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# Effect of trap height and within-planting location on captures of cranberry fruitworm (Lepidoptera: Pyralidae) in highbush blueberries

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**Abstract**

1 Winged traps baited with synthetic sex pheromone lures [(*E,Z*)-8,10-pentadecadien-1-ol and (*E*)-9-pentadecen-1-ol acetate] were evaluated for their effectiveness in monitoring cranberry fruitworm, *Acrobasis vaccinii* Riley, in highbush blueberry, *Vaccinium corymbosum* L., plantings. Trap effectiveness was compared at different heights within the bush canopy and different locations within plantings.

2 In our trap height study, three positions were evaluated: (i) at the top of bush canopy (15 cm below the uppermost branch); (ii) centrally within bush canopy (60 cm below the uppermost branch); and (iii) at the bottom of the bush, 20 cm above ground level. Traps placed 15 and 60 cm below the uppermost branch captured significantly more male moths compared with traps placed 20 cm above ground level at two organic sites.

3 In our trap location study, four treatments were evaluated based on trap location relative to adjacent woodlands: (i) in trees within 1 m of the woodland boundary; (ii) in blueberry bushes adjacent to woodlands, 15 m from the woodland boundary; (iii) in blueberry bushes in the centre of the planting, 75 m from the woodland boundary; and (iv) in blueberry bushes furthest away from woodlands, 150 m from the woodland boundary. Traps located within 1 m of woodland boundary captured significantly more male moths compared with traps located centrally (15 and 75 m) within plantings.

**Keywords** *Acrobasis vaccinii*, monitoring, pheromone-baited traps, *Vaccinium corymbosum*.

## Introduction

The cranberry fruitworm, *Acrobasis vaccinii* Riley, is a major pest of *Vaccinium* spp. in the eastern U.S.A. (Neunzig, 1986). In cultivated plantings of highbush blueberries, *Vaccinium corymbosum* L., uncontrolled feeding damage may exceed 50% (Pritts & Hancock, 1992). Cranberry fruitworm larvae feed inside fruit, consuming between five and eight berries to complete development (Murray *et al*., 1996). Newly hatched larvae exit the fruit near the oviposition site and crawl over the berry surface before re-entering the same berry at either the stem end or the calyx to begin feeding (Beckwith, 1941; Averill & Sylvia, 1998). Damaged blueberry clusters often exhibit silk webbing, rendering the entire cluster unmarketable (Simser, 1994; Murray *et al*., 1996).

Currently, commercial blueberry production relies on the use of broad-spectrum insecticides, mainly organophosphates (phosmet and malathion) and carbamates (carbaryl and methomyl), applied from fruit set until full green to control *A. vaccinii* populations (Eck, 1988). The use of organophosphates and carbamates for control of *A. vaccinii* is effective, but these insecticides often threaten nontarget organisms, pollute the environment, and increase the potential for resistance development (Dinham, 1993). In addition, the United States Food Quality Protection Act (FQPA) targets many of these compounds for elimination or restric-

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tion by 2005 (FQPA, 1996). Alternatives to broad-spectrum insecticides are being developed but, until new strategies are identified, techniques that reduce the amount of insecticides in a cropping system should be implemented. Use of pheromone-baited traps may improve effectiveness for monitoring *A. vaccinii* in blueberry plantings. Effective monitoring programmes for cranberry fruitworm would enable growers to better time insecticide applications rather than adhering to a traditional calendar spray programme.

McDonough *et al.* (1994) identified several components of the cranberry fruitworm sex pheromone from gland extracts of female moths. A combination of (*E,Z*)-8,10-pentadecadien-1-ol and (*E*)-9-pentadecen-1-ol acetate in a 100 : 4 ratio was determined to direct male upwind flight as effectively as female gland extracts in wind tunnel studies (McDonough *et al.*, 1994). Field trials confirmed that this ratio was effective in luring male moths to baited traps. Despite this knowledge, specific guidelines for use of synthetic lures in blueberry integrated pest management (IPM) programmes have not been established.

