Research Reports

Effects of Grape Berry Moth Management Practices and Landscape on Arthropod Diversity in Grape Vineyards in the Southern United States

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Summary. Agricultural monocultures with intensive pest management practices reduce diversity and create instability in agricultural ecosystems, thereby increasing reliance upon pesticides. This study compares the influence of three insect pest management programs in vineyards on arthropod diversity as well as parasitism and control of grape berry moth (*Endopiza viteana*), the key pest of grapes (*Vitis labrusca*) in eastern North America. Vineyards in Bald Knob, Hindsville, Judsonia, Lowell, and Searcy, Ark., were managed with a range of intensity of insecticide use, a reduced insecticide program with Exosex-GBM dispensers for mating disruption, or no pesticide use in abandoned vineyards. Arthropod diversity and carabid (Carabidae) density in each vineyard was sampled with pitfall traps. Grape berry moth flight was monitored by pheromone traps. Grape berry moth–infested grapes were collected from the field and reared in the lab until parasites or moths emerged. There were significant differences in arthropod diversity between vineyard sites, with Shannon diversity index values generally higher in woods and managed vineyards with conventional sprays and/or mating disruption than in abandoned sites. Shannon index values for arthropod diversity were significantly lower at the vineyard edge in Searcy (recently abandoned), vineyard center and edge in Bald Knob (abandoned), and the vineyard edge in Hindsville (conventional sprays). In 2003, carabid density was significantly highest in the edge and center of the Hindsville vineyard (high insecticide usage) and the abandoned Bald Knob vineyard had significantly lowest carabid density. Apparently, insecticide sprays resulted in more food on the vineyard floor for carabids. The vineyard floor management was too variable among vineyards to deduce its effect on carabid density. With some exceptions, low-spray and no-spray vineyards generally showed greater diversity and parasitism of grape berry moth than high-spray vineyards. Parasitism was higher in some high-spray vineyards than in low-spray with mating disruption vineyards. Grape berry moth flight and berry damage were more dependent on spray timing than intensity. This study demonstrates that insect pest management programs impact arthropod diversity and parasitism. Further testing is needed to determine why parasitism of grape berry moth decreased in the vineyards using the mating disruption tactic.

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The most important insect pest of grape in eastern North America is the grape berry moth (Taschenberg et al., 1974). This insect feeds almost exclusively on wild and cultivated grapes (Luciani, 1987). Egg laying is restricted to the edge vines for the first generation, and then each consecutive generation moves further inside the vineyard (Powell and Wylie, 1959). This behavior has resulted in the recommendation to restrict insecticide sprays to the vineyard edge against the first generation hatch (Johnson et al., 2002). First generation larvae infest grape flowers, bud clusters, and immature berries (Taschenberg, 1945). Larvae in succeeding generations burrow directly into one or more grape berries while maturing, creating wormy and unmarketable grapes. Generations per season range from one or two in southern Ontario (Luciani, 1987) to three or four in Arkansas (Johnson et al., 2002). The female moth produces a sex pheromone identified as (Z)-9-dodecenyl acetate (Roelofs et al., 1971).

There are several grape berry moth pest management programs being followed by growers. The conventional pest management program relies upon crop phenology for timing of insecticides. Some growers improved spray timing by using pheromone-baited traps to detect first moth catch (biofix) and thereafter accumulating degree-days to predict larval hatch. Traps are initially placed along a wooded edge adjacent to the vineyard early in the season, then moved towards the vineyard center as the season progresses (Lewis and Johnson, 1999). Mating disruption has reduced, and sometimes replaced, insecticide use in vineyards. The use of 988.4 pheromone dispensers per hectare (400 per acre) reduced grape berry moth pheromone trap catch by >92% and gave comparable larval damage to that of insecticide-treated vineyards (Dennehy, 1991; Trimble et al., 1991). Exosex (Exosect Ltd., Southampton, U.K.) pheromone dispenser is a new auto-confusion system that results in mating disruption. The male is attracted to and enters the dispenser, then becomes contaminated with an electrostatic Entostat powder charged with sex pheromone. The contaminated male exits the dispenser and becomes a point source of sex pheromone and attracts other males. This auto-confusion system needs to be evaluated for mating disruption of pests such as the grape berry moth.

