases of 5 to 10 000 *L. dactylopii* per ha were made in October–December 1985 and at 10 sites where no releases were made.

In 1986–87 data were again collected at 20 sites where augmentative releases were made in October–December 1986.

Augmentative release in orchards sprayed with methidathion

In 1985–86 data were collected at 4 sites where 0.5 g/L methidathion was applied in late November 1985 followed by a release of 10 000 parasitoids per ha in late December-early January and at two sites where methidathion was similarly applied but no release made.

In 1986–87 data was obtained from one site sprayed on 10 December 1986 followed by a release of 8000 parasitoids per ha on 31 December and from one site where methidathion was applied in late November but no release made.

RESULTS

Preliminary evaluation of existing natural enemies

C. montrouzieri and *L. abnormis* were the most common natural enemies of *P. citri* in the 1979–80 study prior to the introduction of *L. dactylopii*. The use of DDT and exclusion cage check trees demonstrated that these species gave considerable control of *P. citri* (Figure 1). However, in spite of the occurrence of *L. abnormis* on up to 40% of infested fruit and to a lesser extent of *C. montrouzieri* (5%), the level of fruit infested at harvest in both blocks (30%) was inadequate for first grade production fruit. *C. montrouzieri* occurred more in the 1984-85 season when it was recorded on up to 20% of mealybug infested fruits.

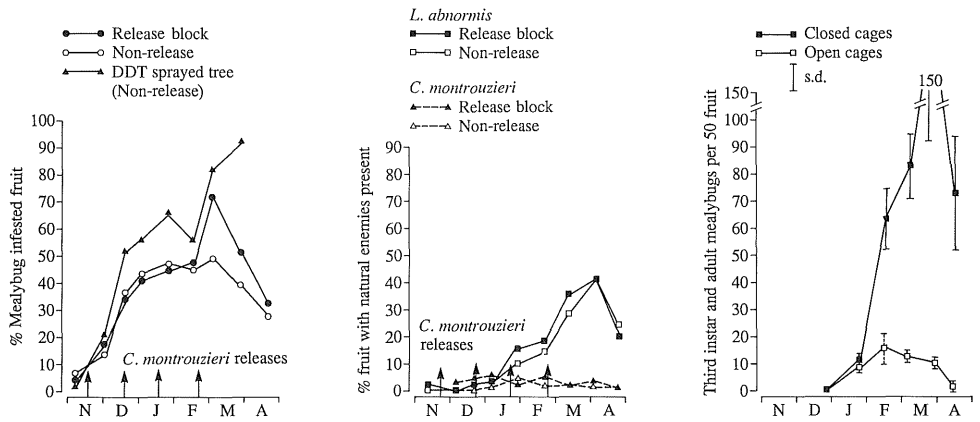


Figure 1. Efficacy of existing natural enemies of *P. citri* at Mundubbera 1979–80 prior to release of *L. dactylopii*.

Data from the DDT sprayed tree and the caged branches were similar for both the release and non release blocks; the data from the non-release block are shown in Figure 1. Data for the caged branches is represented by means and standard deviations. The *P. citri* infestation peaked at 90% of fruit infested on the DDT sprayed trees. In the enclosed cages the infestation peaked at 150 third instar and adult mealybugs per 50 fruit, whereas the highest number recorded in the open cages was 16 per 50 fruit.

C. montrouzieri was recorded on a maximum 5% of mealybug infested fruit in both the release and non release blocks so the augmentative release failed to increase numbers.

Rearing, release and evaluation of *L. dactylopii*

Initial establishment

Data from the three blocks assessed in 1980–81 as means and standard deviations, are shown in Figure 2. *L. dactylopii* successfully established and reduced the mealybug infestations to an average 5% before harvest in April with average parasitism levels of 60% by early March. The first post release generation *L. dactylopii* were recovered in mid December 1980 and by early March 1981 were recorded on 60% of infested fruit. Mealybug numbers increased to an average 500 third instar and adults per 50 fruit in the closed sleeve cages compared with maximum averages of 20 in open cages and 25 in open cages where predators were removed by hand.

