Passionvine hopper, *Scolypopa australis* (Walker) (Hemiptera: Ricaniidae), egg parasitism by Aphelinidae (Hymenoptera) in New Zealand.

John G. Charles and Doug J. Allan

HortResearch, Private Bag 92 169, Auckland, New Zealand

Abstract

The distributions and aspects of the biology of aphelinid egg parasitoids of passionvine hopper (PVH) in New Zealand were measured. *Centrodora scolypopae* Valentine was common in Nelson and has probably dispersed throughout the range of PVH in New Zealand since last surveyed in 1962. *Ablerus* sp. has dispersed since its initial discovery in Auckland in 1985 and is now additionally found in the Waikato, the Bay of Plenty and Nelson. *Ablerus* sp. appears to be a thelytokous, multi-voltine primary parasitoid of PVH eggs, and not, as initially thought, a hyperparasitoid of *C. scolypopae*. Several biotic and abiotic factors that kill PVH eggs have been identified. Future studies to measure the impacts of egg parasitism on PVH populations will require careful sampling procedures that take into account spatial variation in PVH oviposition and parasitism within a site, and large seasonal variations in PVH populations that can be induced by weather and parasitism. Despite the wider distribution of *C. scolypopae* and the arrival of *Ablerus* sp., PVH continues to be a sporadic pest in many places.

Keywords: *Scolypopa australis*, passionvine hopper, Ricaniidae, egg parasitoids, *Centrodora scolypopae*, *Ablerus* sp., Aphelinidae.

Introduction

Passionvine hopper, *Scolypopa australis* (Walker) (Hemiptera: Ricaniidae) (PVH) has become a serious pest of kiwifruit in the Bay of Plenty in some seasons during the past decade following the adoption of the KiwiGreen management strategy that reduced or removed most broad-spectrum insecticide sprays from kiwifruit orchards.

PVH established in New Zealand about 130 years ago from Australia (Hill & Steven 1989). An egg parasitoid, *Centrodora scolypopae* Valentine (Hymenoptera: Aphelinidae), was discovered in New Zealand in 1961 (Valentine 1966) and remains the only presumed host-specific parasitoid of PVH in either New Zealand or Australia (Cumber 1966). In 1995 another aphelinid, *Ablerus* sp., was found in association with PVH eggs in Auckland, but was assumed to be a hyperparasitoid of *C. scolypopae* (Harcourt 1995).

In 1962, numbers of *C. scolypopae* decreased with increasing latitude. They parasitised up to 87% (average of 39%) of PVH eggs north of Auckland, but none was found in Nelson (Cumber 1966). Significantly, Cumber's survey in October and November of 1962 excluded most of the Bay of Plenty, where the kiwifruit industry of today is centred. However, Valentine (1966) reared *C. scolypopae* from PVH eggs in lemon wood from Tauranga in 1961.

One option to reduce the pest status of PVH throughout its range in New Zealand is to improve biological control, especially by the introduction of new natural enemies such as nymphal parasitoids from Australia. The release of suitable species into New Zealand under the Hazardous Substances and New Organisms (HSNO) Act 1996 would require approval of the Environmental Risk Management Authority (ERMA), and, *inter alia*, evidence of the effectiveness of existing natural enemies against which to measure the potential benefits of a new biocontrol agent.

From 1999-2001 we measured the distribution of *C. scolypopae* (and *Ablerus* sp.) in kiwifruit growing regions in much the same way as Cumber in 1962 (Cumber 1966). This provided a unique opportunity to compare the current distribution of *C. scolypopae* with that 37 years earlier. We also initiated investigations into the biology of *Ablerus* sp.