Trap position and location are important factors to consider when refining monitoring programmes. Tomlinson (1970) reported that blacklight traps located 90 cm above vine tips captured more male *A. vaccinii* moths than traps located at vine level in cranberries, *V. macrocarpon* Aiton. The effect of trap height may similarly influence attraction of *A. vaccinii* males to sex pheromone traps in highbush blueberry plantings. Currently, there are no published data to support or refute the hypothesis that trap height influences the attraction of *A. vaccinii* in highbush blueberries.

Another factor to consider when monitoring for *A. vaccinii* is the location of traps within blueberry plantings (within-planting location). In an insecticide efficacy trial, Beckwith (1941) noted higher infestations of *A. vaccinii* at the edge of blueberry plantings compared with the centre, regardless of treatment assignment. More recently, Mallampalli & Isaacs (2002) compared single blueberry plants and individual fruit clusters as sampling units for detecting *A. vaccinii* and found significantly more eggs in blueberries located adjacent to wooded habitats compared with blueberries located further away. Currently, there are no published reports indicating a direct preference for *A. vaccinii* moths to pheromone-baited traps within various locations of highbush blueberry plantings. Our hypothesis was that both trap height and trap location within a planting would influence captures of male moths in pheromone-baited traps.

## Materials and methods

Experiments to investigate the effect of trap height on captures of male *A. vaccinii* moths were conducted at three sites in western Michigan from 10 May to 17 July 2001. Individual sites consisted of 2-ha blocks of *V. corymbosum* cultivar 'Jersey'. There were two organic plantings (Holland & Fennville, MI) and one conventional planting (Covert, MI). Management practices in the conventional planting included the application of organophosphate insecticides (phosmet and malathion) on a calendar schedule. Blueberry bushes at each site were 2–2.5 m in height and spaced 1.5 m between bushes and 2.4 m between rows. We also monitored activity of male *A. vaccinii* moths in a 2-ha section of woodlands located adjacent to the conventional planting that contained predominantly oak, pine and broadleaf weeds.

White cardboard winged sticky traps (model # IPM101-00, Great Lakes IPM, Vestaburg, MI) baited with a single 300 mg cranberry fruitworm lure (model # IPM-CFW-L1500, Great Lakes IPM) were used to monitor *A. vaccinii* activity. The effect of trap height was evaluated using three treatments: (i) at the top of the bush canopy, 15 cm below the uppermost bush (high); (ii) centrally within the bush canopy, 60 cm below the uppermost bush (medium); and (iii) at the bottom of the bush, 20 cm above ground level (low). At the woodland site, *A. vaccinii* populations were monitored at three distinct heights spaced further apart vertically: (i) 4.5 m above ground level (high); (ii) 1.5 m above ground level (medium); and (iii) 20 cm above ground level (low). At the woodland site, our aim was to monitor *A. vaccinii* activity and to document any differences in flight activity between woodland areas and the adjacent highbush blueberry planting.

Treatments were arranged in a randomized complete block design with four replicates per treatment at each of the three blueberry plantings. Monitoring traps were spaced 30 m apart within rows and 35 m between blocks in the plantings. The same design and spacing protocol was adopted in the woodland area. Cranberry fruitworm moths were counted and removed from traps once per week at the conventional site and woodland area, and twice per week at the two organic sites where cranberry fruitworm pressure was greater. Traps and lures were replaced every 3 weeks.

Experiments to investigate the effects of within-planting location of pheromone-baited traps on captures of *A. vaccinii* were conducted in Holland and Covert, MI, from 10 May to 17 July 2001. Each site consisted of a 2-ha block of *V. corymbosum* cultivar 'Jersey', and both sites were distinct from those used to determine the effect of trap height. Four treatments were evaluated based on location within the plantings. Treatments were arranged relative to distance from woodlands with four replicates per treatment (Fig. 1). Treatments included pheromone-baited traps placed: (i) in trees within 1 m of the woodland boundary; (ii) in blueberry bushes adjacent to woodlands, 15 m from the woodland boundary; (iii) in blueberry bushes in the centre of the planting, 75 m from the woodland boundary; and (iv) in blueberry bushes furthest away from woodlands, 150 m from the woodland boundary. At both sites, traps located 150 m from the woodland boundary were adjacent to open (nonwoodland) fields (Fig. 1). Pheromone-baited traps were spaced 50 m between treatment blocks. All traps within blueberry plantings were positioned within the canopy of the bushes, 60 cm below the uppermost branch (medium height). Cranberry fruitworm moths were counted and removed from traps once per week at each site, and traps and lures were replaced every 3 weeks.

