HOST SPECIFICITY OF *COTESIA RUBECULA* AND *COTESIA PLUTELLAE*, PARASITOIDS OF WHITE BUTTERFLY AND DIAMONDBACK MOTH

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ABSTRACT

Cotesia rubecula and *Cotesia plutellae* were assessed as potential biological control agents for white butterfly (*Pieris rapae*) and diamondback moth (*Plutella xylostella*), respectively, in New Zealand. Some literature records indicated a wider host range for *C. plutellae* compared with *C. rubecula*. The specificity of these parasitoids was evaluated by rearing collections of Lepidoptera from natural parasitoid habitats overseas, and by laboratory testing of their host preferences for related Lepidoptera and species from brassica habitats. *C. rubecula* showed strong preferences for white butterfly and developed in no other species. This parasitoid has now been released and its effectiveness and specificity are being confirmed in the field. Whereas *C. plutellae* demonstrated preferences for diamondback moth in oviposition rate and suitability for development, it was capable of developing in several other Lepidoptera in the laboratory. Current laboratory tests require very careful interpretation for predicting the field host range of species such as *C. plutellae*.

Keywords: Host-specificity, parasitoids, white butterfly, *Pieris rapae*, diamondback moth, *Plutella xylostella*

INTRODUCTION

Recent attempts to improve biological control of vegetable brassica pests in New Zealand led to the consideration of *Cotesia rubecula* (Marshall) and *Cotesia plutellae* Kurdjumov (Hymenoptera: Braconidae: Microgastrinae) as candidates for introduction against white butterfly (*Pieris rapae* L.) and diamondback moth (*Plutella xylostella* (L.)), respectively. Information on their host specificity obtained from the catalogue compiled by Shenefelt (1972) indicated that *C. rubecula* was almost specific to *P. rapae* and that *C. plutellae* may attack a range of Lepidoptera families. Fitton and Walker (1992) point out that although *C. plutellae* is widely assumed to be host specific, it has been recorded from several other species of Lepidoptera. Although for some early biological control introductions to New Zealand native alternative hosts were considered as useful parasitoid reservoirs, conservation of native species, including the few attractive native butterflies, is now an important issue. To predict the host ranges of both these parasitoids in New Zealand, we evaluated the literature, assessed their natural host range overseas, and performed laboratory experiments on host location and suitability for parasitoid development. The assessment of *C. rubecula* commenced in 1992 and it was released in New Zealand in 1993/94. *C. plutellae* was imported in 1995 and is still being evaluated in the laboratory and in natural environments overseas.

METHODS

Initial information on the host specificity of *C. rubecula* was based on field collections of *P. xylostella* and *Anaphaeis java* (Pieridae) from brassicas and *Bassaris itea* (Nymphalidae) from nettle in the Adelaide region of South Australia where *C. rubecula* is the dominant parasitoid of *P. rapae*. The specificity of *C. plutellae* in the

field was examined by collecting and rearing Lepidoptera larvae from cruciferous crops and adjacent weeds in areas of Fiji where this parasitoid was present (Walker *et al*. in press). *C. rubecula* was imported from Adelaide in 1992 and *C. plutellae* from Fiji in 1995 for laboratory tests. Lepidoptera species to be tested (Table 1) were collected as adults from light traps except for *Nyctemera amica/annulata* (a hybrid) and *B. itea* that were collected as eggs and larvae. Eggs were collected from gravid females and larvae reared on their usual host plants or on cabbage. Five test species were indigenous in New Zealand: *Diarsia intermixta* which occurs on ferns, *B. itea* on nettle (*Urtica dioica*), *N. amica/annulata* on ragwort (*Senecio jacobaea*), *Graphania mutans* on plantain (*Plantago lanceolata*) and *G. ustistriga*, and two were endemic species: *Uresiphita polygonalis* on kowhai (*Sophora microphylla*), and *Plutella antiphona* which was collected from water cress (*Nasturtium officinalis*) on Chatham Island.

The suitability of different species of Lepidoptera for development of parasitoids was tested by exposing individual larvae to single mated females as described by Cameron *et al.* (1995). The success of oviposition by *C. plutellae* was checked by dissecting some test larvae after 48 h to determine if eggs had been deposited or larvae were developing. The remaining test larvae were reared until parasitoids emerged to form cocoons, or until test larvae became too large to be parasitised. The comparative success of parasitoid development in different test species was also assessed by exposing three to six replicates of 8-12 test larvae to individual females in 4 litre cages for 3 h.

The acceptability of different test species was assessed by observing the flight of adult female parasitoids to larvae on excised leaves in a flight tunnel using methods developed by Keller (1990). The wind speed in the tunnel was set at 50-60 cm/s, adult parasitoids were released at 70 cm from the test insects and the experiments were run at 25ºC. Test females were fed and mated but had no experience of Lepidoptera larvae prior to release in the tunnel. Females were presented with larva-plant combinations alternately or simultaneously. Five to ten test insects were placed on each plant 24 h prior to the experiments to ensure the presence of some leaf damage. Plants were presented as one or two excised leaves to provide a similar leaf area for each test. For the choice tests, the plants were placed approximately 15 cm apart across the air flow, equidistant from the centre line, and their position was alternated between each test.

