Comparison of Three Dispenser Distribution Patterns for Pheromone Mating Disruption of *Paralobesia viteana* (Lepidoptera: Tortricidae) in Vineyards

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ABSTRACT Over two growing seasons, Isomate GBM-Plus tube-type dispensers releasing the major pheromone component of grape berry moth, *Paralobesia viteana* (Clemens) (Lepidoptera: Tortricidae), were evaluated in vineyards (*Vitis* spp.) in Michigan, New York, and Pennsylvania. Dispensers were deployed in three different density-arrangement treatments: 124 dispensers per ha, 494 dispensers per ha, and a combined treatment with 124 dispensers per ha in the vineyard interior and 988 dispensers per ha at the vineyard border, equivalent to an overall density of 494 dispensers per ha. Moth captures and cluster infestation levels were compared at the perimeter and interior of vineyards receiving these different pheromone treatments and in vineyards receiving no pheromone. Orientation of male moths to pheromone-baited traps positioned at the perimeter and interior of vineyards was reduced as a result of mating disruption treatments compared with the nontreated control. These findings were consistent over both years of the study. Disruption of male moth captures in traps varied from 93 to 100% in treated vineyards, with the 494 dispensers per ha application rates providing significantly higher level of disruption than the 124 dispensers per ha rate, but only in 2007. Measurements of percentage of cluster infestation indicated much higher infestation at perimeters than in the interior of the vineyards in all three regions, but in both sample positions there was no significant effect of dispenser density on cluster infestation levels in either year. The contrasting results of high disruption of moth orientation to traps in vineyards that also had low levels of crop protection from this pheromone treatment are discussed in the context of strategies to improve mating disruption of this tortricid pest.

KEY WORDS Lepidoptera, grape, semiochemical, integrated pest management, Isomate

The grape berry moth, *Paralobesia viteana* (Clemens) (Lepidoptera: Tortricidae), is a key pest of grapes in the eastern United States and Canada that causes yield loss and fruit contamination and allows opportunistic pathogens to infect grape (*Vitis* spp.) clusters (Dennehy et al. 1990, Isaacs et al. 2012). This species has multiple generations per season (Tobin et al. 2001, 2002), and the difficulty of determining the occurrence of these generations complicates accurate timing of insecticide applications (Teixeira et al. 2009). Control of this pest also is complicated by its presence in native woodland habitat near vineyards on wild grape (Seaman et al. 1990) and the associated high densities at vineyard perimeters near woods (Hoffman and Dennehy 1989, Botero-Garcés and Isaacs 2003). Current management programs for *P. viteana* are dominated by broad-spectrum insecticides that limit the potential for biological control (Jenkins and Isaacs 2007), but recent registration of selective insecticides provides an opportunity for integration of more sustainable tactics that combine selective chemical control of eggs and larvae with disruption of mating by using pheromones. Mating disruption is a nontoxic approach to management of *P. viteana* that has been studied in vineyards across eastern North America, with the ultimate aim of reducing grower dependence on broad spectrum insecticides for control of this key vineyard pest.

The sex pheromone of *P. viteana* (then named *Endopiza viteana*) was first described by Roelofs et al. (1971) and was later described in more detail by Witzgall et al. (2000). After the original determination, Isomate-GBM dispensers (Pacific Biocontrol, Ridgefield, WA) containing a 9:1 blend of Z-9-dodecenyl acetate and Z-11-teradecenyl acetate were developed that required reapplication to last through the season.

