Releases from 1994-1997 and recovery of the parasitic mite *Hemisarcoptes coccophagus* Meyer (Acari: Hemisarcoptidae) in Gisborne and Bay of Plenty

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Abstract

Hemisarcoptes coccophagus Meyer, introduced to New Zealand in 1987 to control armoured scale insects (Diaspididae), was distributed in the Bay of Plenty and Gisborne between 1994 and 1997. A simple method for distributing them between orchards is described. In 2004/05 the distribution sites were surveyed for *H. coccophagus* establishment. The original release trees were re-sampled where possible. No mites were found at 8 sites in Gisborne. *Hemisarcoptes coccophagus* was discovered on latania scale (*Hemiberlesia lataniae* (Signoret)) on shelter trees at 2 of 8 sites in the Bay of Plenty. Further sampling of scale insects on shelter trees and kiwifruit vines at these sites demonstrated that the mites were present on the orchard shelter trees. A single mite was found in the kiwifruit crop. The implications of these findings for the biological control of armoured scale insects are discussed.

Keywords: *Hemisarcoptes coccophagus*, armoured scale insects, *Hemiberlesia lataniae*, kiwifruit, biological control, Allee effects.

Introduction

The parasitic mite *Hemisarcoptes coccophagus* was introduced into New Zealand in 1987 for the control of the armoured scale insects, greedy scale (*Hemiberlesia rapax* Comstock) and latania scale (*Hemiberlesia lataniae*) (both Hemiptera: Diaspididae) on kiwifruit. *H. coccophagus* was also released into pipfruit and stonefruit orchards in the South Island between 1991 and 1997, targeted at San José scale (*Diaspidiotus perniciosus* (Comstock)), oystershell scale (*D. ostreaeformis* (Curtis) and apple mussel scale (*Lepidosaphes ulmi* (L.)). Early recovery at one site in the South Island was not repeated, and they were presumed not to have survived six years after release (Charles *et al*. 1998). Extensive releases of *Hemisarcoptes* spp. and *Chilocorus* spp. (Coleoptera: Coccinellidae) (the ladybirds on which hypopodes (the dispersal stage) of the mites are phoretic) were made in the North Island, but *Chilocorus* spp. failed to survive (Charles *et al*. 1995b).

Large numbers of *H. coccophagus* were released in the Bay of Plenty and Gisborne from 1989-1993, after which the mite established in Gisborne, and dispersed from original release points (Charles *et al*. 1995a; Hill *et al*. 1993). Dispersal occurred despite the absence of *Chilocorus* ladybirds. Hypopodes of *H. coccophagus* were recorded as phoretic on the local coccinellid species *Halmus chalybeus* Boisduval and *Scymnus fagus* Broun (Charles *et al*. 1995a; Hill *et al*. 1993), but the rarity of sightings led to significant doubts as to the ability of these beetles efficiently to disperse *H. coccophagus*.

Following demonstration of the successful reduction of latania scale populations at one release orchard in Gisborne (Charles *et al*. 1995a; Hill *et al*. 1993), and in light of a probable poor natural dispersal, it was decided to make further releases and to seek quick and cost-effective methods of mass release and re-distribution at orchard sites in the Bay of Plenty and Gisborne. This paper reports on those releases in 1994 and 1997, and provides data from a survey in 2004/05 to assess the survival of the mites 7 to 10 years later.

Materials and methods

Release and assessment of establishment of H. coccophagus

Bay of Plenty:

Three separate batches, each of 250 potatoes (cultivar "Nadine"), were infested with greedy scale crawlers between July and September 1996 and held in a constant temperature room at 23ºC. When the insects from the second generation on the potatoes had matured to the adult stage, between November 1996 and January 1997, they were inoculated with *H. coccophagus* from a laboratory colony. Mite numbers had increased to suitable numbers for release approximately one month after inoculation. The mites were released on the potatoes. The numbers of mites released (approximately 500 per potato) were estimated by sub-sampling a selection of potatoes and counting the numbers of mites/scale insect and scale insects/potato.