RESULTS AND DISCUSSION

Published host records

In Europe, *C. rubecula* is considered to be almost specific to *P. rapae* and very exceptionally it will attack *P. brassicae* (Richards 1940). Rare records of *P. xylostella* as a host in Russia (Mustata 1992) may indicate a very low attack rate on this species or difficulties in verifying the host. A review of the literature (Cameron 1993) indicated that in Australia and probably elsewhere, *C. rubecula* is a specific parasitoid of *Pieris* spp. Numerous field records suggest that *C. plutellae* is a narrowly oligophagous parasitoid of *P. xylostella* that rarely parasitises other Lepidoptera species (Shenefelt 1972). Host records from parasitoid specimens (Wilkinson 1939) included two species of Lasiocampidae and two Noctuidae as rare hosts. More recent literature confirmed field parasitism in two families: less than 0.01% parasitism of an arctiid (Bogavic 1953); rare parasitism of a pyralid (Baloch *et al*. 1966). It is uncertain if *Aglais urticae* (Nymphalidae) is a field host, but Wilkinson (1939) recorded it as a laboratory host. *C. plutellae* has also been reared on three species of Pyralidae in the laboratory (Wang *et al*. 1972; Lim 1982 (cited in Waterhouse and Norris 1987)). These literature records, together with general criteria for selecting test species, suggested three categories of test species in New Zealand: close relatives, i.e. Plutellidae; species on crucifers, i.e. Noctuidae; species in the same family as hosts recorded in the literature, i.e. Nymphalidae, Arctiidae, Pyralidae.

Field survey

In Adelaide, no *C. rubecula* cocoons were obtained from 55 *P. xylostella* larvae on cabbage or 32 *A. java* on *Capparis mitchelli* (Capparacidae), confirming the previous extensive rearing carried out by M.A. Keller and G.J. Baker (pers comm.). No parasitoids were reared from 132 larvae of *B. itea* collected from six locations over two summers.

C. plutellae was common in the main cabbage growing area of Fiji where it

parasitised greater than 70% of *P. xylostella* in the 1995 survey (Walker *et al.* in press). Although other microgastrine parasitoids were present, no *C. plutellae* were reared from 563 *Spodoptera litura*, 43 *Helicoverpa armigera*, 17 *Chrysodeixis eriosoma* (all Noctuidae), 130 *Hymenia recurvalis* (Pyralidae) and 82 *Crocidolomia binotalis* (Pyralidae). These results augment the previous observations of Lim (1982) (cited in Waterhouse and Norris, 1987) that *C. binotalis* and *Hellula hydralis* were parasitised in the laboratory but not in the field.

Host suitability in the laboratory

Attempts to force oviposition by *C. rubecula* were successful only when larvae of *P. rapae* were presented. Rarely, *C. rubecula* probed *Graphania mutans* and *P. xylostella* with their abdomens (Table 1), but their ovipositors were not extended as for oviposition. Rearing and dissection of probed individuals detected no eggs or larvae of the parasitoid, and no cocoons were formed, whereas all parasitoid stages were detected in *P. rapae* control insects. Choice experiments with *P. rapae* and *G. mutans* or *P. xylostella* showed that parasitoids would walk over the alternative species to selectively oviposit in adjacent *P. rapae*.

TABLE 1: Egg and cocoon production from oviposition responses (ovip.) by *Cotesia plutellae* and *Cotesia rubecula* presented with individual larvae, and cocoon production by *C. plutellae* exposed to groups of test larvae on plants.

Family	Test insect	*Cotesia plutellae*			*Cotesia rubecula*	
		Ovip. per n[a]	Eggs /ovip[b]	Cocoons per N[c]	Ovip. per n[a]	Cocoons /ovip[b]
Plutellidae	*Plutella xylostella*	182/190	50/61	60/110	3/76	0/3
	Plutella antiphona	-	-	21/72	-	-
Tortricidae	*Epiphyas postvittana*	6/33	0/6	0/48	0/18	0
Pyralidae	*Uresiphita polygonalis*	15/15	-	13/15[d]	0/20	0
Pieridae	*Pieris rapae*	11/32	0/11	0/60	149/149	145/149
Nymphalidae	*Bassaris itea*	12/66	-	3/66[d]	0/18	0
	Danaus plexippus	-	-	-	0/20	0
Arctiidae	*Nyctemera amica/annulata*	17/24	-	7/22	-	-
Noctuidae	*Agrotis ipsilon*	12/30	0/3	1/50	0/18	0
	Diarsia intermixta	14/20	2/6	9/50	-	-
	Graphania mutans	15/30	-	3/50	7/68	0/7
	Graphania ustistriga	-	-	30/50	-	-
	Helicoverpa armigera	16/30	2/16	0/16[d]	0/24	0
	Neumichtis saliaris	-	-	0/20	-	-
	Spodoptera litura	14/24	1/8	0/47	-	-
Thysanoplusia orichalcea		-	-	-	0/23	0