Findings on biological control of grape berry moth have been variable. Taschenberg (1945) observed 3.4% to 57.2% parasitism of grape berry moth larvae and pupae. These levels of overall parasitism are insufficient to provide adequate control of grape berry moth (Dozier et al., 1932; Garlick, 1935; Gleissner, 1943; Ingerson, 1920; Luciani, 1987). The complex of grape berry moth parasitoids in New York includes 22 species of Ichneumonidae, 13 Braconidae, three Chalcidae, and one Bethylidae (Taschenberg, 1945). Gleissner (1943) found better control of grape berry moth by predators, especially insects such as ants (Formicidae) and ground beetles or carabids. However, no known studies have been conducted on natural enemies of grape berry moth in the southern U.S.

Sustainable agricultural practices, such as integrated pest management, often result in greater biodiversity and stability of the ecosystem (Brown and Schmidt, 2001; Pimentel, 1961; Risch et al., 1983; Striegler et al., 1997). Carabid beetles and rove beetles or staphylinids (Staphylinidae) are often used as a common indicator of biodiversity (Dennis and Fry, 1992) and environmental changes in natural and modified ecosystems. Shah et al. (2003) compared pitfall trap samples in organic and conventional cereal farms and noted 79.7% were carabids and 16.7% were staphylinids. Dritschilo and Wanner (1980) caught significantly greater numbers of carabids in organic corn (*Zea mays*) fields (no commercial fertilizers or pesticides) than in conventionally managed corn fields. In the Pacific northwestern U.S., Epstein et al. (2000) found more carabids, spiders, and other predators of key insect pests in apple (*Malus* ×*domestica*) orchards using mating disruption with selective insecticides than under conventional management. In West Virginia, Brown and Schmitt (2001) observed higher numbers of predators and parasitoids in apple plots receiving no pest management tactics, although large numbers of mite predators and certain parasitoids were observed in pest management plots. In California, Mayse et al. (1998) observed a trend of higher levels of pests, predators, and parasitoids in grapes managed by organic than conventional methods, although numbers were not statistically significant. The grape berry moth is only present in the eastern U.S. Therefore, a more intensive insecticide-based pest management program is required in the east than in California vineyards. Little scientific research has been conducted on the effects of grape berry moth management practices on arthropod diversity in vineyards.

The purpose of this study was to compare five Arkansas vineyards with differing pest management programs for arthropod diversity, carabid density, temporal changes in grape berry moth trap catch and cluster damage, and overall percent larval parasitism.

Materials and methods

Five vineyards from northwest and north-central Arkansas followed slightly different pest management programs: conventional insecticides; insecticides combined with Exosex-GBM mating disruption dispensers; and abandoned (no insecticide use). Only three insecticides were used in these vineyards: carbaryl (Sevin 4F; Bayer Crop Science, Research Triangle Park, N.C.), fenpropathrin (Danitol 2.4 EC; Sumitomo Chemical Co., Tokyo), and azinphos-methyl (Guthion Solupak 50% SP; Bayer Crop Science). Table 1 contains vineyard block descriptions and timing of insecticides in April for several climbing cutworm species (Noctuidae) and May through July for grape berry moth control and placement of Exosex-GBM dispensers. The 8.1-ha (20 acres) Hindsville 'Concord' vineyard (planted in 2000) was conventionally managed with one insecticide spray applied to edge vines in 2003 and four and three whole vineyard insecticide sprays applied in 2002 and 2003, respectively. The 5.7-ha (14 acres) Lowell 'Concord' vineyard was conventionally managed in 2002, receiving the highest insecticide use of all vineyards (three whole vineyard sprays).