The mites were released to 17 orchards in the Bay of Plenty at between 20 and 40 potatoes/orchard at various dates between January and April 1997 (Table 1). All releases were made into organic (or those under conversion to organic) orchards of the green-fleshed kiwifruit cultivar 'Hayward'. Each potato was attached to a scale insect-infested shelter tree or kiwifruit vine by a cable tie. In tall shelter trees, about half of the releases were made at approximately 5 metres above ground, where scale insect populations were often more abundant and less affected by orchard insecticide sprays (Hill *et al*. 1993). Despite a previous history of high numbers of armoured scale insects at each of these orchards, bark samples collected at all sites immediately prior to the mite releases held surprisingly low numbers of scale insects (<1 adult scale insect/2cm^2 of bark). Examination of dead insects showed that they were under attack from large numbers of *Encarsia citrina* and *E. perniciosi* (Hym. Aphelinidae) parasitoids. Hence, in retrospect, none of the orchards provided an ideal release site containing high numbers of host insects to facilitate establishment.

Eight of the 17 release sites were visited in October 2004 and samples of bark with armoured scale insects were taken from 5-10 shelter trees,

Table 1. *H. coccophagus* release sites in kiwifruit orchards in the Bay of Plenty 1997. Sites highlighted in bold had *H. coccophagus* in 2004. Sites in italics were sampled in 2004 but no *H. coccophagus* were found. The other release sites were not sampled in 2004.

No.	District	Release date	Sites at each orchard	Approx number released
1	*Katikati*	*January 1997*	*20*	*10,000*
2	*Katikati*	*January 1997*	*20*	*10,000*
3	Katikati	January 1997	20	10,000
4	*Te Puna*	*January 1997*	*20*	*10,000*
5	*Te Puna*	*January 1997*	*20*	*10,000*
6	Tauranga	January 1997	20	10,000
7	**Tauranga**	**January 1997**	**32**	**16,000**
		April 1997	**20**	**10,000**
8	Tauranga	January 1997	35	17,500
9	Tauranga	January 1997	20	10,000
10	Tauranga	January 1997	20	10,000
11	Tauranga	January 1997	20	10,000
12	Tauranga	January 1997	30	15,000
		April 1997	22	11,000
13	**Te Puke**	**February 1997**	**20**	**10,000**
14	Te Puke	February 1997	40	20,000
15	*Te Puke*	*February 1997*	*20*	*10,000*
16	Te Puke	February 1997	28	14,000
17	*Te Puke*	*February 1997*	*40*	*20,000*
		April 1997	*20*	*10,000*
Total			**487**	**243,500**

and in one case from kiwifruit vines. The area of the bark samples ranged from 24-112 cm^2. The shelter was sampled rather than the vines because large pieces of bark can be taken more easily without causing economic damage to the plant and armoured scale insect populations are often higher on the shelter trees. The samples were examined under a binocular microscope for the presence of *H. coccophagus*. When mites were found, the numbers of live adult scale insects (3rd instar) and *H.coccophagus* active stages and eggs in the sample were counted. At one of these sites separate samples were taken from three shelter tree species. Larger bark samples were taken between February and April 2005 from shelter trees at each of two sites (7 & 13) where mites were found in October 2004, and at one site (13), samples of scale insects were taken from kiwifruit vines and assessed for presence of *H. coccophagus*. At site 13 (Te Puke) samples consisted of 54 bark samples (5004 cm^2) from 5 alder trees, 40 bark samples (5019 cm^2) from 4 lacebark trees and 35 bark samples (3898 cm^2) from 3 *Pittosporum* sp. trees. At site 7 (Tauranga) an average of 100cm^2 of bark was taken from each of 10 *Phebaleum* sp. trees.

