Biological Control Of Pieris Rapae in New England: Host Suppression and Displacement of Cotesia glomerata by Cotesia rubecula (Hymenoptera: Braconidae)

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BIOLOGICAL CONTROL OF *PIERIS RAPAE* IN NEW ENGLAND: HOST SUPPRESSION AND DISPLACEMENT OF *COTESIA GLOMERATA* BY *COTESIA RUBECULA* (HYMENOPTERA: BRACONIDAE)

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ABSTRACT

A survey of the imported cabbageworm, *Pieris rapae* (Lepidoptera: Pieridae), in cole crops in Massachusetts found that a Chinese strain of *Cotesia rubecula* (Hymenoptera: Braconidae), released in 1988, has spread and become the dominant parasitoid of this pest in central and western Massachusetts, with an average of 75% parasitism. The previously dominant parasitoid of this host, *Cotesia glomerata* (Hymenoptera: Braconidae), has been displaced and is now present only at trace levels (<1% of total parasitism).

Key Words: *Cotesia rubecula*, *Cotesia glomerata*, *Pieris rapae*, parasitoid displacement, evaluation, biological control, cole crops

RESUMEN

Un sondeo del gusano importado de repollo, *Pieris rapae* (Lepidoptera: Pieridae) en cultivos de crucíferos en el estado de Massachusetts mostró que la distribución de la variedad china de *Cotesia rubecula* (Hymenoptera: Braconidae), liberada en 1988, ha sido extendida y ha llegado a ser el parasitoide mas dominante de esta plaga en la parte central y occidental del Massachusetts, con un promedio de parasitismo del 75%. El parasitoide anteriormente mas dominante de este hospedero, *Cotesia glomerata* (Hymenoptera: Braconidae), ha sido desplazado y ahora solo es presente en niveles muy bajos (<1% del parasitismo total).

For biological control of the pest butterfly *Pieris rapae* (L.) (Lepidoptera: Pieridae), a population of the parasitoid *Cotesia rubecula* (Marshall) (Hymenoptera: Braconidae) collected near Beijing, China, was released in Deerfield, MA, in 1988. Here I report the outcome of this release at the regional level of western and central Massachusetts.

This same parasitoid, sourced from other locations, has previously invaded or been released in other parts of North America. In 1963 on Vancouver Island in British Columbia, a self-introduced population was detected (Wilkinson 1966), and later found south to Oregon (Biever 1992). This strain was released in Missouri, New Jersey, South Carolina, and Ontario (near Ottawa) (Puttler et al. 1970; Williamson 1971, 1972). It did not establish in Missouri (Parker & Pinnell 1972), but may have done so in Ontario (Corrigan 1982). This strain was determined to have an improperly timed diapause induction response for eastern North America (Nealis 1985). In the 1980s, a collection of this parasitoid from Yugoslavia was released in Missouri, Virginia, and Ontario. In 1988, it was recovered in Virginia, but did not persist (McDonald & Kok 1991). In 1993, *C. rubecula* was found to be the dominant parasitoid of *P. rapae* in farming areas near Montreal, Quebec (Godin & Boivin 1998).

The population of *C. rubecula* released in 1988 in Massachusetts was collected by David Reed of the USDA in Shenyang, China (42° north latitude, 123° east longitude). In total, 99 female and 49 male *C. rubecula* adults, reared in quarantine from Chinese-collected hosts or cocoons, were sent to Massachusetts where they were released in field cages in a pesticide-free, 0.1-ha collard plot in Deerfield, MA (42° n. l.) in 1988. Earlier work (1985 and 1986) at this location indicated that prior to this release, *C. rubecula* was not present and the dominant parasitoid was *C. glomerata* (Van Driesche 1988), which caused 68-81% parasitism per generation in unsprayed collard plots with high host densities (Van Driesche & Bellows 1988). The Chinese strain of *C. rubecula* was released in 17 locations in southern New England and by 2002, it was widely distributed in New England, with recoveries being made up to northern Vermont (Van Driesche & Nunn 2002).