Mating disruption was used in combination with early season insecticide sprays for grape berry moth control in three vineyards. In 2003, the management in the Lowell vineyard was altered to only two whole vineyard sprays in combination with mating disruption by Exosex-GBM dispensers. Two additional whole vineyard sprays were applied both years to the upper canopy to prevent canopy damage by japanese beetle (*Popillia japonica*) in July. An 8.1-ha Searcy 'Venus' vineyard was involved in a pilot grape IPM project in 2001 and 2002 and the 2.4-ha (6 acres) Judsonia 'Mars' and 'Sunbelt' vineyard was added in the project in 2002 and 2003. This program consisted of one or two insecticide sprays applied to the vineyard edge in May followed by one or two whole vineyard sprays applied in June or July. Spray recommendations were based on weekly pheromone trap catch and daily

Table 1. Descriptions of the Arkansas grape vineyards (all *Vitis labrusca* cultivars) sampled in 2002 and 2003 and corresponding timings of insecticide applications and placement of Exosex dispensers for grape berry moth mating disruption.

Vineyard	Date planted	Cultivars	Insecticide use 2002	Insecticide use 2003
Lowell	<1980	Concord	carbaryl[z]: 18[y], 25[x] May, 13, 28[x] June, 8 July to 15[w] Aug.	fenpropathrin: 20[y] May, 21, 28[x] June, 7, 15[w] July; Exosex: 13 June
Judsonia	1995	Sunbelt, Venus	carbaryl: 1[y] May, 2[x] June	carbaryl: 2, 29[x] May; Exosex: 4 June
Hindsville	2000	Concord	azinphos-methyl: 21, 31[x] May, 13, 25[x] June	carbaryl: 3[x] Apr.; fenpropathrin: 19[y] May, 28[x] June, 14[x] July
Searcy	1982	Venus	carbaryl: 14[y], 25[x] May	abandoned, no spray
Bald Knob	1998	Venus	abandoned, no spray	abandoned, no spray

[z]Insecticides included: carbaryl (Sevin; Bayer Crop Science, Research Triangle Park, N.C.), fenpropathrin (Danitol; Sumitomo Chemical Co., Tokyo), azinphos-methyl (Guthion; Bayer Crop Science), and Exosex-GBM (Exosect Ltd., Southampton, U.K.).
[y]Application made only to the vineyard edge (perimeter).
[x]Application made to the whole vineyard.
[w]Weekly sprays applied only to canopy above the top trellis wire to the whole vineyard to control japanese beetle.

cumulative degree-days (Lewis and Johnson, 1999). In 2001, insecticide control of the second and later generations of grape berry moth in the Searcy vineyard were replaced by an early June placement of Isomate-GBM dispensers (Pacific Biocontrol Corp., Vancouver, Wash.) at 988.4 dispensers/ha for mating disruption. In 2002, the Searcy vineyard had insecticide sprayed once to the edge and once to the whole vineyard but Isomate-GBM was not used. The Judsonia vineyard received one edge spray and one full vineyard spray in 2002 compared to 2003 when it received two full vineyard sprays. In 2003, Exosex-GBM dispenser was evaluated against grape berry moth. The manufacturer's recommended rate of 25 Exosex dispensers/ha (10.1 dispensers/acre) were set out on 4 and 13 June, respectively, in both the 'Concord' vineyard in Lowell and a 'Mars' and 'Sunbelt' vineyard in Judsonia. About 9.1 m (30 ft) northeast of the Exosex-treated vineyard in Lowell was a 1.6-ha (4 acres) 'Concord' vineyard that received the same insecticide sprays (Table 1) but no Exosex dispensers (conventional). In Judsonia, a 1.6-ha 'Mars' vineyard conventionally managed with insecticide sprays (Table 1) was 1.6 km (1 mile) from the Judsonia Exosex-treated vineyard.

Samples were collected from abandoned vineyard(s) that received no pesticide. The 4.0-ha (10 acres) Bald Knob 'Mars' vineyard was sampled in 2002 and 2003. No pesticide sprays, fertilizer nor water were applied to this vineyard since 2000. In 2003, the Searcy vineyard was abandoned. The other vineyards were managed conventionally prior to this study.