Methods

Regional survey of parasitism

Cumber (1966) recorded a wide variation in PVH egg parasitism by *C. scolypopae* on different host plants, but noted that parasitism was higher in the commonly sampled bracken fern (*Pteridium aquilinum* var. *esculentum*). Gerard (1989) showed that successful attack by a *C. scolypopae* female is limited by the length of her ovipositor and the depth of the PVH egg in plant tissue, so that *C. scolypopae* parasitises more PVH eggs laid shallowly in plants with a narrow, hard stem (such as bracken) than those laid more deeply in softer-stemmed plants (such as brambles). Hence all samples in this study were collected from bracken and compared to Cumber's data from bracken alone. The fate of individual eggs at any time (e.g. nymphal emergence, aphelinid parasitoid emergence, hyperparasitoid emergence (Cumber 1966, 1967)) can usually be readily identified.

Samples of bracken fern, each containing >50 PVH eggs, were collected in December 1999 and January 2000. At this time of year most PVH eggs had hatched but *C. scolypopae* had only recently started to emerge. PVH nymph and parasitoid emergence, and PVH egg mortality through unidentified causes were recorded in the laboratory at the time of collection. Samples were collected from up to 6 sites in each of the following districts (with regional abbreviations from Crosby *et al*. 1998): Whangarei (ND), Auckland (AK), Hamilton (WO), Te Puke (BP), Hawke's Bay (HB) and Nelson (NN) (Table 1). Unhatched eggs were then maintained in black plastic tubes in the laboratory at 25°C and a 16 h photoperiod. Parasitoids were collected and identified as they emerged until mid February 2000, when the egg samples were transferred to glass Petri dishes. In May 2000, each egg was dissected from the bracken frond and its final fate determined and recorded, using methods similar to Cumber (1967). Although Cumber sampled slightly earlier in the season (from October – November 1962) the fate of the eggs was readily determined in all cases, allowing a direct comparison of data from the two surveys.

Biology and seasonal phenology of *Ablerus* sp.

Following its widespread recovery in 1999/2000, the seasonal phenology of *Ablerus* sp. was investigated the following year at two sites in each of BP and WO. PVH egg populations in bracken were sampled monthly from each of the four sites from August 2000 until August 2001 inclusive. The samples, each of at least 100 eggs, were examined individually in the laboratory immediately after collection. They were then stored in air-tight 5 cm diameter Petri dishes (Falcon 1006) at c.21°C and examined every few weeks for parasitoid emergence. All eggs were dissected from the bracken samples and their fate recorded in February 2002. The eggs sampled were thus exposed to natural, seasonal mortality factors only until collected. They were, however, exposed to different, unnatural mortality through conditions in the laboratory where they were stored awaiting parasitoid or PVH emergence.

The hypothesis that *Ablerus* sp. may complement parasitism by *C. scolypopae* because of a greater ability to parasitise eggs laid at different depths in plants was tested. Twenty female *C. scolypopae* and 30 female *Ablerus* sp. were slide mounted to expose the full length of their ovipositor. The length of each ovipositor was measured from just below the bulbous articulation to the tip under a compound microscope, and the mean ovipositor length for each species compared by *t*-test.

Results and Discussion

Regional survey of parasitism

Twenty-three samples of bracken fern containing more than 8000 PVH eggs were collected (Table 1). Eggs were commonly found in all regions except Auckland and Hawke's Bay. Parasitoids emerged in the laboratory from December until mid-February, but many of the intact eggs dissected in May also contained parasitoids that had died during pupal or adult development. Any contribution to PVH egg mortality from parasitoids that had died during egg or larval stages could not be determined.