Gisborne:

In February 1994, mites were established on Lombardy poplar (*Populus nigra* var. Italiana) shelter at 3 orchard sites from latania scale and *H. coccophagus* infested potatoes (as described for the Bay of Plenty orchards) (table 2).

A technique was then tested that would allow growers themselves to easily distribute mites through a district, and avoiding the process of rearing them on scale insect infested potatoes or pumpkins. In December 1994, bark strips (approximately 8cm x 30cm x 3mm thick) containing latania scale infested by *H. coccophagus* were cut from the trunks of these trees. The bark strips were transferred to a new site within the Gisborne area (site 15, table 2) where they were stapled to the trunks of Lombardy poplar shelter trees. To prevent mortality of mites from desiccation in the days immediately following the transfer, some of the bark strips were covered either with moist paper towels applied to the cut

Table 2. *H. coccophagus* release sites at Gisborne.

No.	Location	Release date	Host plant
1	Te Karaka	October 1996	Avocado *(Persea americana)*
2	Te Karaka	October 1996	Lombardy Poplar *(Populus nigra* L. *italica)*
3	Waipaoa	October 1996	Flevo Poplar (*Populus deltoides* x *nigra)*
4	Ormond	October 1996	Walnut *Juglans regia*
5	Ormond	October 1996	Avocado
6	Ormond	October 1996	Matsudana willow *(Salix matsudana)*, Lombardy poplar
7	Ormond	October 1996	Avocado
8	Ormond	October 1996	Avocado
9	Waerenga-a-hika	February 1994	Avocado
10	Waerenga-a-hika	October 1996	Avocado
11	Waerenga-a-hika	October 1996	Avocado, Lombardy poplar
12	Waerenga-a-hika	October 1996	Lombardy poplar
13	Hexton	October 1996	Avocado
14	Makauri	February 1994	Lombardy poplar
15	Patutahi	Dec1994/Feb1996	Lombardy poplar
16	Patutahi	October 1996	Lombardy poplar
17	Patutahi	February 1994	Lombardy poplar
18	Patutahi	October 1996	Lombardy poplar
19	Manutuke	October 1996	Lombardy poplar
20	Muriwai	October 1996	Avocado

surface or with moist paper towels and plastic kitchen wrap (Gladwrap®) wrapped around them. Other strips of bark were left open to the air.

Further releases to the Gisborne district were subsequently made in October 1996 by tying potatoes (n=42) infested with greedy scale (*Hemiberlesia rapax* (Comstock)) and *H. coccophagus* to shelter belt trees at 17 additional sites (table 2). No estimate of the number of mites per potato were made at the Gisborne sites, but experience suggested they were similar to those released into the Bay of Plenty.

Eight of the 20 1994-1996 release sites were visited in October 2004 and samples of bark (476-3878 cm^2 per site) taken from 10-15 shelter trees at each site. The samples were examined using a binocular microscope and the number of live adult scale insects and *H. coccophagus* active stages and eggs were counted.

Results

Hemisarcoptes coccophagus *establishment: 1994-2005*

Bay of Plenty

H. coccophagus was found on shelter trees at two sites (7 & 13) in the Bay of Plenty in 2004 but was absent from 6 others (1, 2, 4, 5, 15 and 17; table 3). A repeat sample taken from shelter at release site 13 (Te Puke) in February 2005 found no *H. coccophagus* in a sample of 179 latania and 12 greedy scale on 5004 cm^2 of alder bark, nor in 49 latania scale on 5019 cm^2 of lacebark bark. *H. coccophagus* was recovered from two latania scale on samples of bark from 'Hayward' kiwifruit vines in the block adjacent to the shelter (table 4).

Hemisarcoptes coccophagus was present on the bark of all 10 *Phebalium* sp. trees forming part of a kiwifruit shelter belt at site 7, with tree-level parasitism of adult latania scale ranging from 1% to 54% (table 5). There was a negative correlation between % parasitism and armoured scale insect density measured on a per-sample (Spearman r_S = -0.4, P=0.039, n=27), or a tree-level basis (Spearman r_S=-0.56, P= 0.090, n=10; figure 1).