Most vineyards were sampled for arthropod diversity, carabid density, grape berry moth trap catch, berry damage due to grape berry moth, and grape berry moth larval parasitism. Sampling occurred over two growing seasons, from 7 June to 12 Sept. in 2002, and 18 Apr. to 12 Sept. in 2003.

In 2002, pitfall traps were used to assess diversity of insects and spiders, and density of carabid beetles in these five vineyards. Traps consisted of wallpaper trays, 18 × 18 × 96 cm (7.1 × 7.1 × 37.8 inches), with ethylene glycol inside to a 5-cm (2.0 inches) depth. The top edge of each pitfall trap was placed flush with ground level. A cover of standard chicken wire helped keep vertebrate insectivores from removing specimens. Each vineyard had one pitfall trap installed at each vineyard site: under a vine in the vineyard center, two rows in from the vineyard edge, and at the wooded edge (only in Searcy and Lowell). The other vineyards had no wooded edge. Specimens were collected either weekly or bi-weekly throughout the growing season, preserved in 75% ethanol and returned to the laboratory for identification and tabulation.

In 2003, pitfall traps of a different design than used in 2002 were placed in each vineyard site location (three replicates per location). Each trap consisted of a plastic cup [9 cm diameter × 16 cm high (3.5 × 6.3 inches); Solo Cup Co., Highland Park, Ill.], placed flush with ground level, and ethylene glycol added to a 5-cm depth. At each vineyard site, three pitfall traps were placed in the soil: under vines in the vineyard edge and center; and along the woods adjacent to the vineyard (again, only in the Searcy and Lowell vineyards). A cover of 12 × 12-cm (4.7 inches) plywood was placed approximately 3 cm (1.2 inch) above each trap. Covers were anchored to the ground with four 15-cm (5.9 inches) nails to reduce trap overflow due to rain.

Flight of adult male grape berry moth was monitored with Pherocon IC traps (Trécé, Inc., Adair, Okla.) baited with a sex pheromone lure. Each vineyard had two or three traps hung from the top wire along the vineyard edge for the first generation, and repositioned to the vineyard center in mid-May. Moth counts were recorded and averaged weekly or biweekly. Pheromone lures were replaced monthly and trap bottoms replaced as needed.

Grape clusters were sampled biweekly in each vineyard. The percentage infestation by grape berry moth larvae was determined by inspecting 100 to 400 fruit clusters in the vineyard edge and center (more than 10 rows from an edge). Clusters were considered damaged if one or more grape berries showed signs of grape berry moth larval tunneling. During each damage assessment, infested grape berries were collected, transported to the laboratory and reared until adults or parasites emerged (as described by Taschenberg, 1969). Larval-infested grape berries from each vineyard were placed into separate glass cages and maintained in a growth chamber set at 28 °C (82.4 °F) and 16 h light/8 h darkness. Records were kept of the total number of infested berries and the number of emerging parasitoids per vineyard. Each parasite was identified to family. Comparisons were made to determine which vineyard had the highest rate of grape berry moth parasitism.

The Shannon diversity index and evenness formulas (Pielou, 1977) were used to give diversity ratings for pitfall trap data at each vineyard site. Greater order diversity was indicated by higher index values and evenness values close to 1. The mean of the order diversity and carabid density estimates for these sites were compared as described by Magurran (1988) using analysis of variance (ANOVA) and comparing treatment means by least significant difference at $P < 0.05$ ($LSD_{0.05}$) (PROC GLM, SAS Institute, 1999). Vineyard insecticide records (Table 1) were used to help explain vineyard differences in arthropod diversity, carabid density, grape berry moth trap catch, percentage berry damage, and percentage grape berry moth parasitism.