[a] Oviposition response per number of larvae presented individually
[b] Eggs deposited per oviposition response
[c] Cocoons per number of larvae exposed in groups
[d] Cocoons per number of larvae presented individually

C. plutellae attempted to oviposit in all species tested, but dissection of larvae revealed that eggs were not deposited in *Epiphyas postvittana* or *P. rapae* and were rarely found in other species (Table 1). The oviposition response was highest in *P. xylostella* and was initiated more quickly (data not shown) in this species. There was no clear difference between oviposition response in species other than *P. xylostella*, nor was the rate related to success in cocoon formation. For example, no cocoons developed from *Spodoptera litura*, but more than 50% of the larvae attracted oviposition attempts. This demonstrated that oviposition response provided a poor estimate of the suitability of a species, possibly because the response may be elicited by host plant (cabbage)-

associated factors. Of those species where eggs were detected, both *S. litura* and *Helicoverpa armigera* were unsuitable for further development. The rate of cocoon formation (Table 1) indicated that five species were not hosts: that *B. itea, A. ipsilon* and *G. mutans* were occasional laboratory hosts; and that *P. antiphona, U. polygonalis, N. amica/annulata, D. intermixta,* and *G. ustistriga* were all suitable laboratory hosts for *C. plutellae*.

Estimates of the development rate of *C. plutellae* provided another measure of the suitability of some test species. In *P. antiphona*, parasitoids developed from egg to cocoon at the same rate as in *P. xylostella*. By contrast, parasitoid larvae in *D. intermixta* and *G. ustistriga* required 20% longer to develop, those in *N. amica* took 40% longer, and development in *B. itea* required 45% longer than in *P. xylostella*.

Flight tunnel tests

In flight tunnel experiments, *C. rubecula* was attracted to and oviposited in *P. rapae* on cabbage, but females were not attracted to either *A. java* on *Capparis* or *B. itea* on nettle. Any females that alighted on *Capparis* or nettle immediately took flight and often moved to cabbage. In the comparison of *P. rapae* with *P. xylostella* (both on cabbage), female parasitoids flew equally to either plant but oviposition responses were directed only at *P. rapae*.

By contrast, *C. plutellae* females flew to all test combinations of insect and plant species (Table 2). Fewer adults flew to *B. itea* on nettle, but plants with larvae of *D. intermixta* or *N. amica* were as attractive as *P. xylostella.* Flights to *H. armigera* and *Neumichtis saliaris*, species previously demonstrated to be unsuitable for development, strongly suggested that *C. plutellae* is attracted by cabbage volatiles, or by the volatiles from damaged cabbage. This behaviour has also been observed in *C. rubecula* by Agelopoulos and Keller (1994) who reported that, although this parasitoid did not distinguish between damage by host or non-host Lepidoptera, the blend of volatiles emitted from frass was different for *P. xylostella* and *P. rapae*.

TABLE 2: Flights of *Cotesia plutellae* to test insect and host plant combinations compared with *Plutella xylostella* (DBM) in a flight tunnel.

	Number of flights per number of tests	
	Alternate test insect and host plant[a]	Alternate test combination DBM on cabbage
Bassaris itea on nettle	6/43	18/43
Nyctemera amica/annulata on ragwort	6/27	8/27
Diarsia intermixta on cabbage	21/51	19/51
Helicoverpa armigera on cabbage[b]	9/21	10/19
Neumichtis saliaris on cabbage	14/30	13/30

[a] Choice tests except for [b] which was a no-choice test

Current field status

Following its release in New Zealand, *C. rubecula* has significantly reduced populations of large *P. rapae* larvae at experimental sites (Cameron and Walker in press) where parasitism over summer has ranged from 71 - 97%. Collection of test species and the use of trap larvae at sites where *C. rubecula* was present has detected no parasitism of *P. xylostella, B. itea, D. plexippus, G. mutans,* and *E. postvittana*. To extend our data on the natural host range of *C. plutellae* we carried out another field survey in Fiji in November 1996. *C. plutellae* was commonly reared from *P. xylostella*, but for the first time it was also reared from *Chrysodeixis eriosoma* (two from 35 larvae) and *H. armigera* (one from 57). These records confirm *P. xylostella* as the preferred host but add to the list of rare hosts of *C. plutellae*.

CONCLUSION

Laboratory tests based on the suitability of hosts for parasitoid development are appropriate for demonstrating high degrees of specificity such as found in *C. rubecula.*

By contrast, *C. plutellae* developed successfully on a wider range of species in the laboratory than it has been reared from in the field. Flight tunnel tests suggested that host preference may be partly based on insect or plant odours, but did not eliminate the acceptability of native hosts. The relevance of these tests to field specificity is unclear. Laboratory tests are usually considered to overestimate host range in the field (Sands 1993), and Shaw (1994) provided examples where genuine rearing records are freak events outside the natural host range of a parasitoid. For *C. plutellae*, we are now attempting to provide further verification of its natural host range in habitats overseas. This will provide a firmer basis for developing and interpreting behavioral host specificity in the laboratory.

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