Studies in Massachusetts from 1988-1992 (Van Driesche & Nunn 2002) at various release sites suggested that this population of *C. rubecula* established readily and spread quickly. Limited evidence was also collected suggesting that as *C. rubecula* increased in abundance at particular sites, densities of *Cotesia glomerata* (L.), a previously introduced parasitoid attacking *P. rapae*, decreased. By 1992, *C. rubecula* accounted for about half of all *Cotesia* parasitism of *P. rapae* at the Deerfield site (Van Driesche & Nunn 2002). This study also indicated that parasitism by *C.*

rubecula could reach high levels. However, work in this time period was not able to determine if substantial displacement of *C. glomerata* would occur regionally, nor if *C. rubecula* would become widespread and important over the whole landscape. Here I report a survey undertaken in 2007 to assess the outcome of this 1988 release at the landscape level, for the region of central and western Massachusetts. With the above mentioned objectives, in 2007 I visited farms producing cole crops in Massachusetts to evaluate (1) the proportion of sites with *C. rubecula*, (2) the level of parasitism of *P. rapae* by *C. rubecula*, and (3) the fraction of *P. rapae* parasitism due to *C. rubecula*.

Materials and Methods

I collected samples of *P. rapae* from 20 farms or garden plots in 13 towns in 4 counties from central and western Massachusetts, principally in the Connecticut River valley, where vegetable farms are most common. Larvae were returned to the laboratory and dissected. Most larvae collected were 3 or 4th instars, with limited numbers of 5th instars. Because sampling was conducted at the end of the first host generation, 1st and 2nd instars were scarce. Also included in samples were any *Cotesia* cocoons or *P. rapae* pupae found on plants while searching for larvae. In total, 415 insects were examined (either live *P. rapae* larvae, live *P. rapae* pupae, or live cocoons of *C. rubecula* or cocoon groups of *C. glomerata*).

Immature stages of *C. rubecula* could be readily distinguished from those of *C. glomerata* by several characteristics, including the presence of mandibles in 1st instars (*C. rubecula* only), presence of an anal hook or vesicle (*C. rubecula* only), and the number of larvae per host (1 for *C. rubecula* and 10-60 for *C. glomerata*). Eggs also can be determined to species, but no parasitoid eggs were found in this survey because it occurred late in the first parasitoid generation.

In the field, larvae were detected by turning over leaves with feeding holes and also closely examining the young leaves in the center of the plant (a preferred feeding site). Plants sampled were collards, broccoli, and cabbage. Any farm (conventional or organic) or garden plot located was checked and included in the survey if *P. rapae* larvae were present.

Results

Cotesia rubecula was found at all 20 locations sampled, indicating that this species is now present throughout the region. In addition to being present on larger farms, the parasitoid was found in patches of cole crops as small as 2 dozen plants, even plots located in forested areas not near other agricultural fields. Parasitism levels by *C. rubecula* averaged 75% parasitism (summed over all 415 life stages collected), with 16 of 20 sites having more than 60% parasitism (Table 1). Damage to plants by *P. rapae*, while not quantified, was light because few larvae reached the 5th instar, the stage responsible for most feeding, with the sole exception of farm #19, in Grafton, where the lowest level of *C. rubecula* parasitism (9%) was found. At this site, 65% (15/23) of the sample consisted of 5th instars and damage to plants (feeding and frass) was readily observed. In contrast at the other 19 sites, only 10% of life stages collected were 5th instars (44/415, of which 6 were small 5th instars parasitized by *C. rubecula*). By comparison, in New Zealand, introduction of *C. rubecula* caused 48-97% parasitism and reduced *P. rapae* 5th instar density by 88-97% in experimental plots (Cameron & Walker 2002).

At the 20 farms in the survey, *C. glomerata*—once a common, reasonably abundant parasitoid in Massachusetts (Van Driesche 1988)—was virtually absent. Of 310 parasitized *P. rapae* larvae found in samples, 308 were due to *C. rubecula* alone, 1 was a case of multiparasitism of both *C. rubecula* and *C. glomerata*, and 1 was due to an unknown dipteran. Thus of 310 *Cotesia* attacks, 99.7% (309) were due to *C. rubecula*, indicating that *C. rubecula* has displaced *C. glomerata*. In comparison, in 1990-1992, at release sites in Massachusetts, *C. rubecula* accounted for only 49% of all *Cotesia* parasitism and in 1992 in Quebec, another strain of *C. rubecula* accounted for 63% of all *P. rapae* parasitism (Godin & Boivin 1998).