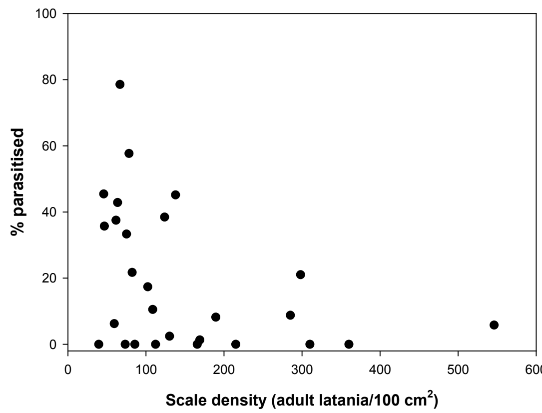

Figure 1. The relationship between % parasitism by *H. coccophagus* and scale density measured per sample of bark (adult latania per 100 cm^2) on 10 *Phebalium* trees at site 7, Bay of Plenty, April 2005.

Table 3. Sites sampled in Bay of Plenty, October 2004 and found to have *H. coccophagus*. In addition to these, a further six sites (numbers 1,2,4,5,15 & 17) were sampled but no mites were found.

Property	substrate	area sampled (cm^2)	live adult Latania	live adult Greedy	% infested scale	active stages/ scale	eggs/ infested scale	scale/ 100 cm^2
7	*Phebalium* sp.	165	46	0	39%	3.1	3.8	27.9
13	Willow (*Salix* sp.)	592	41	1				7.1
13	Alder (*Alnus glutinosa*)	1293	30	0	10%	2.0	1.0	2.3
13	Lacebark (*Hoheria sexstylosa*)	505	13	0	8%	2.0		2.6

Table 4. Re-sampling of scale on 8 kiwifruit vines at site 13 in Bay of Plenty, April/May 2005.

Date	No. mature scale	No. mature latania scale	*H. coccophagus* % parasitism	*H. coccophagus* eggs/scale	*H. coccophagus* actives/scale
8-Apr-05	53	47	0%		
22-Apr-05	58	49	0%		
3-May-05	69	68	1.5%	5.0	3.0
18-May-05	141	134	0.7%	2.0	3.0

Table 5. Re-sampling of site 7, *Phebalium* shelter trees, in the Bay of Plenty. April 2005. All latania scale.

tree	area sampled (cm^2)	no. latania scale	*H. coccophagus* % parasitism	*H. coccophagus* eggs/infested scale	*H. coccophagus* active stages/ infested scale	Latania density (scale/100 cm^2)
1	74.3	19	21%	1.0	1.5	25.6
2	104	53	43%	1.6	2.1	50.8
3	110	308	3%	0.1	0.1	280.6
4	107	197	12%	0.3	0.5	184.6
5	75.5	46	15%	0.5	0.6	60.9
6	146	42	29%	1.0	2.4	28.8
7	79.3	56	54%	1.1	4.1	70.7
8	111	76	9%	0.1	0.3	68.2
9	99	58	43%	1.1	1.5	58.6
10	97	172	1%	0.1	0.1	177.3

Gisborne

By June 1994 *H. coccophagus* was recovered from two of the three February 1994 release sites. Where present, all life stages of the mites (except for hypopodes) were found on many *H. lataniae*, and the mite was clearly well established. By December 1994, populations of the host scale insects had declined dramatically at the three original release sites but mites were found only at one site. Hence bark samples were collected from this site for transfer to the fourth *H. lataniae* infested orchard (site 15). The weather at the time of transfer of *H. coccophagus* using the bark strips was hot and dry, with no rainfall for the month following the transfer. Despite such apparently unfavourable environmental conditions, the mites established, and in February 1995 they were found on poplars bark samples immediately adjacent to each of the three methods of bark transfers. Mites were not found on samples from any of the three original sites in March 1995. Between June and August 1995, 15-17 months after the first *H. coccophagus* releases, an evaluation of *H. lataniae* populations on Lombardy poplar bark at the three sites showed that scale insect numbers had declined substantially from an estimated 25 scale/ 100cm^2 to the point where they were hard to find (T. Lupton personal observation).

