PEST MANAGEMENT

Cutting Wild Grapevines as a Cultural Control Strategy for Grape Berry Moth (Lepidoptera: Tortricidae)

PAUL E. JENKINS[1] AND RUFUS ISAACS

Department of Entomology, Michigan State University, East Lansing, MI 48824

Environ. Entomol. 36(1): 187–194 (2007)

ABSTRACT A 3-yr field study was conducted at commercial grape farms to evaluate cutting wild grapevines as a cultural control strategy for grape berry moth, *Paralobesia viteana* (Clemens). At each farm, wild grapevines were cut in the woods adjacent to one vineyard for control of *P. viteana,* whereas the comparison vineyard received no such cutting. Both vineyards received a standard broad-spectrum insecticide program for control of *P. viteana* and other vineyard insect pests. Monitoring with pheromone traps showed no differences between treatments in the total number of male moths trapped in both woods and vineyards. Egglaying by *P. viteana* was similar between the two wild grape cutting treatments in all 3 yr. During weekly samples of crop infestation by *P. viteana*, no differences were observed between programs in the percent of clusters infested by *P. viteana* larvae. Berries infested by *P. viteana* were collected from vineyard borders during the second and third *P. viteana* generations and held under controlled conditions. In all but one sample, survival of *P. viteana* larvae was similar between the two wild grape cutting treatments, parasitism of *P. viteana* larvae within vineyards was similar between the two wild grape cutting treatments on all sample dates, and similar captures of natural enemies were found on yellow sticky traps in the two treatments throughout the study. The opportunities and benefits of cutting wild grapevines as a cultural control in grape integrated pest management programs in eastern North America are discussed.

KEY WORDS *Paralobesia viteana*, *Endopiza viteana*, biological control, integrated pest management, *Vitis riparia*

The grape berry moth, *Paralobesia viteana* (Clemens) (Lepidoptera: Tortricidae), is native to North America east of the Rocky Mountains and is a primary insect pest of eastern North American vineyards (Dennehy et al. 1990, Botero-Garcés and Isaacs 2003). *P. viteana* overwinter as pupae in leaves and fruit and emerge from May to June. After mating, females oviposit on developing buds, florets, and berries (Clark and Dennehy 1988, Tobin et al. 2003). There are four larval instars, and larvae develop in ≈10–13 d (Tobin et al. 2001). This species has two or three generations per year, with a possible fourth generation in New York (Hoffman and Dennehy 1989) and Pennsylvania (Tobin et al. 2003). In southern regions, such as Virginia and Missouri, a fourth generation is common (Biever and Hostetter 1989, Tobin et al. 2003). *P. viteana* occurs on wild and cultivated *Vitis* spp., and insect management programs in this region are primarily directed at preventing infestation of grape clusters by *P. viteana.* For control of *P. viteana* and other vineyard insect pests, growers in the eastern United States rely on multiple applications of broad-spectrum insecticides. However, the Food Quality Protection Act of 1996 has led to restrictions on the use of broad-spectrum insecticides in this industry, and grape growers need alternative control options for effectively managing insect pests.

In the geographic range of *P. viteana*, vineyards are often found in close association with deciduous woods where wild grapevines (*Vitis* spp.) persist. Grapevines are an important part of the plant community in deciduous woods. They are often a pioneer species in forest development, and their abundance is positively correlated with areas of moderate to high disturbance (Morano and Walker 1995). Four *Vitis* species (*V. aestivalis* Michaux, *V. labrusca* L., *V. riparia* Michaux, and *V. vulpina* L.) are found in Michigan (Galet 1979, Voss 1985, P.E.J., unpublished data). *V. riparia* thrives in lowland and upland woods, particularly along borders (Voss 1985), and is one of the most common species found near Michigan and New York vineyards (Dennehy et al. 1990, P.E.J., unpublished data).

Uncultivated land can have a variety of effects on the insect community in agricultural settings (van Emden 1965, Gurr et al. 1998, Wratten et al. 1998). In eastern grape production, woods containing wild grapevines could provide a habitat for *P. viteana* to

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[1] Corresponding author: Michigan State University, 202 Center for Integrated Plant Systems, East Lansing, MI 48824 (e-mail: jenki132@msu.edu).