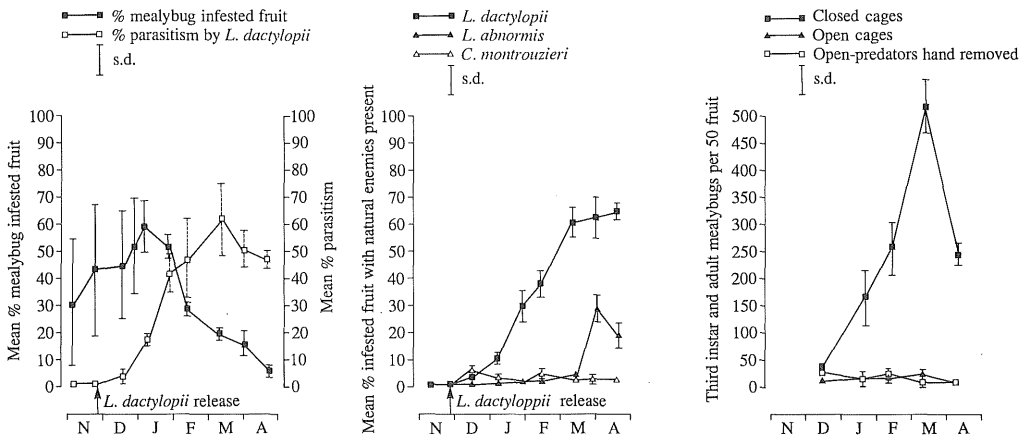


Figure 2. Efficacy of natural enemies of *P. citri* at Nambour and Mundubbera 1980–81 following release of *L. dactylopii*.

Over wintering

L. dactylopii successfully overwintered, June to August inclusive in 1981 but populations were almost undetectable in the spring. The parasitoid was first detected in samples from Nambour in late November, and from Mundubbera in late December and late January. Following the cooler winter of 1982, *L. dactylopii* was not recovered at all three sites until late January 1983. During winter 1981 the average minimum temperature at Nambour was 7.6°C (12 frosts) and for 1982, 6.9°C (8 frosts). At Mundubbera the average minimum for 1981 was 7.5°C (24 frosts) and for 1982, 5.8°C (28 frosts).

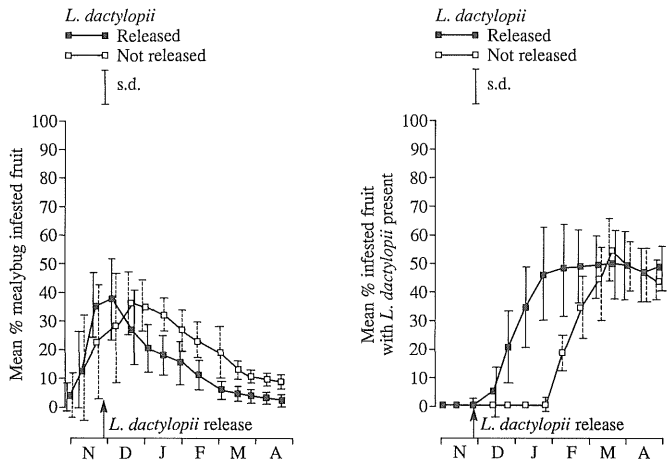
Augmentative releases in orchards not sprayed with methidathion

Data from 86 blocks (1 block in 1982–83, 50 in 1984–85, 15 in 1985–86 and 20 in 1986–87) receiving a release of 5 to 10 000 parasitoids per ha in November to December are shown in Figure 3. Similar data are given for 15 blocks receiving no release during 1985–86. Where released, *L. dactylopii* was first recorded in mid December and by mid February was present on an average of 50% of mealybug infested fruit. The mealybug infestation peaked at an average 38% in early December and before harvest in April had dropped to 3%. Where no releases were made, the parasitoid was first recorded in early February and was present on an average 55% of mealybug infested fruit by mid March. The mealybug infestation peaked at an average 47% mid December and by late April dropped to 10%.