Results and discussion

ARTHROPOD DIVERSITY. Significant differences in arthropod diversity were detected between vineyard sites (Table 2). Barrett (1969) stated, "species diversity is almost always reduced with toxic input." Our results on arthropod order diversity did not always reflect this. In 2003, significantly higher Shannon index values for diversity were noted in the woods edge, vineyard edge and center in Lowell (conventional with mating disruption), vineyard center in Hindsville (conventional), vineyard edge and center in Judsonia (conventional with mating disruption), woods edge and vineyard center in Searcy (recently abandoned) than in the vineyard edge in Searcy (recently abandoned), vineyard edge in Hindsville (conventional sprays) and vineyard edge and center in Bald Knob (abandoned). The Shannon index value for Searcy woods edge dropped from 1.82 in 2002 to 1.73 in 2003 due to unknown animals removing insect specimens from pitfall traps. But the evenness value increased indicating many species collected in 2003 but fewer of each when compared to 2002. The Bald Knob vineyard sites had a small value for diversity and species evenness each year indicating a low

Table 2. A comparison of arthropod species evenness and Shannon index of diversity for the various Arkansas vineyards and sites within each vineyard.

		2002		2003	
Vineyard	Site	Species evenness	Shannon index	Species evenness	Shannon index
Lowell	Woods	0.81	1.95	0.77	1.97 a[z]
Searcy	Center	0.77	1.77	0.80	1.87 a
Hindsville	Center	0.77	1.69	0.68	1.83 ab
Lowell	Center	0.71	1.62	0.71	1.82 ab
Judsonia	Edge	---	---	0.71	1.80 ab
Lowell	Edge	---	---	0.77	1.80 ab
Judsonia	Center	0.69	1.59	0.71	1.77 bc
Searcy	Woods	0.69	1.82	0.78	1.73 bc[y]
Searcy	Edge	---	---	0.78	1.69 cd[y]
Bald Knob	Edge	---	---	0.71	1.68 cd
Hindsville	Edge	---	---	0.66	1.60 cd
Bald Knob	Center	0.54	1.35	0.68	1.55 d

[z]Values in 2003 followed by a common letter are not significantly different ($P \leq 0.05$) by $LSD_{0.05}$.
[y]Low values due to an unknown animal routinely digging up and removing specimens.

Table 3. A comparison of the number of carabids per pitfall trap ±SE for the various Arkansas vineyards and sites within each vineyard in 2003.

Vineyard	Site	No. of carabids
Hindsville	Center	81.7 ± 10.7 a[z]
Hindsville	Edge	50.7 ± 19.7 b
Lowell	Center	31.7 ± 12.7 c
Lowell	Woods	23.3 ± 8.4 c
Judsonia	Edge	16.7 ± 3.2 cd
Lowell	Edge	15.0 ± 4.2 cd
Searcy	Edge	14.0 ± 5.2 cd[y]
Searcy	Center	13.7 ± 5.2 cd
Judsonia	Center	12.0 ± 1.2 cd
Searcy	Woods	7.0 ± 4.6 d[y]
Bald Knob	Edge	5.7 ± 1.5 d
Bald Knob	Center	4.0 ± 1.0 d

[z]Means followed by a common letter are not significantly different ($P \leq 0.05$) by $LSD_{0.05}$.
[y]Low values due to an unknown animal routinely digging up and removing specimens.

abundance of fewer species compared to all other sites.

Carabid density. The mean carabid counts per pitfall trap (density) were significantly higher at both the edge and center (>50 carabids/trap) of the Hindsville vineyard (high insecticide usage) than all other vineyard sites (<32 carabids/trap) (Table 3). The Lowell vineyard center (high insecticide usage) and woods also had significantly more carabids per pitfall trap (>20 carabids/trap) than Searcy woods and Bald Knob vineyard edge and center (<14 carabids/trap). The abandoned Bald Knob vineyard edge and center had the lowest significant carabid density of all vineyard sites (<six carabids/trap). Apparently, the vineyards with high insecticide usage had more food on the vineyard floor for carabids. The vineyard floor management was too variable among vineyards to deduce its effect on carabid density because only the Hindsville and Judsonia vineyards were mowed regularly. Similarly, Good and Giller (1991) used a D-vac suction sampler and pitfall traps and noted significantly fewer species of staphylinid beetles in recently mowed silage and cereal fields than undisturbed pastures and meadows.