Two species of parasitoid emerged from PVH eggs - *C. scolypopae* and *Ablerus* sp. The combined egg parasitism, expressed as a percentage of the number of PVH eggs collected, was compared to the equivalent data (for *C. scolypopae* alone) from Cumber (1966) (Fig. 1). Data were divided into geographical zones more or less delimited by latitude throughout the 650 km distribution of PVH from Northland to Nelson. In 1999, *C. scolypopae* was found in all regions surveyed including the Bay of Plenty and Nelson. *C. scolypopae* clearly has spread south since Cumber's survey in 1962 and is now probably present throughout the range of PVH in New Zealand. Cumber attributed the gradual decline in mean percent parasitism over the lower half of the North Island in 1962 to the recent colonisation or absence of *C. scolypopae*. The 1999 data show no such difference in parasitism. Nor was there any significant difference in 1999 (*t*-test; $P = 0.65$) between angular transformed percentage parasitism at the latitudinally similar, but climatically different, Waikato and Bay of Plenty collection sites. Hence the 1999 data point to a more even distribution and impact of *C. scolypopae* (together with *Ablerus* sp.) throughout the country than recorded by Cumber in 1962.

The data in Fig. 1 imply that parasitism in the north of the country was considerably lower in 1999 than in 1962. Statistically, parasitism in Northland and Waikato was significantly higher in 1962 than in 1999 (*t*-test of means of angular transformed percentage parasitism; $P < 0.04$ and 0.01 respectively), but it was not in Auckland ($P = 0.29$). At a site in the Waikato from 1980-84, PVH egg parasitism in bracken was also higher (between 37 and 80%) than in 1999 (Gerard 1985). However, PVH egg and parasitoid populations are driven substantially by weather and can be expected to vary considerably from year to year (Gerard 1985). Hence the apparent differences in parasitism cannot imply that there had been any long-term decline in their effectiveness between 1962 and 1999.

Ablerus sp. adults emerged from PVH eggs collected in Auckland, the Waikato, the Bay of Plenty and Nelson, but at fewer sites than *C. scolypopae* (Table 1). *Ablerus* was commonly reared at some sites but not others (only two *Ablerus* sp. adults were reared from the Nelson samples). *Ablerus* sp. is a distinctive species, and it is inconceivable that Cumber and Gerard would not have found it during their studies in the 1960s and early 1980s respectively, had it then been present. Hence Harcourt's records in 1995 probably reflected the recent arrival of *Ablerus* sp. in New Zealand, rather than a lack of observation in the past. It appears to have spread (and be spreading) rapidly through New Zealand at a rate of c. 125 km/year (Auckland to Nelson = 650 km in 5 years). Whether spread has been natural or with human assistance cannot be determined.

Both species of parasitoid were found in the Bay of Plenty at sites from Tauranga to Te Puke, where they can be expected to have an impact on PVH populations that infest kiwifruit orchards.

Table 1. Summary of PVH egg collection data from bracken fern, 1999-2000

			Fate of eggs (mean %)		No. of sites with identified parasitoid	
Region	No. of Sites	Total no PVH eggs collected	PVH emerged	parasitised (C. scolypopae and Ablerus)	*C. scolypopae*	*Ablerus*
ND	5	1441	53.8	30.3	4	3
AK	2	354	62.1	32.3	2	2
WO	6	2137	51.8	23.9	6	6
BP	5	2612	44.2	19.2	5	1
HB	1	46	69.6	23.9	1	0
NN	3	1525	64.0	29.4	3	1
	23	**Total = 8115**			**20**	**13**

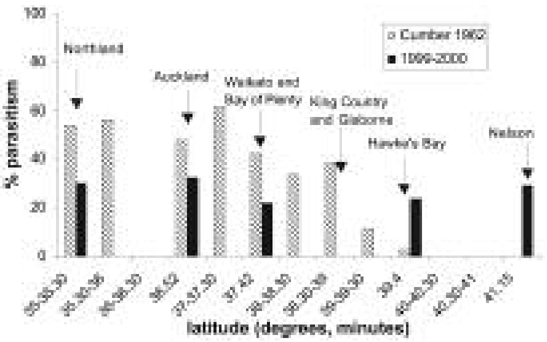

Fig 1. Distribution of *Centrodora scolypopae* and the mean % parasitism of PVH eggs in 1962 and 1999. The 1999 data include unmeasured parasitism from *Ablerus* sp.