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Evaluations in New York state by using these dispensers at 988 dispensers per ha showed them to be effective at reducing crop infestation when applied before bloom and reapplied in the middle of the season in vineyards classified as being at low or intermediate risk of damage from *P. viteana* using the Grape Berry Moth Risk Assessment Protocol (Dennehy et al. 1990). In Ontario, Canada, control of *P. viteana* also was achieved using this dispenser (Trimble et al. 1991, Trimble 1993). Despite these positive results, adoption of this technology by grape growers has been limited (D. Thompson, personal communication). Potential reasons for this include the cost of the product compared with insecticides, cost of application, and efficacy. Recent grower experiences with Isomate-GBM dispensers in New York and Michigan have raised questions about the efficacy of pheromone-based mating disruption at the minimum application rate of 494 dispensers per ha, especially in commercial vineyards where *P. viteana* populations are at levels requiring insecticide applications. Unless deployment strategies can be developed and tested that provide effective control and are economical, the levels of adoption of Isomate-GBM are likely to remain low.

An alternative approach to distributing dispensers evenly across the vineyard is to focus application in the regions of vineyards at the greatest risk from *P. viteana* infestation. Theoretical predictions (e.g., Miller et al. 2006) suggest increasing dispenser density will decrease the ability of male moths to locate female mates. Consequently, if pest abundance is greatest at vineyard perimeters adjacent to wooded habitat as is the case for *P. viteana* (Botero-Garcés and Isaacs 2003), one potential tactic would be to deploy more dispensers at the vineyard perimeter adjacent to such habitat, than in the interior. An equivalent of 494 dispensers per ha can be achieved through application at a rate of 988 dispensers per ha at the vineyard perimeter (≈40% of the area) and 124 dispensers per ha in the remaining interior of the vineyard away from such habitat. Such an approach may provide a practical density-dependent application strategy to reduce the chance that male moths locate females in the regions of highest population.

Given the expense of pheromone dispensers, growers are reluctant to incur the additional cost of this specific pest control product, particularly when there are other nonlepidopteran insects that still require control. Eastern U.S. vineyards are also at risk of infestation by various coleopterans and hemipterans that are not controlled by pheromones for *P. viteana.* Under this scenario, the relatively low expense of insecticide that can control all three main types of insect pests provides a compelling motivation for growers to avoid the additional expense of mating disruption for *P. viteana* control. As mentioned, the efficacy of the low density approach to dispenser deployment has been questioned, but not rigorously tested in a replicated design. Because pest pressure from *P. viteana* is greatest at vineyard perimeters, it also may be necessary to supplement this with a higher dispenser density in these regions. Trimble and Marshall (2010) have demonstrated improved disruption of female moths by using higher perimeter dispenser densities, but it is important to also determine whether such treatments affect pest infestation of the crop. In this study, we aimed to determine the effect of dispenser density and distribution on the level of disruption of *P. viteana* and the levels of fruit infestation in Eastern U.S. vineyards. This study was conducted in 2 yr across three major viticultural regions in the eastern United States to determine whether dispensers could prevent damage to grape clusters by *P. viteana.*

Materials and Methods

Four 0.8–4.0 ha (2–10 acre) vineyards planted with *Vitis labrusca* L. (Michigan, PA) or *Vitis vinifera* L. (New York) were selected at each of four grape farms in southwest Michigan (Van Buren and Berrien counties), two farms in the New York–Pennsylvania Lake Erie grape region (Erie county), and at two farms in New York's Finger Lakes region (Schuyler and Yates counties). At each farm, four vineyards with similar histories of *P. viteana* infestation were chosen, and treated with different application rates or distributions of Isomate GBM-Plus dispensers (Pacific Biocontrol), containing 243.8 mg of Z-9-dodecadienol and designed to release this compound for up to 150 d. One untreated control vineyard received no pheromone, a second received Isomate GBM-Plus dispensers evenly distributed at 124 dispensers per ha (i.e., one quarter of the recommended application rate of 494 dispensers per ha), a third received a uniform distribution of the dispensers at the recommended minimum application rate of 494 dispensers per ha, and the fourth vineyard was treated with the dispensers at 988 dispensers per ha on the perimeter vines at the region of the vineyard adjacent to the wooded border and at 124 dispensers per ha in the interior, for an overall application density of 494 dispensers per ha. This was achieved by applying the perimeter high density treatment to ≈40% of the area, defined as the portion of vineyards adjacent to wooded areas. Depending on the vineyard size and shape, the actual areas treated with the high dispenser rate ranged from 0.6 to 0.9 ha (1.5–2.3 acres) and typically covered the outermost nine rows, extending 30–35 m into the vineyards. Pheromone dispensers were deployed from 26 April to 19 May 2006 and from 25 April to 18 May in 2007. Vineyards received the same pheromone treatments in 2006 and 2007, and all vineyards within a farm received the same insecticide and fungicide program.