No *H. coccophagus* mites were found in the Gisborne 2004 survey samples (table 6).

Discussion

The observed substantial decline in latania scale numbers on shelter trees in Gisborne following the establishment of *H. coccophagus* in February 1994 is further evidence that these mites can reduce latania scale insect populations on trees in New Zealand. Observations of the mite and latania scale populations on the bark of Lombardy poplar shelter

Table 6. Sites sampled in Gisborne, October 2004

Property	Substrate	Area sampled (cm^2)	live adult latania scale	Latania scale/100 cm^2
7	Lombardy poplar	1260	45	3.6
9	Lombardy poplar	2112	11	0.5
12	Lombardy poplar	901	72	8.0
14	Lombardy poplar	1821	23	1.3
15	Black poplar *(Populus nigra)*	730	3	0.4
17	Matsudana willow	504	4	0.8
19	Matsudana willow	3878	28	0.7
19	Pussy willow *(Salix caprea)*	476	38	8.0
19	Matsudana willow	585	26	4.4
20	Avocado	1836	17	0.9

in 1995, following the transfer of mites on strips of bark, shows that this simple technique can be an effective way of transferring these mites, even under very dry climatic conditions. The technique allows growers to cooperate in the distribution of the biological control agent throughout a district while avoiding the expense, time and technical expertise required to establish large numbers of scale insects and then mites on potatoes. However, it is also apparent from these measurements that *H. coccophagus* can quickly drive its host latania scale populations down to a point where there are few mites left to transfer. Thus if the bark transfer method is to be used as a simple and cost effective means of distributing the mite, it must be carefully timed to coincide with periods of maximum mite numbers, prior to their substantially reducing armoured scale insect populations. This time period after the initial mite establishment on a tree is likely to vary with the time of year when the initial introductions are made, and repeated observations may be necessary to ensure optimal times for re-distribution of mite populations on strips of bark. However on the basis of the current observations, re-distribution should be undertaken 4-8 months after the initial release of the mites onto the trees in February.

The re-discovery in 2004-2005 of *H. coccophagus* at two Bay of Plenty release sites up to eight years after its release confirmed its establishment in the region and its ability to persist, albeit at low levels, in kiwifruit shelter and in unsprayed kiwifruit. This was the first time that the mite has been recovered from armoured scale insects on a kiwifruit vine. The vine was from an experimental (but commercially managed) block at the HortResearch Te Puke Research Orchard which had remained unsprayed for several years.

Despite the mite's persistence in the Bay of Plenty, it is clearly not abundant. Its absence from all of the re-surveyed Gisborne release sites, including the original establishment site (no.14 table 2; Hill *et al*. 1993), suggests either that it did not persist much beyond five years (Charles *et al*. 1995a) or that it is now very rare. More extensive surveys would be required to search further for establishment, but were beyond the scope of the current project. Reasons for its failure to establish more widely, or to be more common, remain conjectural. Ecological studies of *H. coccophagus* in Israel, where the mite occurs naturally (Izraylevich *et al*. 1996; Izraylevich *et al*. 1995), showed that the response of *H. coccophagus* to its host is complex and is dependent upon the host species, the host life stages available and the tree substrate. The ecology of *H. coccophagus* has received insufficient study in New Zealand to allow the critical factors affecting its population dynamics to be quantified. However the twin observations of rapid and effective reduction in pest populations leading to local extinctions, coupled with presumed low rates of dispersal over distances greater than a few metres due to lack of effective phoretic agents, may be key factors affecting the overall population dynamics of the mite and its hosts (Gerson *et al*. 2003; Hill *et al*. 1993).