Ablerus sp. (Hym: Aphelinidae)

Taxonomy/identity

Ablerus sp. voucher specimens have been deposited with the New Zealand Arthropod Collection (NZAC) held by Landcare Research. All *Ablerus* sp. reared from PVH eggs were the same as that found by Harcourt (1995). However, this *Ablerus* sp. is not the *Ablerus* sp. of Noyes and Valentine (1989) (J. Berry, Landcare Research, Auckland pers. comm.). Cumber searched for PVH parasitoids in Australia in 1965, and recorded *Ablerus* sp. as a hyperparasitoid in Sydney. This species emerged from a small circular hole in the side of the egg (see Fig. 1 in Cumber 1967), and is clearly quite different from the New Zealand *Ablerus* sp. In New Zealand, the appearance of the meconia (post-pupal waste products) and the ragged-edged emergence-hole cut in the host egg by both *Ablerus* sp. and *C. scolypopae* were so similar that a simple means to identify which parasitoid had emerged from an empty PVH egg was not determined. A single *Ablerus* sp. emerged from each PVH egg, leaving a single set of aphelinid pupal exuviae and meconia. This strongly indicates that *Ablerus* sp. is a primary parasitoid of PVH eggs, not a hyperparasitoid as presumed by Harcourt (1995). All *Ablerus* sp. were females, and microscopic examination showed no significant difference between the mean ovipositor length of *C. scolypopae* (0. 62 ± 0.14 mm, n = 20) and *Ablerus* sp. (0.63 ± 0.005 mm, n=30) (*t*-test; $P > 0.3$). The ovipositor length of *C. scolypopae* in this study was similar to that found by Gerard (1985) (0.60 ± 0.01 mm), although the range of ovipositor length in our specimens (0.41 – 0.69 mm) was slightly greater than that (0.48 – 0.65 mm) found by Gerard (1985). The hypothesis that *Ablerus* sp. may complement *C. scolypopae* due to a greater ability to parasitise eggs in different plants is thus rejected, at least on the basis of ovipositor length.

Seasonal phenology of *Ablerus*

About 6500 PVH eggs were collected in monthly samples between August 2000 and August 2001. Both *C. scolypopae* (n = 845) and *Ablerus* sp. (n = 136) were frequently reared from PVH eggs from all four sites. In the field, *C. scolypopae* females oviposit in late summer, most larvae diapause within the PVH egg, and adult emergence in January is synchronised with the next year's PVH oviposition. A partial second, asynchronous generation may sometimes occur in late summer when diapause is not triggered (Gerard 1985), but once diapause is induced *C. scolypopae* development

Table 2. Emergence of *Ablerus* sp. in the laboratory from PVH eggs collected in the Waikato (WO) and Bay of Plenty (BP), 2000-01.

Date PVH eggs collected	Date by which *Ablerus* sp. emerged	*Ablerus* sp. adults (n)
14 August	6 Sept – 25 Oct	15
17 Oct	c17 Nov	1
6 + 14 Nov	14 - 20 Dec	20
6 + 15 Mar	19 July	8
5 + 20 Apr	19 July	10
8 + 16 May	19 - 20 July	16

retains its synchrony with PVH development. In the laboratory, despite the artificial storage conditions in Petri dishes, most *C. scolypopae* retained the synchrony with PVH oviposition and emerged from late January to early March. By contrast, most *Ablerus* sp. emerged within a month or 6 weeks of PVH egg collection regardless of the time of year the eggs were collected (Table 2). Some *Ablerus* sp. adults emerged during same months as *C. scolypopae*, but others emerged in spring/early summer and late summer/autumn (Table 2).

Hence we postulate that *Ablerus* sp. in New Zealand is multivoltine, with possibly 3 more or less synchronised generations a year - in spring (November/December), summer (late January/ February) and autumn (May/June). There is no evidence of, or possibly need for, close synchrony with PVH oviposition, but multi-voltinism may require alternative hosts for its long-term persistence at a site. None is, as yet, known.