Moth flight by *P. viteana* was monitored in each vineyard from early May to harvest in both years by using plastic delta traps suspended from the trellis wire. These were baited with a gray rubber septum lure (Suterra, Bend, OR) containing 0.1 mg of a 10:1 ratio of Z-9-dodecadienol and Z-11-tetradecenyl acetate and suspended from the top of the trap above the sticky insert by a pin. Lures were replaced once per month through both summers. In each vineyard, four traps were arranged in two transects, with the transects at least 30 m apart. In each transect, one trap was

Table 1. Number of male *P. viteana* moths captured per trap through the season, percentage of disruption relative to untreated control, and damage to grape berries at the interior and perimeter of vineyards at harvest in Michigan, Pennsylvania, and New York during 2006

State and treatment	No. moths captured per trap		% disruption		Damaged berries per 25 clusters	
	Interior	Perimeter	Interior	Perimeter	Interior	Perimeter
Michigan (n = 4)						
Untreated control	296.4 ± 173.8a	268.0 ± 112.2a			8.3 ± 4.3	34.1 ± 6.0
124 dispensers per ha	21.8 ± 18.5b	20.1 ± 8.6b	95.5 ± 2.4	92.9 ± 1.7	4.1 ± 1.3	32.6 ± 13.1
124 + 988 dispensers per ha	2.8 ± 2.3b	4.1 ± 4.1b	99.4 ± 0.2	98.6 ± 1.4	5.6 ± 1.5	30.0 ± 10.6
494 dispensers per ha	3.4 ± 2.2b	55.8 ± 47.9b	98.4 ± 1.4	89.0 ± 8.3	8.3 ± 2.8	20.6 ± 7.7
Pennsylvania (n = 2)						
Untreated control	146.0 ± 61.0a	224.5 ± 41.0a			90.5 ± 11.5	94.8 ± 59.8
124 dispensers per ha	8.5 ± 3.0b	12.3 ± 0.3b	91.9 ± 5.4	94.4 ± 0.9	33.0 ± 17.5	114.0 ± 54.0
124 + 988 dispensers per ha	8.5 ± 1.5b	9.5 ± 0.5b	92.4 ± 4.2	95.6 ± 1.0	35.5 ± 13.0	84.5 ± 28.5
494 dispensers per ha	10.0 ± 0.5b	10.0 ± 4.0b	91.5 ± 3.9	95.1 ± 2.7	23.8 ± 16.8	178.5 ± 76.5
New York (n = 2)						
Untreated control	1.0 + 1.0	1.3 ± 1.3			14.3 ± 8.8	40.8 ± 19.8
124 dispensers per ha	1.5 + 1.5	4.8 ± 4.8	0.0	50.0 ± 50.0	2.5 ± 0.5	27.0 ± 5.5
124 + 988 dispensers per ha	0.5 + 0.5	0.0 ± 0.0	50.0	100.0 ± 0.0	1.0 ± 0.0	16.5 ± 2.0
494 dispensers per ha	0.0 + 0.0	0.0 ± 0.0	100.0	100.0	3.0 ± 0.5	37.8 ± 7.3

Values are treatment averages in each state (±SE), and those with no SE had insufficient moth captures to calculate variation. Averages within a group of averages followed by the same letters are not significantly different ($P < 0.05$).

hung on the trellis wire (1.5 m in height) at another was placed 65 m inside the vineyard. Traps were checked once per week from April to October of each year.

