Parasitism of Cranberry Fruitworm (*Acrobasis Vaccinii*; Lepidoptera: Pyralidae) by Endemic or Released *Trichogramma Pretiosum* (Hymenoptera: Trichogrammatidae)

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PARASITISM OF CRANBERRY FRUITWORM (*ACROBASIS VACCINII*; LEPIDOPTERA: PYRALIDAE) BY ENDEMIC OR RELEASED *TRICHOGRAMMA PRETIOSUM* (HYMENOPTERA: TRICHOGRAMMATIDAE)

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ABSTRACT

Two levels of commercially-reared *Trichogramma pretiosum* were released during the oviposition period of the cranberry fruitworm (*Acrobasis vaccinii*) in eight Massachusetts (U.S.A.) cranberry bog sites. Release levels of 4.8×10^5 *T. pretiosum* per ha or 1.9×10^6 *T. pretiosum* per ha were made at 3–5 day intervals, with a total of nine releases. Parasitism was estimated by collecting cranberry fruits and examining them for the presence of *A. vaccinii* eggs and *T. pretiosum*. Eggs were classified as unhatched, hatched, parasitized or emergent parasite. Collections of cranberries from four 'neglected' bog sites (not currently under cultivation) were examined and classified similarly, but *T. pretiosum* were not released, to determine the level of parasitism from endemic populations.

Cumulative parasitism from the neglected sites was consistently higher than levels recorded from the release sites throughout the season. Parasitism in the neglected sites was determined to be from natural populations of *T. pretiosum*. Comparisons of cranberries damaged by *A. vaccinii* showed that damage was greatest in the neglected sites, but was not significantly different from fruit damage within either the low release or high release level. Collections of cranberries were also made within bog sites managed under current Massachusetts Cooperative Extension IPM guidelines. Damage to cranberries was lowest in the IPM-managed sites; although this value was less than the other bog sites, it did not differ significantly.

Cranberry fruitworm (*Acrobasis vaccinii* Riley) is a primary, direct pest of cranberries (*Vaccinium macrocarpon*) and also feeds on other *Vaccinium* (Shawa et al. 1984). In the northeastern United States, immature cranberry fruitworm overwinter beneath the cranberry bog surface within hibernaculae and emerge as moths throughout June, dependent upon cranberry variety and environmental conditions (Anonymous 1982). Typically, peak flight of the moths coincides with full bloom (late June) of the cranberry crop (Roberts & Brodel 1985).

Female *A. vaccinii* generally deposit a single, flattened egg in the calyx of the developing cranberry. Larvae hatch, move to the upper berry surface and bore into the green fruit, then begin feeding. Larval development includes five instars (Brodel & Roberts 1985) and is usually completed by August. At this time, this univoltine pest drops to the soil to form a hibernaculum and over-

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winters as a larva. Pupation occurs in the spring. During its feeding period, a larva will enter and feed in 5–8 berries. Thus, high populations can substantially reduce cranberry yields, causing losses which may exceed 50%. This pest is generally controlled by several insecticidal applications.

At the time of these field trials, the ongoing pest management strategy listed first application of an insecticide (parathion, diazinon, chlorpyrifos or carbaryl) at 7–9 days after > 50% of the plants are post-bloom. This timing is determined by sampling 20 cranberry vines ('uprights') per ha and estimating the percentage of flowers that have set fruit. A second spray is applied 10 days later and a third spray is applied if a single fruitworm egg is found in a sample of 100 berries per ha.