Mating disruption of grape berry moth. Figures 1 and 2 show the relative numbers of grape berry moth males per pheromone trap by sample date in each vineyard in 2002 and 2003, respectively, and Table 4 lists total catches in traps for the 2002 season and early and late 2003 season and the corresponding percent of fruit clusters with one or more berries damaged by grape berry moth near harvest. In 2002, cumulative seasonal grape berry moth catch after 7 June varied from 25.6 in Hindsville to 111.6 in Lowell. In 2003, the cumulative overwintered grape berry moth catch from 20 Mar. to 10 June was <32.4 moths/trap at all sites except the Lowell vineyard (569 moths/trap). Between 2002 and 2003, the Lowell vineyard was downsized from 24.3 to 7.08 ha (60 to 17.5 acres) concentrating the resident grape berry moth population. However, after 13 June the mating disruption–treated vineyards (Exosex-GBM) reduced trap catches: 7.7 moths/trap in Judsonia mating disruption vineyard vs. 86.1 in Judsonia conventional vineyard about 1.6 km to the northeast; and 40 moths/trap in Lowell mating disruption vineyard vs. 80.5 in the conventional vineyard only 9.1 m to the northeast. Part of the drop in trap catch was attributed to applications of two (Judsonia vineyard) and three (Lowell vineyard) insecticide sprays against first- and second-generation grape berry moths. This drop in trap catch was similar to use of Isomate-GBM in New York (Dennehy, 1991;

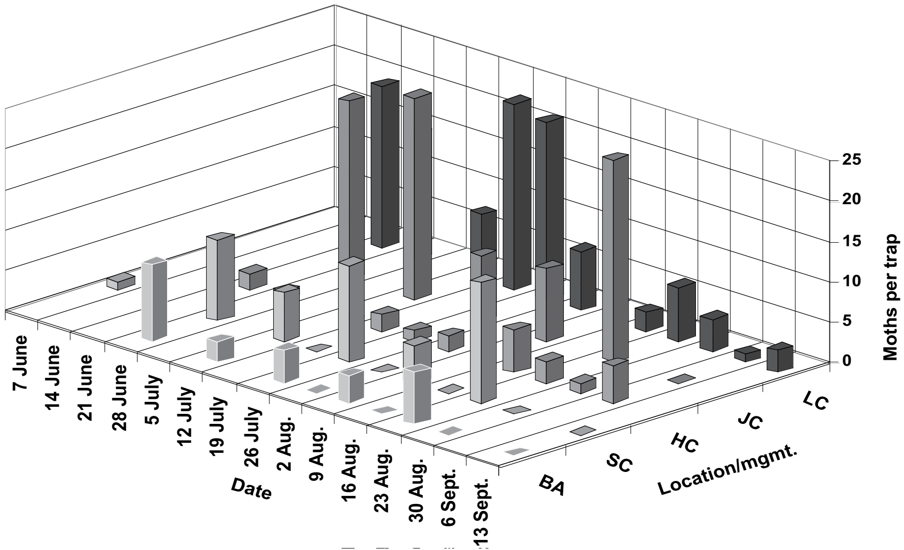

Fig. 1. A comparison of the average number of grape berry moth males per pheromone trap in 2002 for five Arkansas vineyard locations each under one of two pest management programs (Location/mgmt): Lowell conventional (LC), Judsonia conventional (JC), Hindsville conventional (HC), Searcy conventional (SC), and Bald Knob abandoned (BA).