Infestation by *P. viteana* was measured by examining five randomly selected grape clusters on each of five vines adjacent to each trap location. This assessment was performed three times at each vineyard and incidence (percentage of clusters infested) and severity (number of damaged berries) of infestation were recorded. Infestation sampling times were chosen to coincide with key crop stages when infestation levels by each of the three *P. viteana* generations can be detected and occurred on 19 June–7 July 2006 and 21 June–17 July 2007 (postbloom); 25 July–17 August 2006 and 6–22 August 2007 (verasion), and 7 September–2 October 2006 and 30 August–2 October 2007 (preharvest).

Data from the inside and edge of the vineyard were analyzed separately because moth captures and infestation are generally much greater on vineyard perimeters (Botero-Garcés and Isaacs 2003). The average total numbers of moths captured throughout the season in the two traps placed in the interior or perimeter of the vineyard were used to determine percent trap disruption separately for each treatment and trap location, calculated as (1 − moths in treated/moths in no-pheromone) × 100. The number of infested damaged berries per 25 clusters was averaged for the two sampling locations inside or at the edge of the vineyard. For comparison of damage across treatments, we used berry infestation data from the preharvest period only because this is the most economically important period and because the results at this period of the season reflect an integration of the treatment effect across the whole season.

Moth capture data were square root transformed for homogeneity of variance, and percentage of infestation data were arcsine transformed before analysis. Data were analyzed in a randomized complete block design with pheromone treatment as fixed factor and farm as random factor by using PROC MIXED and macro PDMIX800 of SAS (SAS Institute 2001), with analyses conducted separately by state. Differences among treatments were determined using the least significant difference method with $\alpha = 0.05$. Trap disruption data were arcsine transformed and analyzed using the same method as the other data sets.

Results

Moth Capture. The number of moths captured per trap in the untreated control vineyards was much higher in Michigan and Pennsylvania than in New York, both in 2006 and 2007. In 2006, significantly more moths were captured in pheromone-baited traps placed in the untreated control vineyards than in traps placed in any of the vineyards treated with pheromone in Michigan and Pennsylvania but not in New York (Michigan: $F = 11.57$; df = 3, 9; $P = 0.002$; Pennsylvania: $F = 11.02$; df = 3, 3; $P = 0.04$; and New York: $F = 1.0$; df = 3, 3; $P = 0.5$, respectively) (Table 1). In Michigan during 2007 (Table 2) significantly more moths were captured in the untreated control vineyards than in the other treatments ($F = 11.10$; df = 3, 9; $P = 0.002$). In Pennsylvania, numerically greater moths were captured in the untreated control vineyards, but there was no significant effect of the dispenser treatments ($F = 9.10$; df = 3, 3; $P = 0.05$), whereas in New York the number of moths captured was low and differences among treatments were not significant ($F = 0.82$; df = 3, 3; $P = 0.57$).

At the edge of the vineyards in both years (Tables 1 and 2), significantly more moths were captured in the untreated control vineyards than in any of those treated with pheromone (Michigan 2006: $F = 9.86$; df = 3, 9; $P = 0.003$ and 2007: $F = 14.37$; df = 3, 9; $P < 0.001$; Pennsylvania 2006: $F = 59.24$; df = 3, 3; $P = 0.004$

Table 2. Number of male *P. viteana* moths captured per trap through the season, percentage of disruption relative to untreated control, and damage to grape berries at the interior and perimeter of vineyards at harvest in Michigan, Pennsylvania, and New York, during 2007