Franklin (1950) reported that *Trichogramma pretiosum* Riley were native egg parasites of *A. vaccinii* in Massachusetts. He speculated that these wasps could limit insect pest populations in cranberries. Inundative release of *T. pretiosum* could reduce fruit injury by *A. vaccinii* by eliminating their eggs prior to hatch. The potential for *T. pretiosum* and other *Trichogramma* species to generate significant control against a range of lepidopterous pests has been long promulgated (Stinner 1977, Ridgeway et al. 1981). Prior (Stinner et al. 1974, Oatman & Platner 1978, Burbutis & Koepeke 1981) and more recent control attempts (Gross et al. 1984, Kanour & Burbutis 1984, King et al. 1986, Brower 1988) against several lepidopterans have used an inundative release strategy. Results have been erratic, but encouraging, and these studies have reflected a need for continuing field trials. Commercial rearing techniques have been developed (Morrison et al. 1978) so that at least six *Trichogramma* species are now available.

In this field study, two release levels of *T. pretiosum* were made during *A. vaccinii* oviposition and were compared with parasitism found in four neglected bogs with natural populations of *T. pretiosum*. Cranberry damage was compared between these treatments and with four commercial bogs that used insecticides for control.

METHODS AND MATERIALS

Site selection. The field study was conducted in 1988 in Carver, MA. Eight cranberry bogs were selected as sites for parasite release based upon the following criteria: (1) the bog was approximately 0.5 ha in size; (2) it had a history of cranberry fruitworm damage; and (3) it was equipped with a solid-set irrigation system which could be shut off from the main system, thus avoiding accidental contamination from insecticidal sprays. A single 0.25 ha release area was measured and flagged within each selected bog such that it was at least 5m from any bog edge. All data were collected from within this boundary. Thirty release points within the release area were arranged in a grid pattern, with points spaced ca. 10 m apart. Four bogs not currently under production (i.e., 'neglected') were also chosen for comparisons. These sites ranged from < 0.01–0.02 ha and were within the same general area (Carver, MA) as the release treatments, but were at least 100 m from these sites. Four cranberry bogs managed within guidelines established by the MA Cooperative Extension Agency were selected for fruit damage comparisons, but field parasitism was not noted in these treatment bogs.

Parasite release. *Trichogramma pretiosum* were purchased from an insectary (Rincon-Vitova, Oak View, CA) on a weekly schedule. Each shipment was examined to confirm that parasites had not emerged. Production cards, consisting of construction paper with parasitized host eggs (Morrison et al. 1978) were then placed within a refrigerator at 4.5 °C until field release. Cards with the appropriate number of parasites were divided and transported to field sites within a chilled (< 8 °C) cooler. This technique effectively placed emerging *Trichogramma* on a site within hours following removal from refrigeration (see Morrison 1985, for details of this technique). Four release sites received 1.2×10^5 *T. pretiosum* per release ('Low level' equivalent to 4.8×10^5 wasps per ha) and four sites received 4.8×10^5 *T. pretiosum* per release ('High level' equivalent to 1.9×10^6 wasps per ha). Each release episode within a site was standardized to include placement of cards with 4,000 wasps or 16,000 wasps, respectively, at each of 30 release points. Cards were arranged with the paper backing topmost to prevent sunscald or egg damage by precipitation. The first release was initiated near the end of bloom (25 June) and releases were made at three to five day intervals thereafter, for a total of nine releases through 30 July 1988. A sample of at least five cards was examined during each subsequent release to ensure that wasps had eclosed.

Cranberry classification. At least 100 cranberries were collected at random from each site immediately following every release. Cranberries were examined with a hand lens (10×) and classified as: (1) cranberry without *A. vaccinii* egg; (2) cranberry with egg; or (3) cranberry with parasitized egg; or (4) egg with emergent parasite. Phenology of *A. vaccinii* oviposition was determined by recording the total number of eggs collected during each sampling period from all treatments and expressing this value as the cumulative percentage of all eggs collected throughout the entire sampling period. Eggs with unhatched fruitworm were held individually in petri dishes at ambient temperature until larval hatch or parasite emergence. Cumulative parasitism was recorded for each of these three treatments. *Trichogramma* recovered from the neglected sites (two male specimens) were sent to Mr. Gary Platner (Department of Entomology, University of California, Riverside, CA) for determination.