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escape pest management programs during the growing season (Hoffman and Dennehy 1989, Seaman et al. 1990, Botero-Garcés and Isaacs 2004a), maintaining a pest population outside the area of management that can reinfest vineyards (Dennehy et al. 1990, Seaman et al. 1990). Indeed, infestation of grape clusters at vineyard borders near deciduous woods is often greater than that found at vineyard interiors (Biever and Hostetter 1989, Hoffman and Dennehy 1989, Trimble et al. 1991), and infestation by *P. viteana* has been reported to be positively correlated with wild grape abundance in adjacent habitats (Sanders and DeLong 1921, Dennehy et al. 1990, Botero-Garcés and Isaacs 2004a). Cutting wild grapevines to prevent fruiting has been suggested as a strategy to reduce *P. viteana* populations in woods and therefore reduce the pest pressure in adjacent vineyards, leading to reduced need for insecticide treatments (Botero-Garcés and Isaacs 2004a). Using a similar approach, insecticide applications were reduced by ≈75% compared with conventional orchards after the principal host plants of codling moth, *Cydia pomonella* L., were removed within 200 m of a small commercial apple orchard in Massachusetts (Prokopy 2003).

Cultural control practices that alter habitats to create less suitable environments for pests may also indirectly affect natural enemy populations (Debach and Rosen 1991). Wild grapevines may act as a natural source of pest infestation in vineyards. However, because they may provide a refuge for natural enemies of *P. viteana* outside the region treated with insecticide (Dennehy et al. 1990, Seaman et al. 1990), the removal of such hosts may have unintended consequences for natural enemy populations.

The average maximum displacement by male *P. viteana* moths has been documented at ≈105 m between woods and adjacent vineyards and 39 m within vineyards (Botero-Garcés and Isaacs 2004b). The limited flight potential of *P. viteana,* coupled with the close association between this species and the distribution of wild and cultivated grapevines, suggests that removing or reducing the availability of its host plant would lead to a reduction in its population. If effective, this could be an important component of an integrated pest management (IPM) program for management of *P. viteana.* This long-term study aimed to assess whether cutting wild grapevines near vineyards would reduce the abundance of *P. viteana* and the associated fruit infestation in adjacent vineyards. Additionally, the impacts of this cultural control strategy on natural enemies within the vineyard and adjacent habitat were measured.

Materials and Methods

Study Sites and Insect Management. This study was conducted at two mature 1.4- to 4-ha *V. labrusca* variety Concord grape vineyards at each of five farms from 2003 to 2005 in Van Buren and Berrien Counties, MI. Vineyards were selected with histories of *P. viteana* infestation and bordered on at least one side by woods containing wild grapevines. Stand composition was not recorded, but all woodlots in this study were mature, deciduous, and had an upper canopy >20 m. At each farm, wild grapevines in the woods adjacent to one of the vineyards (experimental treatment) were cut to prevent the vines from fruiting. Vines were first cut near ground level between 5 and 13 May 2003 using 75-cm orchard loppers (Sandvik, Scranton, PA). During the course of this study, regrowth of wild grape was monitored and prevented by recutting during each subsequent spring (19–20 May 2004 and 18–19 May 2005). Localized herbicide applications (triclopyr, Pathfinder II; Dow Agrosciences, Indianapolis, IN) were made in 2004 to spot treat problematic areas. Vines were cut to a depth of 60 m from the edge of the woods adjacent to the vineyard (at four of five farms) or to the end of the woods (one of five farms to 40 m). The wild vines in the woods adjacent to the comparison vineyard (untreated control) were not cut. Within each farm, both vineyards received the same insecticide and fungicide program, which was applied by the growers. In 2004, five leaves were sampled from five randomly chosen wild grapevines in both treatments at each farm and identified to species. Voucher specimens of wild *Vitis* spp. are held in the Michigan State University Herbarium.

***Paralobesia viteana* Moth Captures.** Flight activity of adult male *P. viteana* was monitored using large plastic delta traps (Suterra, Bend, OR) baited with *P. viteana* sex pheromone [90:10 ratio of (Z)-9–12Ac and (Z)-11–14Ac; Suterra]. Traps were placed at a height of 1.5 m at each of the following locations: vineyard interior, vineyard border, wooded edge adjacent to each vineyard, and wood interior. Two traps were placed at each location to account for variability in moth captures, and traps were distributed evenly across the width of the vineyard, at least 27 m apart within each location. Vineyard interior traps were placed 24.3 m from the vineyard border, and wood interior traps were placed 19.8 m from the edge of the woods. The distance between the vineyard border, and the wood border ranged from 5.2 to 24.3 m. Traps were monitored weekly for the number of male *P. viteana* captured, and the moths were removed or traps were replaced with new inserts. Pheromone lures were replaced every 4 wk using lures from the same lot in each season. Each year, the total moth captures from each trap were averaged within location and compared between locations and treatments using analysis of variance (ANOVA; PROC MIXED; SAS Institute 2001). Data were log-transformed ($\log n + 1$) to meet normality assumptions before analysis and Tukey's test was used to determine differences between means at $\alpha = 0.05$.