Measuring the impact of PVH egg mortality factors

Monthly collection of PVH eggs from the field and consequent laboratory storage was not an entirely satisfactory method for capturing details of seasonal mortality. PVH nymph and parasitoid survival (as measured by emergence) was high in older eggs collected from July onwards. However, no PVH nymphs emerged from young eggs collected between March and September and stored for up to a year. PVH egg mortality has been shown to increase under conditions of low humidity (Matheson 1978), and it is reasonable to infer that improved laboratory storage conditions, at higher RH, are required to keep young PVH eggs (and their parasitoids) collected early in the season alive for up to 12 months.

In 1962, Cumber recorded other PVH egg mortality factors such as predation by *Pyemotes* mites, destruction by stem boring insects, death by unknown causes ('shrivelled eggs') or infertility. Superparasitism of PVH eggs may also be common (Gerard 1992). Of the eggs collected from bracken in 1962 the 'death by unknown causes' (an average across the country of 23%) was the greatest mortality factor apart from 'emerged parasitoids' (Cumber 1966). No *Pyemotes* mites were found between 1999 and 2001, but additional mortality factors were identified, including 'overlaying' – where eggs in one batch were punctured by subsequent oviposition from a different female, usually from the other side of the bracken frond. This was a common occurrence - especially at sites with large egg populations - and perhaps reflected a shortage of favoured oviposition sites. Similar levels of unknown mortality were found in 1999. Many eggs from the Waikato were full of fungal hyphae when examined in February 2002. It was not determined whether the fungi were entomopathogenic, but Gerard (1985) found fungi to be the second largest egg mortality factor in her study in the Waikato.

In summary, observations from these trials, Cumber (1966, 1967) and Gerard (1985, 1986, 1992) show that PVH eggs may be commonly killed by parasitoids (at least 2 species of aphelinid and 1 unidentified scelionid), *Pyemotes* mites, 'overlaying', superparasitism, low humidity, and 'unknown causes' – possibly including entomopathogens. *C. scolypopae* in Australia is attacked by a hyperparasitoid, but this is unknown in New Zealand. The generational mortality of PVH eggs would appear to be relatively easy to measure, because the eggs are easily found; the mortality factors can be readily identified under a binocular microscope with a little experience; and discrete generations can be studied over a long period. However, within any one host-plant site, PVH oviposition and parasitism (at least by *C. scolypopae*) and development period varies according to vegetation structure and height and from season to season. Studies to quantify in detail the impacts of parasitism on PVH egg mortality will require careful sampling procedures that take into account the spatial variation in PVH oviposition and parasitism within a site, and the large seasonal variations in PVH populations that can be induced by weather. Time specific life-tables developed by Gerard (1985) for PVH in the Waikato showed that nymphal mortality was very low, and that delayed density dependent parasitism by *C. scolypopae* was the key mortality factor.

Conclusions

The geographical range of *C. scolypopae* has increased since 1962. This parasitoid is now present in Nelson and probably throughout the range of PVH in New Zealand. Hill and Steven (1989) postulated that *C. scolypopae* arrived with PVH eggs "many years ago". On the other hand, its absence from earlier Cawthron Institute records (e.g. Gourlay 1930) indicates that it had only recently arrived in 1962, with a small population present south of Hawke's Bay and none in Nelson.

The aphelinid wasp *Ablerus* sp. is present in Auckland, the Waikato, the Bay of Plenty and Nelson. It has spread rapidly since its initial establishment in New Zealand, and was very common in some samples collected in 1999. The New Zealand species has not been found from any other host in New Zealand, and is presumed to have arrived recently from Australia, where it has not yet been reported. Both species of parasitoids were found in 1999 at sites in the Bay of Plenty from Tauranga to Te Puke, an area not covered by Cumber in 1962.