Damage estimation. Damage due to *A. vaccinii* was estimated in early September by selecting ten samples (30 × 30 cm) randomly at each treatment site. Sampling was also conducted on four additional sites that had been treated with insecticidal sprays as recommended by the Massachusetts Cooperative Extension Service integrated pest management strategy ('IPM' sites). The ten samples per treatment were made once within each site. All cranberries within the defined area were collected and rated, using the following categories established by Roberts and Brodel (1985). These categories were: (1) sound cranberry, unblemished and marketable; (2) cranberry damaged by another larval Lepidoptera (e.g., *Sparganothis sulfureana* [Clemens]); and (3) cranberry damaged by *A. vaccinii.*

Cranberries were regarded as damaged by *A. vaccinii* only if a feeding entry hole or frass within the cranberry cavity was observed. Cranberries were considered damaged by *S. sulfureana* only if a characteristic external feeding scar was noted. Cranberries that were otherwise damaged or affected by a pathogen were noted, but were not included in these comparisons. The number of damaged cranberries was then expressed as a percentage of the total number per treatment and transformed to arcsine proportion prior to one way analysis of variance. Mean values were separated by Duncan's Multiple Range Test.

RESULTS

A total of 11, 278 cranberries were examined and 264 *A. vaccinii* eggs were detected over the entire sampling period. Multiple *A. vaccinii* eggs were not observed on any single cranberry fruit. Over 80% of *A. vaccinii* eggs were

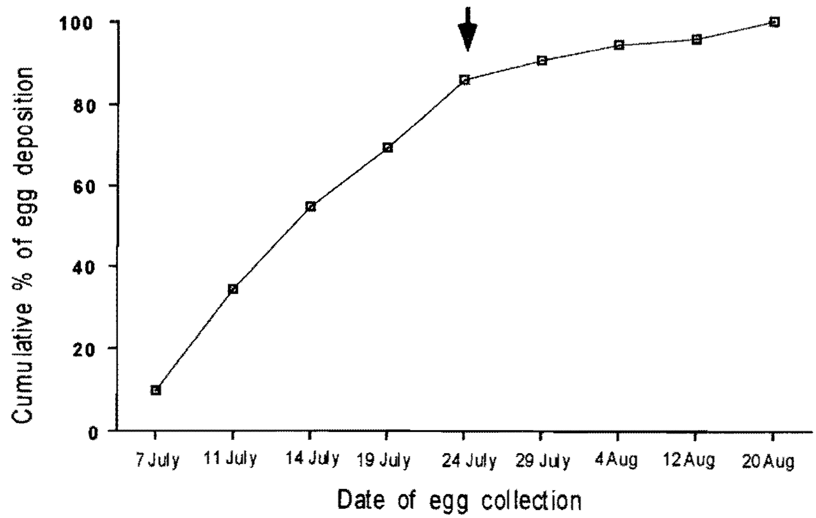

Figure 1. Cumulative deposition of *A. vaccinii* eggs during oviposition period from July–August, 1988. Values are combined data from twelve sites (three treatments). Arrow indicates the date of 80% accumulation of eggs.

deposited between 7 July and 24 July (Fig. 1), the period of cranberry fruit formation. The early deposition of *A. vaccinii* eggs is consistent with results from others (Anonymous 1982) and demonstrates that control measures of *A. vaccinii* must be directed during its earliest appearance since the presence of a larva within a cranberry prevents control materials from contacting and killing the insect. The inundative release strategy used in this trial included three separate releases of parasites, at low and high levels, prior to 2 July, ensuring that adult parasites were released well in advance of the first *A. vaccinii* eggs. Presumably, these parasites were searching actively for host eggs during the oviposition period.