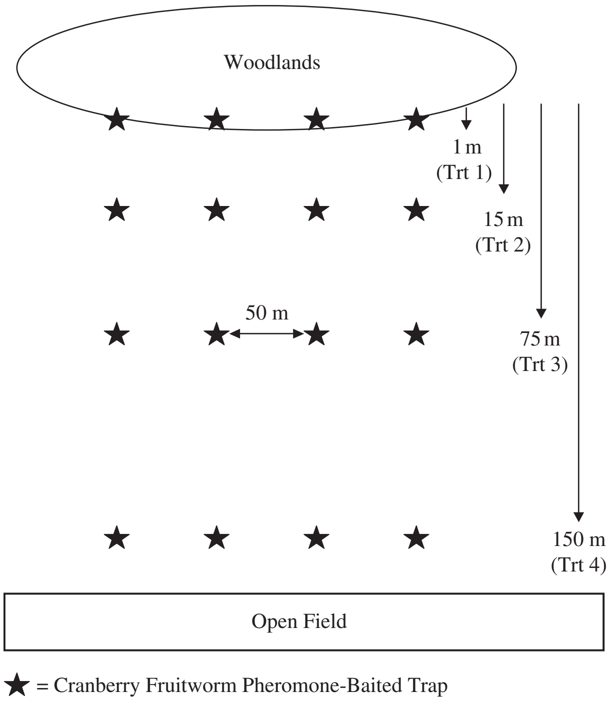


**Figure 1** Spatial orientation of pheromone-baited traps for monitoring male *Acrobasis vaccinii* moths in the trap location study (Holland and Vovert, MI). Trt, Treatment.

At the Holland site, fruit samples were also collected to monitor for the presence of *A. vaccinii* larvae in blueberry clusters located adjacent to pheromone-baited traps in the planting. Twenty-seven blueberry clusters of 10 berries each (nine clusters from each of three replicates; 270 berries per treatment) were harvested from each treatment twice per week starting 28 June and ending 19 July 2001. Samples were taken randomly from bushes located within a 3-m radius of pheromone-baited traps corresponding to individual treatments, 15, 75 and 150 m from the woodland boundary. No fruit was collected from the woodland area due to the absence of berries along the woodland boundary. Individual cluster samples were placed into resealable plastic bags, then placed into a cooler and transported back to the laboratory for visual analysis and dissection.

Clusters were categorized as uninfested, or exhibiting single berry infestation or multiple berry infestation, depending on the presence of *A. vaccinii* larva and/or whether the cluster exhibited no feeding (uninfested), feeding in one berry (single infestation), or feeding in more than one berry (multiple infestation). The presence of silk webbing and frass was also used to identify multiple berry infestation. Data are reported as the percentage of clusters exhibiting one of the three categories of infestation (uninfested, single infestation, or multiple infestation). In addition, we determined total infestation, calculated as the sum of single and multiple infestation of blueberry clusters.

Data collected from the trap height and trap location studies were square-root transformed to account for deviations from normality and then subjected to an analysis of variance (ANOVA) followed by mean separation using least significant difference (LSD) tests (SAS Institute, 2001). Data were also subjected to repeated measures analysis (using PROC MIXED, SAS Institute, 2001) to examine the interaction effect between treatment and time (sampling date) throughout the monitoring period.

Percentage data collected from the fruit sampling analysis (trap location study) were arcsine-square-root transformed to account for deviations from normality and then subjected to an ANOVA followed by mean separation using LSD tests (SAS Institute, 2001) for each category (uninfested, single and multiple infestation).