Studies at one site in the first few years after release have shown that the mite can be an effective natural enemy of armoured scale insects on kiwifruit shelter at high densities, and that it appears to be able to drive its host population locally extinct on shelter tree bark at a sampling scale of $60cm^2$ (Charles *et al*. 1995a; Hill *et al*. 1993). There was no evidence for prey density effects on rates of *H. coccophagus* parasitism in these earlier studies, in contrast to the suggestion of negative spatial density dependence of parasitism in the present study. There are insufficient data to determine the implications of this result on the dynamics of the host populations, but previous reviews of density dependent mortality in insect populations have shown that inverse spatial density dependence is as prevalent as direct density dependent effects, and it may also have a stabilising effect on host populations (Jervis & Kidd 1996).

In New Zealand, pest armoured scale insects have only 1-2 generations a year and their populations build up slowly. They are also unlikely to have refuges from which they can escape mite parasitism. These factors may make it difficult for the mite to maintain its population over large areas of habitat and on some, if not most, substrates. However, the possibility remains that if *H. coccophagus* can persist on populations of latania scale over several years on large tree hosts such as *Phebalium* shelter*,* it may be able to re-colonise local populations of scale insects on other hosts (e.g., kiwifruit shelter trees) after they have built up to sufficient densities to again support *H. coccophagus* populations.

Features of the ecology of both *Hemiberlesia* spp. (e.g., clumped distribution, poor dispersal) and *Hemisarcoptes coccophagus* (e.g., poor dispersal in the absence of phoresy *via* coccinellid ladybirds) in New Zealand increase the likelihood that both prey and mite populations may be subject to Allee effects. An Allee effect is a positive relationship between species fitness and population density, and is increasingly regarded as a potentially important component of survival at low population density. A component Allee effect acts on a component of fitness (in this case immature and adult survival); however if the relationship extends to an overall effect on species fitness, it is said to be a 'demographic' Allee effect (Stephens *et al*. 1999). Both, by definition, reduce fitness more strongly at low population densities. In this system, for example, observations that *H. coccophagus* parasitism is associated with high levels of local extinctions of *H. lataniae* populations on kiwifruit shelter trees (Hill *et al*. 1993; Charles *et al*. 1995) may be evidence of 'component' Allee effects on the prey (Allee 1958; Stephens *et al*. 1999) while the rapid demise of local mite populations following apparently successful establishment and control of their prey may be evidence of Allee effects on the parasite. There are insufficient data to determine whether this system exhibits a 'demographic' Allee effect, although the poor dispersal abilities of the mite and the large scale insect population reductions observed following its release (Charles *et al*. 1995a; Hill *et al*. 1993) would support such a conclusion (Gascoigne & Lipcius 2004).

The presence of a competent phoretic agent, *Chilocorus* spp.*,* that disperses the mite effectively and seeks out patches of high host density using olfactory and visual cues (Hattingh & Samways 1995), may ameliorate Allee effects, allowing the mite population to persist in space and time. Such impacts should be the subject of research should *Chilocorus* spp. be re-considered for introduction to New Zealand in future, or should they arrive accidentally.

In the meantime, the fact that it is able to persist in the environs of kiwifruit orchards over a number of years, as shown in this study, leaves open the possibility that *H. coccophagus* may be having a beneficial effect upon the numbers of pest diaspidid scale insects. While it's utility as an effective classical biological control agent in most horticultural environments in New Zealand remains in some doubt, its evident ability to reduce scale insect populations suggests that it may be of use as an augmentative biological control agent for reducing armoured scale insect populations on exotic plants in indoor plant collections or displays (e.g., botanic gardens).

Finally, the recent discovery of the genus *Hemisarcoptes* in Australia (Gerson 1994) raises the possibility that endemic species of *Hemisarcoptes* may also exist elsewhere in New Zealand, attacking some of the many indigenous Diaspididae in native bush habitats.

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