State and treatment	No. moths captured per trap		% trap disruption		Damaged berries per 25 clusters	
	Interior	Perimeter	Interior	Perimeter	Interior	Perimeter
Michigan (n = 4)						
Untreated control	109.1 + 61.9a	102.1 ± 36.7a			0.3 ± 0.1	9.9 ± 5.1
124 dispensers per ha	4.8 + 1.2b	1.0 ± 0.7b	93.2 ± 1.9b	99.2 ± 0.4	0.0 ± 0.0	13.8 ± 6.5
124 + 988 dispensers per ha	0.5 + 0.4b	1.5 ± 1.5b	99.5 ± 0.3a	98.0 ± 2.0	0.0 ± 0.0	9.9 ± 4.4
494 dispensers per ha	0.3 + 0.3b	5.0 ± 4.8b	99.9 ± 0.1a	97.1 ± 2.6	0.6 ± 0.1	5.5 ± 3.0
Pennsylvania (n = 2)						
Untreated control	253.0 + 142.0	277.8 ± 93.3a			23.3 ± 10.3	55.3 ± 6.3
124 dispensers per ha	28.0 + 23.0	6.5 ± 4.0b	91.3 ± 4.2	97.9 ± 0.7	32.0 ± 16.0	78.3 ± 29.8
124 + 988 dispensers per ha	1.5 + 0.0	0.8 ± 0.3b	99.1 ± 0.5	99.7 ± 0.2	24.0 ± 10.0	94.8 ± 53.8
494 dispensers per ha	0.0 + 0.0	0.8 ± 0.3b	100.0 ± 0.0	99.7 ± 0.2	24.3 ± 7.3	94.8 ± 24.8
New York (n = 2)						
Untreated control	0.8 + 0.3	2.3 ± 2.3			0.8 ± 0.8	14.8 ± 13.3
124 dispensers per ha	8.8 + 8.8	4.3 ± 4.3	50.0 ± 50.0	50.0 ± 50.0	0.0 ± 0.0	7.5 ± 7.5
124 + 988 dispensers per ha	0.5 + 0.5	0.0 ± 0.0	50.0 ± 50.0	100.0 ± 0.0	0.5 ± 0.5	14.3 ± 6.3
494 dispensers per ha	0.0 + 0.0	0.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	0.3 ± 0.3	10.5 ± 10.5

Values are treatment averages in each state (±SE), and averages within a group followed by the same letter are not significantly different ($P < 0.05$).

and 2007: F = 28.76; df = 3, 3; P = 0.01). There were no significant differences among the treatments in the number of moths captured in traps positioned at the perimeter of vineyards in New York (F = 0.76; df = 3, 3; P = 0.59 and F = 0.69; df = 3, 3; P = 0.62 in 2006 and 2007, respectively).

Communication Disruption. The percentage of trap disruption ranged from 89 to 100% in vineyards treated with pheromone that had lower moth captures compared with the untreated control vineyards (Michigan and Pennsylvania). In 2006, inside vineyards there were no significant differences in the level of trap disruption in any of the pheromone-treated vineyards in Michigan or Pennsylvania (Michigan: F = 0.86; df = 2, 6; P = 0.47 and Pennsylvania: F = 0.37; df = 2, 2; P = 0.73, respectively) (Table 1). In 2007 in Michigan, the percentage trap disruption in the vineyards treated with 124 dispensers per hectare was significantly lower than in the vineyards treated with 50 + 400 or 200 dispensers (F = 19.43; df = 2, 6; P = 0.002) (Table 2). In Pennsylvania, there were no significant differences among vineyards treated with pheromone (F = 10.00; df = 2, 2; P = 0.09). At vineyard borders in 2006 and 2007 (Tables 1 and 2), there were no significant differences in the percentage trap disruption among pheromone treated vineyards (Michigan 2006: F = 1.84; df = 2, 6; P = 0.24 and 2007: F = 0.15; df = 2, 6; P = 0.86; Pennsylvania 2006: F = 0.38; df = 2, 2; P = 0.72 and 2007: F = 5.62; df = 2, 2; P = 0.15). There were insufficient data for analysis of variance (ANOVA) of trap disruption data from New York because no moths were captured in several of the untreated control and pheromone-treated vineyards.