***Paralobesia viteana* Cluster and Berry Infestation in Vineyards.** Infestation by *P. viteana* was quantified monthly by visually examining 30 clusters (5 clusters on three vines spaced ≈2.7 m apart, at two sampling sites) at the border and interior of the vineyard. For each vine, the number of *P. viteana* eggs, *P. viteana* larvae, and clusters with *P. viteana* larvae was recorded and summed within each sampling site for each date. Berries showing signs of *P. viteana* infestation were scored as being infested and, because of their web-spinning behavior, adjacent berries webbed together were counted as one larva. The total number of eggs found at each farm throughout the season, and for each specific sampling date, was compared between treatments and locations using ANOVA (PROC MIXED; SAS Institute 2001). The weekly average of *P. viteana* clusters infested by *P. viteana* larvae and the number of larvae were compared between treatments and locations for each date and across each season using ANOVA (PROC MIXED; SAS Institute 2001). For all analyses, data were log-transformed (log $n + 1$) to meet normality assumptions before analysis and Tukey's test was used to determine differences between means at $\alpha = 0.05$.

Survival and Parasitism of *P. viteana* in Vineyards. To compare the effect of cutting wild grapevines on *P. viteana* survival and parasitism within vineyards, 100 berries (five subsamples of 20 berries) showing signs of *P. viteana* infestation were collected from each vineyard border adjacent to woods. Sampling dates were chosen each season to be ≈10 d after insecticide applications for control of *P. viteana* and when *P. viteana* larvae were susceptible to parasitism. Berry samples were taken on 19 August, 9 September, and 30 September in 2003, on 29 July, 12 August, and 26 August in 2004, and 14 July, 28 July, and 10 August in 2005. In 2003, each subsample of 20 berries was placed in a 473-ml polypropylene deli container (Fabri-Kal, Kalamazoo, MI) and brought back to the laboratory where the container was held at 24°C and 16:8 L:D. These methods were changed to improve insect survival in 2004 and 2005; individual berries were placed into separate 37-ml plastic cups (Bioserv, Frenchtown, NJ) with white paper insert lids (Bioserv). In all years, small strips of plastic were provided in each container as pupation substrate for *P. viteana.* At the end of 5–6 wk, samples were placed at −20°C for 24 h to ensure mortality of specimens. The containers were opened, and the numbers of *P. viteana* adults, pupae, larvae, and parasitoids of *P. viteana* were totaled and recorded. From these values, the proportion of *P. viteana* surviving and the proportion of parasitized *P. viteana* from each sampling date were calculated. *P. viteana* survival and parasitism data were compared among treatments for each sample date using the Mann–Whitney *U* test (PROC NPAR1WAY; SAS Institute 2001). All parasitoids were identified by specialists to genus or species. Voucher specimens of *P. viteana* and parasitoids are held in the A. J. Cook Arthropod Collection at Michigan State University.

Natural Enemies on Yellow Sticky Traps. Natural enemies were monitored each season in vineyards and adjacent habitats using unbaited yellow sticky traps (Great Lakes IPM, Vestaburg, MI). Traps were deployed at four locations (vineyard interior, vineyard border, wood border, and wood interior) from 24 April to 20 September 2003, 17 April to 16 September 2004, and 16 April to 17 September 2005. In 2003, two traps per location were deployed in both experiments. Power analyses (Analyst Application, SAS Institute 2001) on data collected in 2003 indicated that greater sample size was required, and so the sample size was increased to six traps per location in 2004 and 2005. All traps in all years were collected and replaced with new traps approximately every 14 d. On return to the laboratory, all traps were placed at −20°C until assessed. For all years, traps were assessed for the number of natural enemies in the following dominant groups: green lacewings (Neuroptera: Chrysopidae), brown lacewings (Neuroptera: Hemerobiidae), ladybird beetles (Coleoptera: Coccinellidae), parasitoid wasps (Hymenoptera: Ichneumonidae, Braconidae), and syrphid flies (Diptera: Syrphidae). Each year, the total number of natural enemies from each trap were compared between treatments and locations using ANOVA (PROC MIXED, SAS Institute 2001). Additionally, the response of each individual natural enemy group to wild grape cutting treatments was analyzed separately using ANOVA (PROC MIXED, SAS Institute 2001). All data were log-transformed (log $n + 1$) to meet normality assumptions before analysis and Tukey's test was used to determine differences between means at $\alpha = 0.05$.