Cumulative parasitism in low and high release levels was similar in pattern throughout the season, but parasitism within the neglected sites was higher consistently than either level (Table 1). There was little difference between the high or low release levels during the season, with a peak cumulative parasitism of 21.4% (6/28) within low release sites, 12.2% (19/156) within high release sites and 46.3% (37/80) within neglected sites. Curiously, while the low level release sites resulted in a higher percentage of cumulative parasitism than the high level releases throughout this study, host density in the low release sites was substantially lower. Parasitism was not estimated in IPM bog sites due to the application of insecticides during the study period. However, application of fungicidal compounds on low and high release bog sites could have interfered with parasite performance, although this variable was not tested here.

Since parasitism was estimated from vacant *A. vaccinii* eggs that showed an emergence hole, few adult parasites were collected. However, two adult males were recovered from eggs found within the neglected sites and were sent for determination. They were identified as *T. pretiosum*, using the standard technique of examining male specimens (Pinto et al. 1978). This finding

Table 1. Cumulative parasitism (# parasitized eggs/ # host eggs) within low release level, high release level and neglected cranberry bog sites**.

Date	Low level sites	High level sites	Neglected sites
7 July	0/ 3 (0.0%)	0/ 19 (0.0%)	2/ 5 (40.0%)
11 July	1/13 (7.7%)	0/ 56 (0.0%)	5/23 (21.7%)
14 July	2/17 (11.8%)	3/ 95 (3.2%)	8/32 (25.0%)
19 July	3/22 (13.6%)	8/112 (7.1%)	19/49 (38.8%)
24 July	3/23 (13.0%)	15/141 (10.6%)	24/63 (38.1%)
29 July	3/24 (12.5%)	15/145 (10.3%)	30/69 (43.4%)
4 Aug	3/24 (12.5%)	15/147 (10.2%)	34/76 (44.7%)
12 Aug	3/25 (12.0%)	15/151 (9.9%)	35/77 (45.5%)
20 Aug	6/28 (21.4%)	19/156 (12.2%)	37/80 (46.3%)

**values are combined from four replicates per treatment.

confirms earlier observations in cranberries of endemic levels of this species (Franklin 1950). No other egg parasites emerged from eggs held during the incubation period.

Although the percentage of *A. vaccinii*-damaged cranberries in the IPM sites was less than in the other sites, means were not significantly different among low release, high release or neglected sites, nor between low or high releases or IPM sites ($F= 1.56$; df = 3, 12; ns). Cranberry damage by *A. vaccinii* was low, relative to other damage factors (Table 2). The number of sound, unblemished cranberries was similar among low, high and IPM bog sites, but was significantly lower in neglected sites ($\chi^2 = 36.34$; df = 3; $P< 0.01$)

Analysis of the relationship between the level of fruitworm-damaged cranberries and parasitization provided insight into the effect of *Trichogramma* in suppressing *A. vaccinii.* A significant, negative correlation ($r^2 = -0.747$; $Y = -5.37X + 98.31$; $P < 0.05$) between the percentage of fruitworm-damaged berries and percentage of *Trichogramma* parasitization was determined from data collected within the neglected sites. No significant correlation was noted in sites with released *Trichogramma.*

DISCUSSION

Female *A. vaccinii* deposited 80% of their total complement of eggs during the early fruiting period of cranberry development (from 7–24 July), thus permitting their progeny to develop concurrently with the formation of the cranberries. Because each larva can consume 5–8 cranberries before pupation (Roberts & Brodel 1986), early oviposition would enhance larval survival, as

Table 2. Mean number (± SE) of sound or damaged cranberries from treatments*.

	Low level sites	High level sites	Neglected sites	IPM sites
Sound cranberries	183.6 (± 36.0)	173.6 (± 70.5)	96.3 (± 17.6)	192.1 (± 15.2)
Unidentified damage	36.9 (± 6.8)	32.4 (± 17.8)	28.5 (± 8.4)	27.4 (± 2.9)
A. vaccinii damage	9.7 (± 3.2)	9.6 (± 5.9)	10.9 (± 1.6)	2.5 (± 0.6)
Total cranberries	230.2	215.6	135.7	222.0
% damage by *A. vaccinii*	4.2%	4.5%	8.0%	1.1%

*Mean of ten samples per replicate and four replicates per treatment, except three replicates for neglected bogs.

only a single larva can infest a single cranberry. This fact was supported by the absence of multiple eggs on a single cranberry.