Discussion

These results indicate that in Massachusetts at the landscape (not study plot) level a *C. rubecula* population of Chinese origin (1) has displaced *C. glomerata* and become the dominate parasitoid of *P. rapae* and (2) is widespread and exerts a high level of control of the target pest. The introduction of *C. rubecula* from China has achieved in large measure the goal of this classical biological control project by causing high levels of mortality of young *P. rapae* larvae. Also, because *C. glomerata* has had an undesirable effect on the native butterfly *Pieris napi oleracea* Harris in New England (Benson et al. 2003; Van Driesche et al. 2004), the disappearance of *C. glomerata* due to competition with *C. rubecula* may over time allow this species to recolonize areas from which it has disappeared (Scudder 1889), given that *C. rubecula* has little effect on this species in the field (see laboratory and field host preference test data in Van Driesche et al. 2003). Finally, the area surveyed did not reach the boundaries of this parasitoid's distribution in the region and surveys in adjacent areas (NY, VT, CT, RI, NJ) are likely to find similar outcomes.

TABLE 1. RATES OF PARASITISM BY *COTESIA* WASPS IN *PIERIS RAPAE* FROM VEGETABLE FARMS IN MASSACHUSETTS, JUN, 2007.

Farm#	Location: Town (Co.[1])	Date (Jun)	Farm type[2]	% parasitism ± 95% CI (*n*[3])	No. hosts attacked by each parasitoid		
					Cotesia rubecula	*Cotesia glomerata*	Other
1	Hadley (HS)	6	CF	81 ± 13 (32)	32	0	0
2	Amherst (HS)	6	CG	20 ± 35 (5)	1	0	0
3	Westhampton (HS)	6	G	27 ± 26 (11)	3	0	0
4	Northampton (HS)	6	CG	84 ±13 (32)	26	1	1
5	Westhampton (HS)	6	OF	67 ± 17 (30)	20	0	0
6	Whately (HS)	7	OF	73 ± 16 (30)	22	0	0
7	Whately (HS)	7	OF	100 ± 0 (3)	3	0	0
8	E. Deerfield (F)	7	OF	80 ± 14 (31)	25	0	0
9	Montague (F)	7	OF	100 ± 0 (4)	4	0	0
10	Hadley (HS)	11	OF	88 ± 12 (27)	24	0	0
11	Hadley (HS)	11	OF	93 ± 9 (31)	29	0	0
12	Sunderland (HS)	12	CF	67 ± 19 (24)	16	0	0
13	Hadley (HS)	12	OF	63 ± 18 (27)	17	0	0
14	Agawam (HD)	13	OF	92 ± 11 (25)	22	0	0
15	Agawam (HD)	13	CF	90 ± 11 (27)	26	0	0
16	Amherst (HS)	13	OF	28 ± 33 (7)	2	0	0
17	Charlemonte (F)	14	OF	80 ± 35 (5)	4	0	0
18	Lancaster (W)	18	CF	65 ± 17 (29)	19	0	0
19	Grafton (W)	18	OF	9 ± 12 (23)	2	0	0
20	Northbridge (W)	18	CF	100 ± 0 (12)	12	0	0
Total				75 ± 4 (415)	309	1[4]	1[5]

[1]Counties: Hampshire (HS), Hamden (HD, Franklin (F), and Worcester (W).
[2]Type of farm: conventional vegetable farm (CF), organic vegetable farm (OF), community garden plots (CG), individual garden (G).
[3]Samples consisted of *Pieris rapae* larvae of all instars, plus all *Cotesia* cocoons or *Pieris rapae* pupae found on foliage. Intended sample size was 25-30 per site, unless this number could not be obtained.
[4]This was an instance of multiparasitism by both *C. rubecula* and *C. glomerata*.
[5]This was 1 instance of parasitism by an unidentified dipteran.

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