Results

Although four *Vitis* spp. are known in Michigan, only *V. riparia* was identified in random samples of leaves collected from the wild grapevines at each farm within both treatments in this study.

***Paralobesia viteana* Moth Captures.** Male moths were caught from late April until traps were collected at harvest in September each year, with the greatest captures in May and June, before and during bloom. Similar numbers of moths were captured in the experimental and untreated control treatments in 2003, 2004, and 2005 ($F = 1.1$; df = 1,4; $P = 0.35$ in 2003; $F = 1.6$; df = 1,4; $P = 0.27$ in 2004; $F = 0.47$; df = 1,4; $P = 0.53$ in 2005; Table 1). On two dates, 19 July and 7 September 2004, moth captures were significantly greater in the experimental treatment compared with the untreated control ($F = 7.64$; df = 1,4; $P = 0.051$ and $F = 11.28$; df = 1,4; $P = 0.028$, respectively). There was no significant interaction between treatment and location in the total number of male moths captured in any year ($F = 1.89$; df = 3,24; $P = 0.16$ in 2003; $F = 0.16$; df = 3,24; $P = 0.92$ in 2004; $F = 0.43$; df = 3,24; $P = 0.73$ in 2005; Table 1). Moth abundance was different between locations within farms; in all years, male moth captures followed the same trend: captures at the vineyard interior > wood interior > wood border > vineyard border, although not all comparisons were significantly different (Table 1). In each year of this study, moth captures were significantly greater at the vineyard interior compared with the vineyard border ($F = 12.65$; df = 1,24; $P = 0.0016$ in 2003; $F = 17.32$; df = 1,24; $P = 0.0004$ in 2004; $F = 19.84$; df = 1,24; $P = 0.0002$), greater at the wood interior compared with the vineyard border ($F = 21.88$; df = 1,24; $P < 0.0001$; $F = 12.30$; df = 1,24; $P = 0.0018$; $F = 15.35$; df = 1,24; $P = 0.0006$), and greater at the wood interior than the wood border ($F = 5.76$; df = 1,24; $P = 0.0245$ in 2003; $F = 6.96$; df = 1,24; $P = 0.0144$ in 2004; $F = 6.12$; df = 1,24; $P = 0.0208$ in 2005). In 2003, moth captures were

Table 1. Average total captures of male *P. viteana* moths per trap ± SE for each location in Michigan juice grape vineyards where adjacent wild grapevines were cut (experimental) or not cut (untreated control) during 2003–2005[a]

Location	Wild grape program	2003	2004	2005
Vineyard interior	Experimental	39.8 ± 9.3	34.3 ± 8.4	34.1 ± 4.8
	Untreated control	29.9 ± 14.5	29.8 ± 11.2	23.8 ± 5.3
Vineyard border	Experimental	10.9 ± 1.2	11.3 ± 1.7	13.3 ± 4.2
	Untreated control	14.3 ± 7.2	11.0 ± 5.2	10.4 ± 2.5
Wood border	Experimental	19.1 ± 4.5	17.2 ± 3.9	15.4 ± 2.5
	Conventional	26.2 ± 10.9	10.8 ± 3.6	16.3 ± 5.2
Wood interior	Experimental	31.0 ± 7.3	27.7 ± 6.5	25.6 ± 5.0
	Untreated control	31.0 ± 10.5	20.7 ± 5.2	26.2 ± 6.0

[a] No significant difference was observed between wild grapevine cutting treatments for any location within vineyards or adjacent woodlands.

significantly greater at the wood border compared with the vineyard border (F = 5.18; df = 1,24; P = 0.032). In 2004 and 2005, moth captures were significantly greater at the vineyard interior compared with the wood border (F = 10.84; df = 1,24; P = 0.0031 and F = 9.06; df = 1,24; P = 0.0061, respectively).

Paralobesia viteana **Cluster and Berry Infestation in Vineyards.** Comparisons between the two treatments indicate that egglaying was consistent between both treatments; for all years, there was no significant difference in the number of eggs found between treatments for each specific sampling date and across each season (F = 0.57; df = 1,4; P = 0.49 in 2003; F = 0.02; df = 1,4; P = 0.90 in 2004; F = 0.82; df = 1,4; P = 0.42 in 2005; Fig. 1). In all years, the number of *P. viteana* eggs detected was significantly greater at the vineyard border compared with the vineyard interior (F = 48.07; df = 1,8; P = 0.0001 in 2003; F = 129.01; df = 1,8; $P < 0.0001$ in 2004; F = 120.9; df = 1,8; $P < 0.0001$ in 2005). There was no significant interaction between program and location in any year (F = 0.89; df = 1,8; P = 0.37 in 2003; F = 0.0; df = 1,8; P = 0.97 in 2004; F = 0.22; df = 1,8; P = 0.65 in 2005).