## Results

### Trap height

At the Holland organic site, we found that traps placed 15 and 60 cm below the uppermost branch were significantly ($F = 4.2$, d.f. = 2.6, $P = 0.05$) more effective in detecting male *A. vaccinii* moths compared with traps placed 20 cm above the ground (Table 1). Similar observations were recorded at the Fennville organic site; traps placed 15 and 60 cm from the uppermost branch captured significantly ($F = 25.8$, d.f. = 2.6, $P < 0.01$) more male moths compared with traps placed 20 cm above ground level (Table 1). At the conventional site, male moth captures for each of the three trap heights were not significantly different (Table 1).

The interaction effect between treatment (trap height) and time (sample date) was significant ($F = 4.45$, d.f. = 14.63, $P < 0.01$) only at the Fennville organic site. Treatment separation was consistent when moth captures were high. Specifically, traps placed 15 and 60 cm from the uppermost branch captured significantly more *A. vaccinii* moths compared with traps placed 20 cm above the ground. Treatments were not significantly different when moth populations were low, before 4 June and after 9 July

In the woodland area, where we monitored *A. vaccinii* activity, moth distributions among treatments followed a trend similar to those observed at the two organic sites. Pheromone-baited traps located 4.5 m above ground level captured significantly ($F = 75.0$, d.f. = 2.6, $P < 0.01$) more male moths compared with traps 1.5 m and 20 cm above the ground. In addition, traps located 1.5 m above the ground were significantly ($F = 75.0$, d.f. = 2.6, $P < 0.01$) more effective in detecting male moths compared with traps located 20 cm above ground level. Overall, traps located 4.5 and 1.5 m above ground level attracted 6.3 and 2.5 times, respectively, more male moths compared with traps positioned 20 cm above ground level.

The interaction effect between treatment and time was significant ($F = 3.2$, d.f. = 22.99, $P < 0.01$) in the woodland area. Although trap height did not affect male moth captures before 14 June or after 10 July, traps placed 4.5 m above ground level consistently captured significantly ($F = 18.7$, d.f. = 2.6, $P < 0.01$) more moths than traps located 20 cm above ground level during the period corresponding to peak moth flight.

**Table 1** Captures of male *Acrobasis vaccinii* moths in pheromone-baited traps placed at different heights with respect to blueberry bush canopy

| Trap height | Organic (Holland, MI) | Organic (Fennville, MI) | Conventional (Covert, MI) | Woodland (Covert, MI) |
|---|---|---|---|---|
| 15 cm from uppermost branch | $77.3 \pm 7.6^{a}$ | $78.3 \pm 14.5^{a}$ | $46.5 \pm 5.5$ | – |
| 60 cm from uppermost branch | $78.3 \pm 8.6^{a}$ | $68.8 \pm 3.9^{a}$ | $47.0 \pm 16.3$ | – |
| 20 cm above ground level | $47.5 \pm 10.4^{b}$ | $12.3 \pm 5.5^{b}$ | $45.5 \pm 21.8$ | – |
| 4.5 m above ground level | – | – | – | $96.8 \pm 20.4^{a}$ |
| 1.5 m above ground level | – | – | – | $37.8 \pm 12.9^{b}$ |
| 20 cm above ground level | – | – | – | $15.3 \pm 11.9^{c}$ |

Data are mean ± SEM of *A. vaccinii.*
Means within columns followed by the same superscript letter are not significantly different, $P = 0.05$, LSD test.
Analysis was performed on square-root transformed data, but means shown reflect untransformed data.
Sampling was conducted once per week at the conventional and woodland sites and twice per week at the two organic sites from 10 May to 17 July 2001.
Treatment means are the sum of data collected over all sampling dates.