Augmentative release in orchards sprayed with methidathion

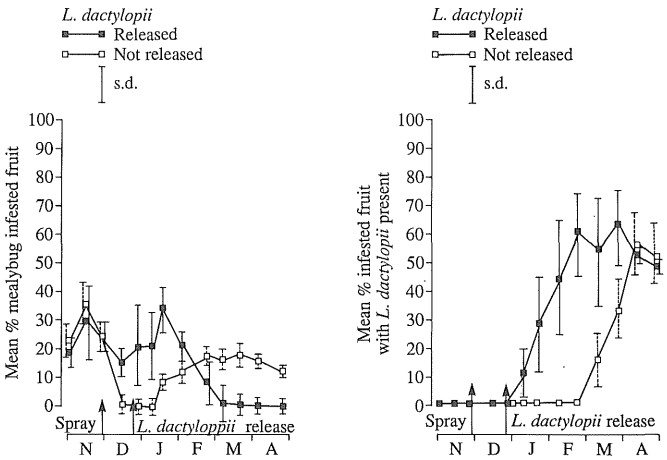
Data from five blocks (4 in 1985–86 and 1 in 1986–87) sprayed with methidathion in late November or early December followed after four weeks by a release of 8 to 10 000 parasitoids per ha are shown in Figure 4. Similar data are given for three blocks (2 in 1985–86 and 1 in 1986–87) sprayed with methidathion in late November but receiving no releases. Where released, *L. dactylopii* was first recorded in mid January and by mid February was present on an average 45% of mealybug infested fruit. The mealybug infestation peaked at an average 32% in late November, dropped after spraying to 16%, rose in late January again to 35% and by late April dropped to 2%. Where no releases were made the parasitoid was first recorded in mid March and by mid April was present on 57% of mealybug infested fruit. The mealybug infestation peaked at an average 37%

in late November, dropped after spraying to 1%, rose by late February to 19% and by harvest at the end of April was 14%.



Gayndah-Mundubbera 1982-87

Figure 3. Effect of augmentative releases of *L. dactylopii* on levels of fruit infested with *P. citri* at Gayndah and Mundubbera 1982–87.



Mundubbera 1985-87

Figure 4. Effect of augmentative releases of *L. dactylopii* on levels of fruit infested with *P. citri* following spraying with methidathion at 0.5 g/L at Mundubbera 1986–87.

DISCUSSION

Following its introduction and release *L. dactylopii* became the most common natural enemy of *P. citri* in citrus throughout south-east Queensland. However, the parasitoid was almost undetectable from June to November because of slow recovery of populations after winter. The population then increased naturally from late January reaching high levels by early march. These levels reduced mealybug numbers to 10% fruit infested by harvest. The presence of mealybug on 25% or more of the fruit from December to March

usually resulted in excessive amounts of sooty mould. In contrast, augmentative releases in November to December resulted in high levels of parasitoid activity from mid January and less than 10% of fruit with mealybug from mid February on. As *L. dactylopii* numbers increased in release blocks there was slow dispersal to surrounding non release areas. However, even in immediately adjacent non-release blocks parasitoid levels were observed to be six weeks behind the levels present in release blocks.

Growers not using Integrated Pest Management (IPM), commonly use one or two methidathion sprays to control mealybug and scales. Where these were applied in spring–early summer, results showed that control of *P. citri* was improved by augmentative release four weeks after spraying. This interval was advisable to minimise residues toxic to *L. dactylopii.* Currently *L. dactylopii* is commercially mass reared in Mundubbera and augmentatively released each spring–summer in 150 ha of navel oranges and 20 ha grapefruit in the Gayndah–Mundubbera and Nambour areas. Releases are also recommended on other varieties during spring–summer if more than 10% of fruit becomes infested. Half of the releases are in orchards practising IPM and half where more regular spraying with chemicals such as methidathion occurs in spring–early summer. The current cost of releasing 10000 parasitoids per ha is $A250 which is approximately equivalent to the cost of making one high volume application of methidathion at 0.5 ga/L.

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