Infestation by *P. viteana* larvae was also greatest at the vineyard border throughout this experiment; the number of *P. viteana* larvae was significantly greater at the vineyard border compared with the vineyard interior (F = 92.91; df = 1,8; $P < 0.0001$ in 2003; F = 61.58, df = 1,8; $P < 0.0001$ in 2004; F = 154.16; df = 1,8; $P < 0.0001$ in 2005; Fig. 2). There was no significant interaction between treatment and location in any year (F = 0.1; df = 1,8; P = 0.75 in 2003; F = 0.4; df = 1,8; P = 0.54 in 2004; F = 0.03; df = 1,8; P = 0.86 in 2005). For all years, there was no significant difference in the number of larvae found between treatments across each season (F = 0.04; df = 1,4; P = 0.0.86 in 2003; F = 2.14; df = 1,4; P = 0.22 in 2004; F = 0.01; df = 1,4; P = 0.93 in 2005).

Similarly, the number of clusters infested by *P. viteana* larvae was significantly greater at the vineyard border compared with the vineyard interior in each year (F = 140.91; df = 1,8; $P < 0.0001$ in 2003; F = 55.14; df = 1,8; $P < 0.0001$ in 2004; F = 148.44; df = 1,8; $P < 0.0001$ in 2005). There was no significant interaction between program and location in any year (F = 0.01; df = 1,8; P = 0.92 in 2003; F = 0.13; df = 1,8; P = 0.72 in 2004; F = 0.01; df = 1,8; P = 0.92 in 2005). For all years, there was no significant difference between treatments in the number of clusters with larvae found across each season (F = 0.1; df = 1,4; P = 0.77 in 2003; F = 1.92; df = 1,4; P = 0.24 in 2004; F = 0.07; df = 1,4; P = 0.81 in 2005).

Survival and Parasitism of *P. viteana* in Vineyards. Significantly fewer *P. viteana* survived in the untreated vineyards compared with the vineyards where wild

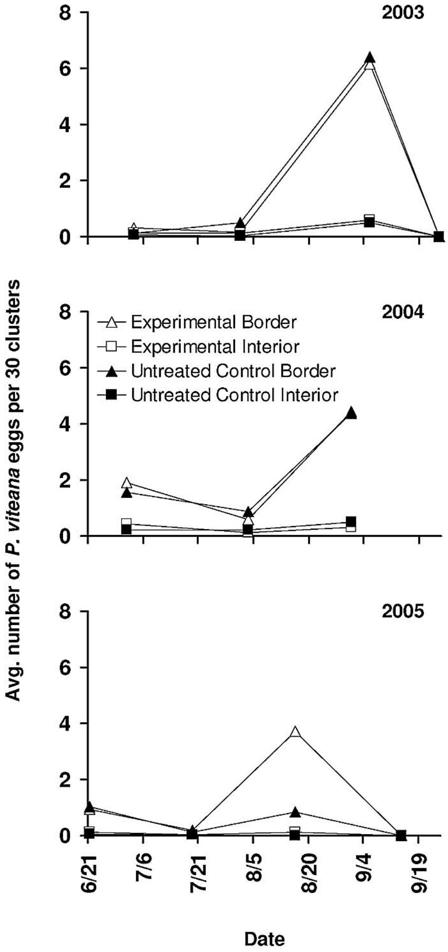

Fig. 1. Average number of *P. viteana* eggs at the vineyard border and vineyard interior in juice grape vineyards in Michigan where adjacent wild grapevines were cut (experimental) or not cut (untreated control) during 2003–2005.