## Within-planting trap location

Trap captures of male *A. vaccinii* moths were approximately three-fold higher at the Holland site compared with the Covert site (Table 2). In Holland, we recorded significantly ($F = 7.0$, d.f. = 3.9, $P = 0.01$) higher male moth captures on pheromone-baited traps located within 1 m of the woodland boundary compared with traps located 15, 75 and 150 m within the plantings (Table 2). In Covert, traps located within the woodland boundary captured significantly ($F = 11.5$, d.f. = 3.9, $P < 0.01$) more male *A. vaccinii* moths compared with traps located 15 and 75 m within the planting (Table 2). However, *A. vaccinii* captures in traps located at the far edge of the planting (150 m away) did not differ significantly from captures in traps located along the woodland boundary.

Interaction effects between treatment (location of traps) and time were significant at both the Holland ($F = 2.5$, d.f. = 24.95, $P < 0.01$) and Covert ($F = 1.9$, d.f. = 24.95, $P < 0.01$) sites. As in our trap height study, treatment differences were observed only during the sampling dates corresponding to peak moth flight. At both sites, male *A. vaccinii* moths were captured more frequently in pheromone-baited traps located along the woodland boundary compared with traps located within the planting during peak flight. Treatment separation for traps located within the planting varied throughout the same period, although traps located 150 m from the woodland boundary frequently captured more moths compared with traps located at 15 and 75 m.

Data from our fruit infestation analysis followed a similar trend tho those obtained with our trap catches from the Holland planting. The percentage of blueberry clusters with single infestation (larval feeding in only one berry of the cluster) within 15 m of the woodland boundary was significantly ($F = 5.5$, d.f. = 2.4, $P = 0.05$) higher compared with clusters located 150 m from the woodland boundary (Table 3). There were no significant differences among clusters exhibiting multiple berry infestation, regardless of distance relative to the woodland boundary (Table 3). The total infestation percentage of blueberry clusters harvested from bushes located 15 and 75 m within the planting was significantly ($F = 32.0$, d.f. = 2.4; $P < 0.01$) higher compared with clusters harvested from bushes 150 m away from the woodland boundary (Table 3).

## Discussion

Our study indicated that the most efficient trap height for monitoring male *A. vaccinii* activity in highbush blueberry plantings ranges between 15 and 60 cm below the uppermost branch. Data supporting this finding were especially pronounced at the Fennville organic site, where the relative separation between treatments was greater because bushes in that planting were slightly taller than bushes at the Holland organic and conventional (Covert) plantings. Traps located close (20 cm) to ground level did not appear

**Table 2** Captures of male *Acrobasis vaccinii* moths in pheromone-baited traps placed at different locations within blueberry plantings with respect to adjacent woodlands

| Trap position | Holland, MI | Covert, MI |
|---|---|---|
| Woodland boundary | $233.8 \pm 42.2^{a}$ | $89.0 \pm 22.1^{a}$ |
| 15 m from woodland boundary | $132.0 \pm 9.2^{b}$ | $19.5 \pm 2.2^{b}$ |
| 75 m from woodland boundary | $73.3 \pm 0.6^{b}$ | $31.5 \pm 6.6^{b}$ |
| 150 m from woodland boundary | $124.8 \pm 32.5^{b}$ | $71.7 \pm 7.9^{a}$ |

Data are mean ± SEM of *A. vaccinii.*
Means within columns followed by the same superscript letter are not significantly different, $P = 0.05$, LSD test.
Analysis was performed on square-root transformed data, but means shown reflect untransformed data.
Sampling was conducted once per week from 10 May to 17 July 2001.
Treatment means are the sum of data collected over all sampling dates.