Ablerus sp. appears to be a thelytokous, multivoltine primary parasitoid of PVH eggs, and not, as initially thought, a hyperparasitoid of *C. scolypopae*. It has yet to be determined what impact it is having, or may have, on PVH or *C. scolypopae* populations. The ecological impact of *Ablerus* sp. on PVH population dynamics, or on possible alternative hosts, remains to be investigated. However, the evidence suggests that neither the arrival of *Ablerus* sp., nor the wider distribution of *C. scolypopae* has dramatically lowered PVH populations over the past 15-30 years. Several biotic and abiotic factors that kill PVH eggs have now been identified. Future studies to measure the impacts of egg parasitism on PVH populations will require careful sampling procedures that take into account the spatial variations in PVH oviposition and parasitism within at site, and the large seasonal variations in PVH populations that can be induced by weather. In the meantime, PVH continues to be a usually minor pest, but one that periodically can become significant – both in economic crops and in the wider environment.

Acknowledgments

We thank Roddy Blank, Andrew Tomkins, Cathy McKenna, Shirley Dobson, Peter Lo and Peter Shaw for organising PVH egg collections from Northland, Waikato, Bay of Plenty, Hawke's Bay and Nelson respectively; and Jo Berry (Landcare Research, Auckland) for *Ablerus* identifications.

References

Crosby TK, Dugdale JS, Watt JC. 1998. Area codes for recording specimen localities in the New Zealand subregion. *New Zealand Journal of Zoology 25:* 175-183.

Cumber RA. 1966. Factors influencing population levels of *Scolypopa australis* Walker (Hemiptera-Homoptera: Ricaniidae) in New Zealand. *New Zealand Journal of Science 9(2):* 336-356.

Cumber RA. 1967. Factors influencing egg survival of *Scolypopa australis* Walker (Hemiptera-Homoptera: Ricaniidae) in the Sydney area (N.S.W. Australia). *New Zealand Journal of Science 10:* 639-643.

Gerard PJ. 1985. The ecology of *Scolypopa australis* and its parasite *Centrodora scolypopae*. PhD thesis, University of Waikato.

Gerard PJ. 1989. Influence of egg depth in host plants on parasitism of *Scolypopa australis* (Homoptera: Ricaniidae) by *Centrodora scolypopae* (Hymeoptera: Aphelinidae). *New Zealand Entomologist 12:* 30-34.

Gerard PJ. 1992. Observations on superparasitism in a natural population of *Centrodora scolypopae* (Hymeoptera: Aphelinidae). *New Zealand Entomologist 15:* 32-38.

Gourlay ES. 1930. Preliminary host-list of the entomophagous insects in New Zealand. *Bulletin of the New Zealand DSIR* 22. 13 pp.

Harcourt SJ. 1995. Screening of insecticides for use against passion-vine hopper, *Scolypopa australis* Walker (Homoptera: Ricaniidae): A basis for integrated pest management in kiwifruit. MSc thesis, University of Auckland.

Hill RL, Steven D. 1989. *Scolypopa australis* (Walker), passionvine hopper (Homoptera: Ricaniidae). Pp. 241-244 in Cameron, P.J.; Hill, R.L.; Bain, J.; Thomas, W.P. (eds), *A review of biological control of insect pests and weeds in New Zealand 1874 to 1987.* Technical Communication, CAB International Institute of Biological Control

10, CAB International, Wallingford, UK.

Noyes JS, Valentine EW. 1989. Chalcidoidea (Insecta: Hymenoptera) – introduction and review of genera in smaller families. *Fauna of New Zealand 18:* 1-91.

Valentine EW. 1966. A new species of Centrodora (Hymenoptera: Aphelinidae) parasitic upon the eggs of *Scolypopa australis* Walker (Hemiptera: Ricaniidae). *New Zealand Journal of Science 9(2):* 331-335.