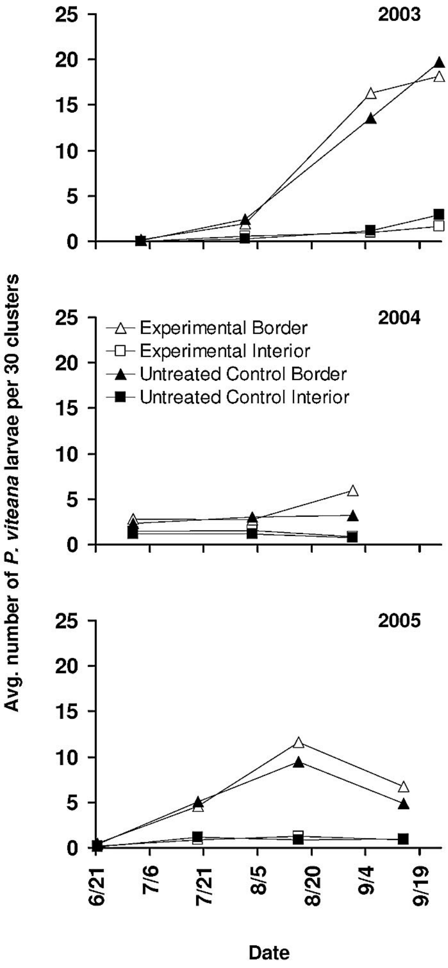

Fig. 2. Average number of *P. viteana* larvae at the vineyard border and vineyard interior in juice grape vineyards in Michigan where adjacent wild grapevines were cut (experimental) or not cut (untreated control) during 2003–2005.

grapes were cut on 19 August 2003 ($F = 4.75$; df = 1,48; $P = 0.034$), but for all other dates, there was no significant difference in survival of *P. viteana* between treatments ($F < 2.7$; df = 1,48; $P > 0.11$; Fig. 3). In all years, no change or trend in the level of parasitism of *P. viteana* was detected in response to cutting wild grapevines in surrounding habitats ($F < 1.3$; df = 1,48; $P > 0.26$; Fig. 4).

Natural Enemies on Yellow Sticky Traps. Each of the natural enemies sampled were found on each sampling date, and total natural enemy abundance was similar between grape cutting treatments for all 3 yr ($F = 0.12$; df = 1,4; $P = 0.75$ in 2003; $F = 0.05$; df = 1,4; $P = 0.83$ in 2004; $F = 0.11$; df = 1,4; $P = 0.76$ in 2005). Natural enemy abundance varied significantly between locations; captures were significantly greater at the wood border compared with the wood interior ($F = 17.72$; df = 1,24; $P = 0.0003$ in 2003; $F = 24.40$; df = 1,24; $P < 0.0001$ in 2004; $F = 20.24$; df = 1,24; $P = 0.0001$ in 2005), and at the wood border compared with the vineyard border ($F = 36.34$; df = 1,24; $P < 0.0001$ in 2003; $F = 20.49$; df = 1,24; $P = 0.0001$ in 2004; $F = 64.42$; df = 1,24; $P < 0.0001$ in 2005). The only exception to this trend was in 2004 when vineyard border captures were greater than wood border captures. Natural enemy abundance was significantly greater at the vineyard border compared with the vineyard interior in 2003 and 2005 ($F = 6.43$; df = 1,24; $P = 0.018$ and $F = 13.53$; df = 1,24; $P = 0.0012$, respectively) and was greater but not significantly different in 2004 ($F = 3.97$; df = 1,24; $P = 0.058$). In 2003, there was a significant interaction between grape cutting treatments and location in the abundance of natural enemies ($F = 3.18$; df = 3,24; $P = 0.042$), but not in 2004 and 2005 ($F < 1.71$; df = 3,24; $P > 0.19$). In general, natural enemy species composition was similar for both grape cutting treatments. Although there were more ladybird beetles in the wild cutting treatment in 2005 ($F = 7.29$; df = 1,4; $P = 0.054$), no differences were observed in the response of green lacewings, brown lacewings,