Berry Infestation. Berry infestation levels were consistently higher at the border than inside the vineyard in all states and years, and overall damage was higher in Pennsylvania than in the other states (Table 2). In 2006, there were no significant differences among the number of damaged berries in untreated control and pheromone-treated vineyards (inside: Michigan, F = 1.2; df = 3, 9; P = 0.36; Pennsylvania, F = 2.65; df = 3, 3; P = 0.22; and New York, F = 3.03; df = 3, 3; P = 0.19; border: Michigan, F = 0.83; df = 3, 9; P = 0.51; Pennsylvania, F = 6.42; df = 3, 3; P = 0.08; and New York, F = 2.84; df = 3, 3; P = 0.21). In 2007, infestation levels were low across all vineyards in Michigan, and there were too few damaged berries to detect differences in infestation among treatments. At the edge and interior of vineyards in all states, there were no significant differences in the number of damaged berries in untreated control and pheromone-treated vineyards (inside: Pennsylvania, F = 1.38; df = 3, 3; P = 0.40 and New York, F = 0.43; df = 3, 3; P = 0.75; outside: Michigan, F = 0.48; df = 3, 9; P = 0.70; Pennsylvania, F = 0.91; df = 3, 3; P = 0.53 and New York, F = 0.69; df = 3, 3; P = 0.38).

Discussion

Our results show that pheromone dispensers are effective at disrupting orientation of *P. viteana* males to pheromone-baited traps, with low moth captures in vineyards where dispensers were deployed in both growing seasons of this study. Despite the apparent effect on male moths measured using this method, assessment of crop infestation over two growing seasons did not show lower infestation of clusters in vineyards receiving these dispensers. This result is in contrast to previous studies (Dennehy et al. 1990, Trimble et al. 1991) and raises the question of why this study did not detect a reduction in crop infestation. One possibility is the relatively high density of infestation in some of the vineyards in which these trials were conducted. For example, harvest-time infestation levels ranged from 5 to 95% of clusters infested. At these densities of *P. viteana*, mating disruption is expected to be challenging due to the chance of male and female moths being able to locate each other

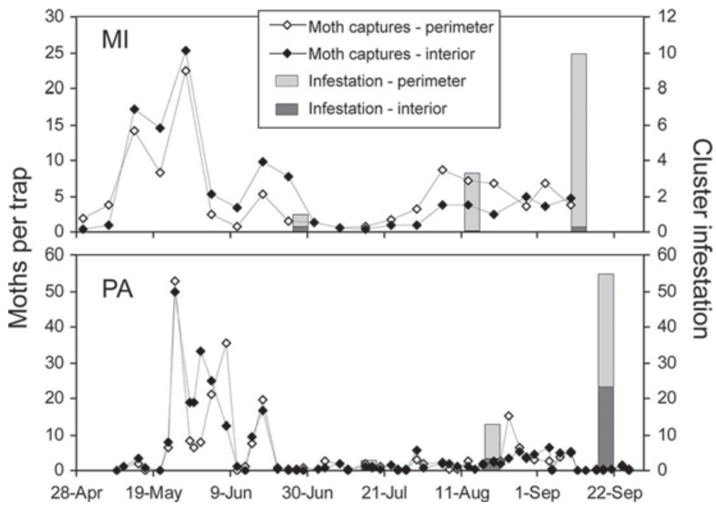

Fig. 1. Captures of male *P. viteana* in monitoring traps and larval infestation on clusters (percentage of clusters infested), in samples made at the perimeter and interior of vineyards without pheromone application in Michigan and Pennsylvania, 2007.