**Table 3** Percentage of blueberry clusters infested by *Acrobasis vaccinii* at different locations within a planting in Holland, MI

| | Level of infestation | | | |
|---|---|---|---|---|
| Distance from woodland boundary | Uninfested | Single berry infestation | Multiple berry infestation | Total infestation |
| 15 m | $35.7 \pm 3.8^{b}$ | $24.3 \pm 3.8^{a}$ | $40.0 \pm 7.5$ | $64.3 \pm 3.8^{a}$ |
| 75 m | $42.7 \pm 1.3^{b}$ | $22.0 \pm 1.2^{ab}$ | $35.0 \pm 1.0$ | $57.3 \pm 1.3^{a}$ |
| 150 m | $62.7 \pm 0.7^{a}$ | $14.0 \pm 2.1^{b}$ | $23.0 \pm 2.7$ | $37.3 \pm 0.7^{b}$ |

Data are % clusters ± SEM infested by *A. vaccinii*.
Percentages within columns followed by the same superscript letter are not significantly different, $P = 0.05$, LSD test.
Analysis was performed on arcsine-square-root transformed data, but percentages shown reflect untransformed data.
Blueberry clusters were collected twice per week from 28 June to 19 July 2001 and sampled for *A. vaccinii* infestation.

as attractive to male moths as traps located higher within the blueberry bush canopy. These observations were particularly clear during the interval corresponding to peak moth flight (mid-June). A number of factors may explain the elevated moth captures in traps located higher within the bush canopy: pheromone concentration and release rate, microclimate, and trap placement, and these may affect the efficacy of monitoring programs that employ sex pheromone technologies (Shorey, 1973). AliNiazee (1983) found that male filbertworm, *Melissopus latiferreanus* (Walsingham), moths respond preferentially to pheromone-baited traps located within or slightly above the canopy of cultivated filbert trees compared with lower traps, regardless of absolute height. The observed differences were attributed to little activity below the tree canopies and the mate-seeking advantages associated with localizing in the upper canopy where females were found. Ahmad (1987) suggested that reduced catches of the almond moth, *Cadra cautella* (Walker), in pheromone-baited traps located close to ground level could have been due to inadequate dispersal of the pheromone plume. These theories may lend insight to the observations recorded in our experiments.

Our hypothesis that height influences preference of male moths to pheromone-baited traps was further supported by data collected in the woodland monitoring area, where captures of *A. vaccinii* were significantly different among all three trap heights. We presume that the use of broad-spectrum insecticides and the resulting lower moth population at the conventional planting may have prevented clear treatment separation for captures of *A. vaccinii* in pheromone-baited traps at the various heights. However, the reason for the observed nonsignificant differences in the conventional plot treatment remains unclear and needs further research.

Regarding the within-planting location of traps, our results suggest that traps positioned at the edge of woodlands adjacent to plantings may serve as a prime location for monitoring male *A. vaccinii* activity. The high trap captures for woodland treatments in our experiments indicate that male moths may be moving between plantings and adjacent woodlands. In our location study, traps located along the woodland periphery and in blueberry bushes at the edge of the planting adjacent to open fields (150 m away from woodland boundary) captured more male moths than traps located centrally (75 m) within the planting. These results imply that high populations of male *A. vaccinii* moths aggregate near planting boundaries. Mallampalli & Isaacs (2002) recorded significantly more *A. vaccinii* eggs in blueberries located adjacent to woodland boundaries and hypothesized that woodlands may serve as a reservoir for individuals that affect commercial plantings because of the wild hosts they may contain. The high incidence of moths captured in traps located adjacent to open fields may be the result of pheromone dispersal patterns, where the plume may have been carried over longer distances in the field than within plantings. Alternatively, male dispersal patterns may be affected by planting adjacency to open fields. Regardless of these hypotheses, our recommendation to growers is to monitor for *A. vaccinii* moths both within the interior of plantings as well as at the periphery (woodlands and open fields).

Inherent limitations exist when using sex pheromone traps for monitoring *A. vaccinii* activity, primarily because only male moths can be monitored. Female moths may or may not exhibit movements between plantings and woodlands similar to males, although measurements of larval infestation can be used to predict their behaviour and preferences within a planting. The infestation trends we observed at the Holland site paralleled our monitoring trap data, indicating that females prefer to oviposit in blueberries adjacent to wooded areas. Nonetheless, the purpose of using pheromone-baited traps is to quantify the timing of moth development for use in developing conservative spray schedules. Traps should be placed in locations of high moth density because these areas may offer more precise estimates of insect pressure.

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