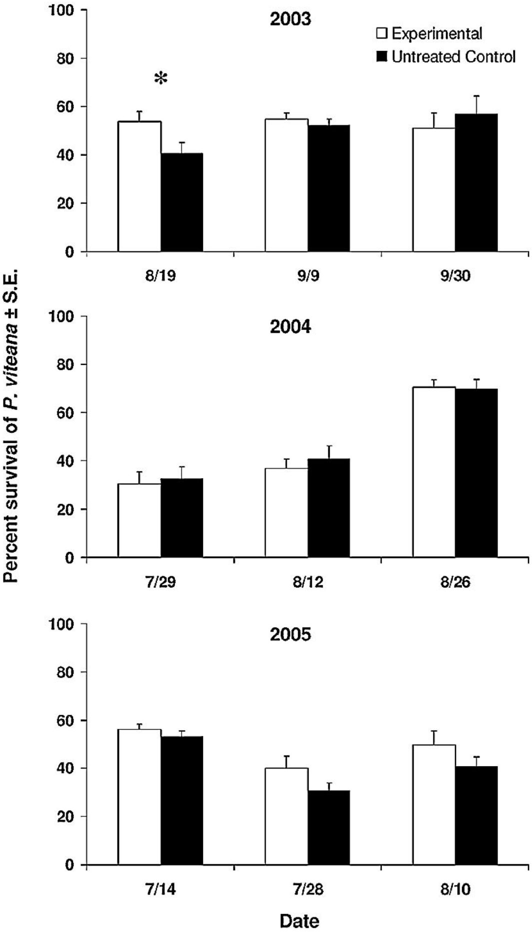

Fig. 3. Average percent survival of *P. viteana* ±SE in juice grape vineyards in Michigan where adjacent wild grapevines were cut (experimental) or not cut (untreated control) during 2003–2005. Pairs of bars with an asterisk are significantly different between programs at $P < 0.05$.

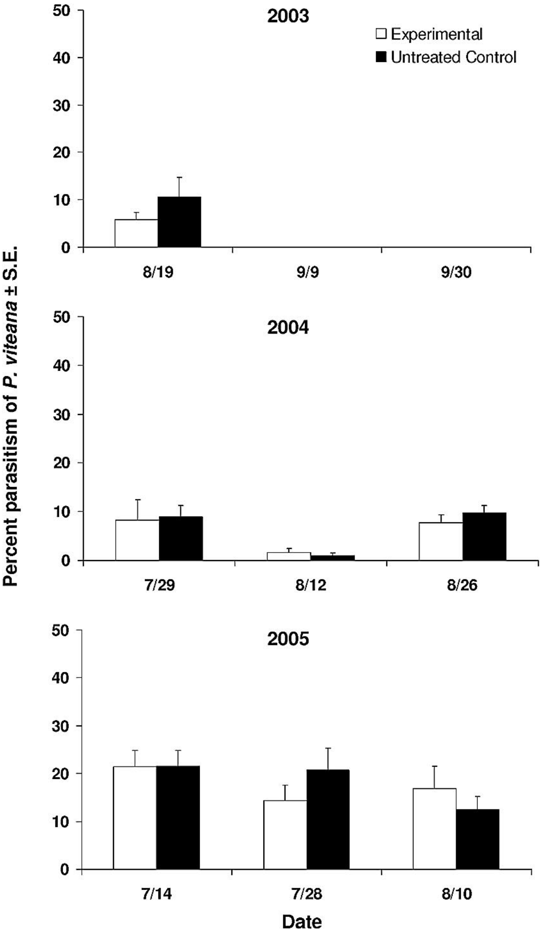

Fig. 4. Average percent parasitism of *P. viteana* ±SE in juice grape vineyards in Michigan where adjacent wild grapevines were cut (experimental) or not cut (untreated control) during 2003–2005.

ladybird beetles, parasitoid wasps, and syrphid flies to wild grape cutting ($F < 3.59$; df = 1,4; $P > 0.13$).

Discussion

This study shows that cutting wild grapevines in woodlots up to 60 m deep for three growing seasons has no effect on infestation of adjacent vineyards by *P. viteana*, the main insect pest in this agricultural system. This is the first published evaluation of the effects of vineyard insect pest control from cutting wild grapevines adjacent to vineyards, and in general, there are few studies that have documented the effects of wild host removal on insect pest control in perennial crops. *P. viteana* adults move a relatively short distance, with an average maximum displacement of 105 m between woods and adjacent vineyards and 39 m within vineyards for male moths (Botero-Garcés and Isaacs 2004b). The greater movement between habitats than within habitats suggests that *P. viteana* will move further when its host plant is not present, and this may help explain the lack of effect in this study.

Our results reveal a lack of positive correlation between *P. viteana* male moth captures in monitoring traps and cluster infestation levels; moth captures were higher at the vineyard interior compared with the vineyard border where larval infestation was greatest. This pattern of abundance has been noted previously (Biever and Hostetter 1989, Hoffman and Dennehy 1989, Hoffman et al. 1992, Martinson et al. 1994, Botero-Garcés and Isaacs 2003, Tobin et al. 2003), but to date, no study has investigated the underlying reasons for this relationship. Hoffman et al. (1989, 1992) proposed that the poor spatial correlation between trap captures and infestation levels is caused by high densities of female *P. viteana* at vineyard borders competing with synthetic pheromone and that, in general, pheromone traps are not reliable indicators of population density.