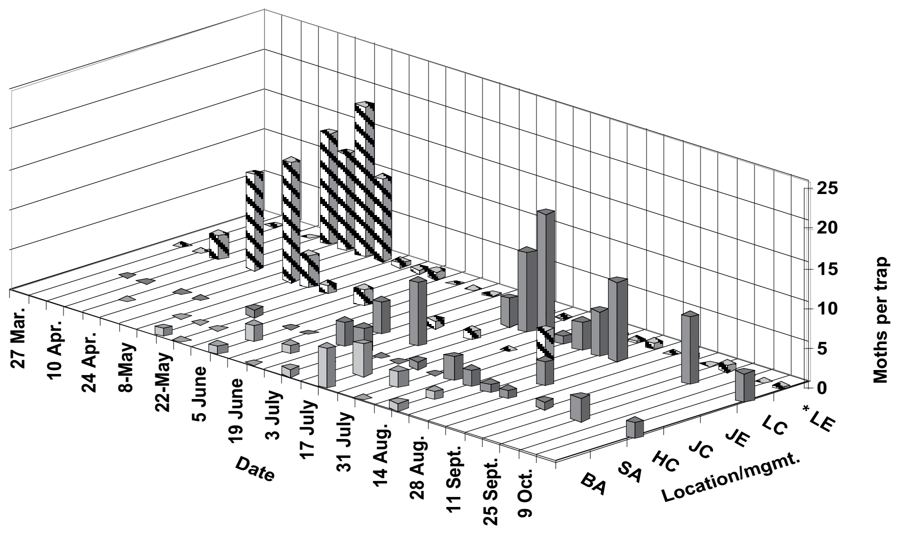

Fig. 2. A comparison of the average number of grape berry moth males per pheromone trap in 2003 in six Arkansas vineyard locations each under one of three pest management programs (Location/mgmt.): Lowell Exosex mating disruption (* LE = multiply number of moths per trap by 10), Lowell conventional (LC), Judsonia Exosex mating disruption (JE), Judsonia conventional (JC), Hindsville conventional (HC), Searcy abandoned (SA), and Bald Knob abandoned (BA).

Table 4. A comparison of the mean number of grape berry moths per pheromone trap and percent of grape clusters sampled that had grape berry moth larval tunneling in one or more berries at harvest in the various Arkansas vineyards following different pest management practices in 2002 and 2003.

	2002			2003			
Vineyard[y]	Moths, season[z] (no./trap)	E[x]	C[x]	Moths, early[z] (no./trap)	Moths, late[z] (no./trap)	E[x]	C[x]
Judsonia C	95.0	14	4	---	86.1	15.1	5.5
Judsonia MD	---	----	---	32.4	7.7	22.9	7.3
Lowell C	111.6	4	6	---	80.5	39	14
Lowell MD	---	---	---	569.0	40.0	68	17
Hindsville C	25.6	2	0	6.2	22.0	0	0
Searcy A	33.5	38	0	2.0	7.3	0	0
Bald Knob A	40.0	---	---	1.0	6.5	---	---

[z]Season = 7 June to harvest 2002; early = trap catch of over wintered moths from 20 Mar. to 13 June 2003 (date of placement of Exosex dispensers); late = trap catch from 13 June to harvest 2003.
[y]A = abandoned; C = conventional insecticide use; MD = early season insecticide use followed by mating disruption (Exosex-GBM).
[x]E = percent damage in vineyard edge; C = percent damage in vineyard center.

Trimble et al., 1991) and the Searcy vineyard in Arkansas in 2001 (Johnson, unpublished data). In both 2002 and 2003, the conventional Hindsville vineyard had season totals of <30 moths/trap and <2% damage.

Abandonment of a vineyard reduced percent grape berry moth damage. The Searcy vineyard was considered a high risk site for grape berry moth with >50% of perimeter adjacent to woods (Hoffman and Dennehy, 1987). After integrating Isomate-GBM mating disruption in 2001 and degree-day timed insecticide sprays of the vineyard edge in 2001 and 2002, the season catch in 2002 was 33.5 moths/trap with 38% damage in edge vines but 0% damage in the vineyard center. After being abandoned in 2003, the season catch dropped to 9.3 moths/trap and 0% damage in edge and center possibly due to 67% larval parasitism. Moth counts in the abandoned Bald Knob vineyard dropped from 40 moths/trap in 2002 to 7.5 in 2003. Black rot (*Xanthomonas campestris*) infection destroyed all the host fruits by early June each year and there were no moth infestations nearby.