A large population of larval *A. vaccinii* could remove much of a marketable cranberry crop. Overwintering adult parasites, such as *Trichogramma*, would be present in relatively low numbers during the ovipositional period of *A. vaccinii*, and would likely parasitize a low percentage of eggs. However, the high level of parasitism noted in the neglected sites (between 21.7%–38.8% from 7–19 July) would indicate that endemic *Trichogramma* are seeking and locating, and successfully parasitizing, these host eggs. The feeding damage to cranberries in neglected sites was higher than other treatments, however, but could be due to the lower total number of cranberries in these areas.

The relatively low level of parasitism generated by either release (i.e., consistently less than the level found within the neglected bog sites) would indicate that these parasites did not locate and oviposit in their target host eggs. Other trials have demonstrated that even low releases of *Trichogramma* over a 21 day period (62,000 per ha) would generate a parasitization rate of between 11–40% in *Heliothis* spp. (Johnson 1985). In this case, naturally-occurring *Trichogramma* (*T. pretiosum* and *T. exiguum* Pinto and Platner) were noted to parasitize 59% of eggs on the initial sampling date; the percentage dropped rapidly thereafter.

Lower levels of parasitism were noted in another study, where *Heliothis virescens* (F.) eggs were placed near the edge of a soybean field, and endemic parasitism was between 8–14% during the two seasons of the study (Thorpe 1984). Thus, the levels of parasitization noted in the current trial are relatively high when compared with other studies.

Repeated indundative release of *T. pretiosum* has been attempted within a simulated warehouse of storage peanuts, and parasitism rates here were similar to those noted in the *A. vaccinii* release sites. Weekly release of 500 or 1,000 *T. pretiosum* over an 11 week period resulted in overall suppression of *Cadra cautella* (Walker) at 12.5 and 34.7%, respectively, and of *Plodia interpunctella* (Hübner) at 11.2 and 16.6%, respectively (Brower 1988). The author concluded that these results were promising, but releases should be made prior to the emergence of a pest species.

The relatively low levels of parasitism generated within the release sites may be a result of critical factors from either pre- or post release periods. Production of *Trichogramma* by commercial preparation could result in a significant proportion of 'inferior wasps' unable to locate and parasitize host eggs. Post release factors could include predation of the host eggs by spiders, ants, and other generalist feeders within the bogs, limiting survival of the emergent wasps (Hohmann et al. 1988). Additionally, various fungicides, including copper hydroxide, chlorothalonil, or tribasic copper sulfate are applied as a prophylactic cover spray against several fruit pathogens during the fruiting and developmental period. As such, these compounds could have interfered with the newly eclosed adult *Trichogramma*. Another complicating factor in this release program was the presence of other lepidopteran pests, such as *S. sulfureana*, which feed externally on cranberries during and after bud development. Application of an insecticide (such as carbaryl, azinphos-methyl or chlorpyrifos) is necessary for control when populations of this pest require attention. This treatment could subsequently interfere with *T. pretiosum* released during the *A. vaccinii* egg period.

The higher rate of cumulative parasitism noted in the neglected sites, however, warrants further study. Although the size disparity of neglected and release bogs cannot be dismissed, parasitism generated by the naturally-occurring *T. pretiosum* strain which may have evolved to local environmental conditions, and to the biology of *A. vaccinii*, should receive further attention.

In light of the current IPM insect-pest threshold (e.g., one *A. vaccinii* egg noted on a sampling of 25 cranberries per ha), the parasitism generated during the season by either the low or high release level would not provide the degree of suppression required to eliminate even a single insecticide application. It thus appears unlikely that an inundative release of *T. pretiosum* will suppress *A. vaccinii* populations to tolerable levels.

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