Wild grape removal may need to be applied over a larger spatial scale than was done in this study to minimize immigration of moths into vineyards and to realize a significant effect on vineyard infestation. Additionally, the lack of effect of wild grape removal may have been influenced by the commercial vineyards being sprayed for insect control. Although results from unsprayed vineyards may have differed from those presented here, our study sites were representative of the conditions where this proposed cultural control tactic would need to be effective for its integration into IPM programs.

The scale at which wild grape was cut in this study was selected to simulate what a grower may do on their own property. Although host removal was not effective for reducing pest pressure in this study, host removal has been shown to be an effective component of an IPM program in apples (Prokopy 2003), when applied over a larger area and for a greater duration. This suggests that external pest pressure can be minimized if the scale at which alternate hosts are removed is appropriate. Although it may be economically and politically challenging, increasing the spatial scale at which wild hosts are removed to the landscape level may make cultural control of *P. viteana* possible. In general, our understanding of insect movement and dispersal behavior at the landscape level is inferior compared with our understanding at the field level (Barrett 2000), but it is expected that mobile pest insects will be more affected by cultural controls implemented across multiple adjacent farms (Altieri and Nicholls 2004).

Cutting wild grapevines and preventing regrowth is a time consuming and labor-intensive process. In this study, the average time taken to cut wild vines and the approximate number of wild vines cut was recorded in 2004 and 2005. In 2004, it took ≈17 h to cut ≈1,500 vines, and in 2005, it took ≈6.75 h to cut ≈350 vines at all sites. It should also be noted that sucker growth from vines cut in 2003 was extensive, and up to 35 suckers on one vine were observed (P.E.J., unpublished data), prompting herbicide application in 2004. Coupled with the fact that no additional control of

P. viteana is achieved, our data suggest that growers should not invest their time and labor resources in cutting wild grapevines in woodlots adjacent to their vineyards, unless this is required for other reasons such as protection of the quality of the woodland.

When integrating alternatives into insect control programs of crop pests, the impact on natural enemies must be considered. In general, this study shows that cutting wild grapevines for control *P. viteana* has minimal effect on the community of natural enemies in vineyards. After 3 yr, *P. viteana* parasitism was not affected by cutting of wild grape. Parasitism and survival of *P. viteana* were similar in vineyards where wild grapevines were cut and not cut in the adjacent habitat. While wild grapevines may act as a natural source of pest infestation in vineyards, they may also provide a refuge for natural enemies of *P. viteana* outside the region treated with insecticide (Dennehy et al. 1990, Seaman et al. 1990), and so the removal of such hosts may have unintended consequences for natural enemy populations. For example, *Acer saccharum* Marshall, *Robinia pseudo-acacia* L., *Rosa multiflora* Thunberg, *Salix nigra* L., *Vitis riparia* Michaux, and *Zanthoxylum americanum* Miller were determined to be important plant species for overwintering sites of *Anagrus* spp. parasitoids near vineyards (Williams and Martinson 2000) and, in western U.S. grape production, vineyards bordered by *Rubus* spp. and French prune trees, *Prunus domestica* L., effectively increased biological control of leafhoppers by *Anagrus epos* Girault (Pickett et al. 1990, Corbett and Rosenheim 1996, Murphy et al. 1998).

Similar captures of green lacewings, brown lacewings, ladybird beetles, parasitic hymenoptera, and syrphid flies on yellow sticky traps throughout three growing seasons suggest that the natural enemies in this system are highly mobile and are likely operating on a larger spatial scale than that used to compare the two wild grape cutting treatments. Although green lacewing larvae (*Chrysoperla carnea* Stephens) will feed on *P. viteana* under no-choice laboratory conditions (P.E.J., unpublished data), the effect of predation on *P. viteana* by these natural enemies in vineyards has not been documented. Further research to quantify predation of *P. viteana* by generalist insect predators in vineyards is needed. Yellow sticky cards are useful for measuring the abundance of natural enemies within a system but alternative methods for assessing predation, such as deployment of sentinel prey, should be considered in future research.

Acknowledgments

We thank K. Ahlstrom and J. Luhman for identification of parasitoids; members of the MSU Small Fruit Entomology Laboratory for technical assistance; and the cooperating grape growers for access to vineyards. Funding for this research was provided in part by the Rhodes (Gene) Thompson Endowed Fellowship in Entomology, the National Grape Cooperative, Project GREEEN, the Viticulture Consortium-East, and the USDA-CSREES Pest Management Alternatives Program (Grant 2004-34381-14647).

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Received for publication 10 August 2006; accepted 25 October 2006.