without needing to rely on pheromonal communication (Miller et al. 2006). Another potential explanation is that the Isomate-GBM Plus formulation contains only the major component of the pheromone, and is therefore an incomplete blend that may be less effective than a more complete blend could be. Blend completeness has been cited as a potential reason for poor mating disruption success (Minks and Cardé 1988, Cardé and Minks 1995), but less than complete blends have been shown to have similar mating disruption efficacy for tortricid fruit pests (e.g., Evenden et al. 1999). For *P. viteana,* a multi-component pheromone blend has been characterized by Witzgall et al. (2000), showing that the minor component Z-11-teradecenyl acetate significantly increases male moth capture, whereas the other components were either repellent or neutral. This suggests that future development of dispensers for mating disruption of *P. viteana,* or at least their testing in advance of commercial sales, should include formulations that contain the major and minor pheromone components.

The number of male moths captured in pheromone-baited traps often does not correlate with the level of damage to the clusters (Dennehy et al. 1990). Traps capture the highest number of moths early in the season, whereas most damage to the berries, and oviposition, occurs much later in the season (Teixeira et al. 2009). The same pattern was found in this study; most moths were captured in May and June ant the most damage occurred in August and September (Fig. 1). This indicates a poor correlation between male moth captures in traps and the level of oviposition by female moths. However, it is not clear why relatively fewer moths were captured later than early in the season. One hypothesis is that infestation late in the season is the result of gravid females immigrating from wild grapevines found at the edge of the vineyards. This would explain why infestation is greater at the edge of the vineyard, but even inside the vineyard (see Pennsylvania data in Tables 1 and 2) infestation is higher late in the season without a corresponding increase in moth capture. Another hypothesis is sampling bias caused by the different nature of cluster damage early and late in the season. Early in the season, after bloom, webbing is the most prevalent type of damage, that may be harder to detect than berry infestation later in the season. Finally, it may be that late in the season pheromone-baited traps are less efficient because of factors related to moth behavior, changes in grape berry volatile chemistry, or grape plant canopy structure. Such changes also may affect the performance of mating disruption technologies.

In a majority of moth species, competitive attraction is the mechanism mediating the disruption of sexual communication using point sources of pheromone (Miller et al. 2006). Under this mechanism, pheromone-releasing dispensers compete with female moths (and pheromone-baited traps) for male moth flight approaches. Preliminary studies underway with *P. viteana* indicate that the pattern of trap disruption is consistent with competitive attraction (L.A.F.T., unpublished data). The low captures of male moths in pheromone-baited traps late in the season may help explain the poor performance of mating disruption; if lure-baited traps are not effective in attracting moths, then dispensers also may be inferior competitors against females during the period approaching harvest. The key to understanding and improving the performance of mating disruption of this species may be to determine the reason why traps capture relatively few moths late in the season.

Mating disruption using sex pheromones has been successful in European wine grape vineyards for control of *Eupocelia ambiguella* (Hübner) and *Lobesia botrana* (Denis & Schiffermüller) (Lepidoptera: Tortricidae). Several studies have shown efficacy of this approach for control of these pests (Kast 2001, Harari et al. 2007), particularly when mating disruption is deployed in an areawide approach. This provides high levels of disruption and few nontreated reservoirs for moths to escape the effects of the treatment. In the eastern United States, high populations of *P. viteana* and widespread background populations in woods combine to create a challenging environment for implementation of this tactic. Areawide application of pheromones to regions of grape production may be the most effective way to provide pheromonal control of this pest, as has been demonstrated for codling moth, *Cydia pomonella* (L.), in orchards (Calkins et al. 2000, McGhee et al. 2011). However, this will require large-scale investment to conduct the research at this scale, followed by widespread cooperation among neighboring growers. The development of less labor-intensive approaches to deployment of pheromone such as puffers (Shorey and Gerber 1996a,b; Isaacs et al. 1999; Stelinski et al. 2007, 2009) and applicators that can allow rapid mechanical application of wax matrices to vineyards (Teixeira et al. 2010) also may provide greater likelihood of adoption of this tactic for integration into pest management programs for protection against *P. viteana.*

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