Grape berry moth damage to grape clusters (Figs. 3–4) follows a trend similar to that of grape berry moth pheromone trap catches (Figs. 1–2), at least at the vineyard center sites. Edge vines had greater berry damage, due to the reported edge effects of larval attack by first and second-generation grape berry moth (Johnson et al., 2002). Two of the vineyards with high pesticide use (Lowell and Judsonia) had the highest cluster damage. The Hindsville vineyard had high pesticide inputs and low cluster damage, but had not yet built up a significant grape berry moth population. Interior damage was not found at the Hindsville or Searcy sites in 2003. The Searcy site was not sprayed at all in 2003 but still had a very low grape berry moth population that was attributed to use of Isomate-GBM in 2001 and well timing insecticide sprays applied to the edge vines in both 2001 and 2002. Damage assessment at the Bald Knob vineyard could not be recorded because of 100% black rot infection by June of each year.

GRAPE BERRY MOTH PARASITISM. The four vineyards produced a total of 20 ichneumonid (Ichneumonidae) specimens and 43 braconid (Braconidae) specimens that emerged from grape berry moth pupae. The Searcy vineyard (abandoned in 2003) had a very low grape berry moth population but produced two larval parasites out of three larvae (67%). Percent parasitism varied widely among conventionally managed vineyards: Hindsville (3.6% of 28 larvae); Judsonia (40.6% of 32 larvae); and Lowell (48.6% of 37 larvae). Two vineyards integrating early season insecticide sprays with mating disruption had moderate rates of parasitism of grape berry moth: Judsonia (25% of four larvae); and Lowell (15.6% of 179 larvae). The Bald Knob vineyard could not be monitored for parasitism in June and July due to a lack of grapes after an early black rot infection.

Conclusion

The abandoned Bald Knob vineyard (no fertilizer or insecticide used) had significantly less arthropod diversity (Table 2) and carabid density (Table 3) than did the vineyards using conventional and conventional with mating disruption pest management. Shah et al. (2003) reported that organic farms producing oats (*Avena sativa*) (organic fertilizer but no synthetic pesticides) had lower Coleopteran species diversity but a much higher density of several carabid beetle species than did

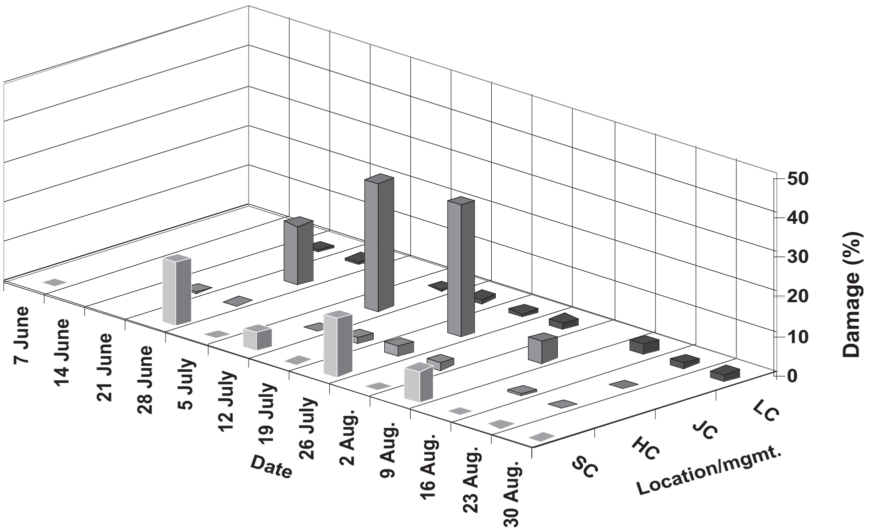

Fig. 3. A comparison of the percentage of grape clusters with one or more berries damaged by grape berry moth larvae in 2002 in four Arkansas vineyard locations, each under one of two pest management programs (Location/mgmt.): Lowell conventional (LC), Judsonia conventional (JC), Hindsville conventional (HC), and Searcy conventional (SC).

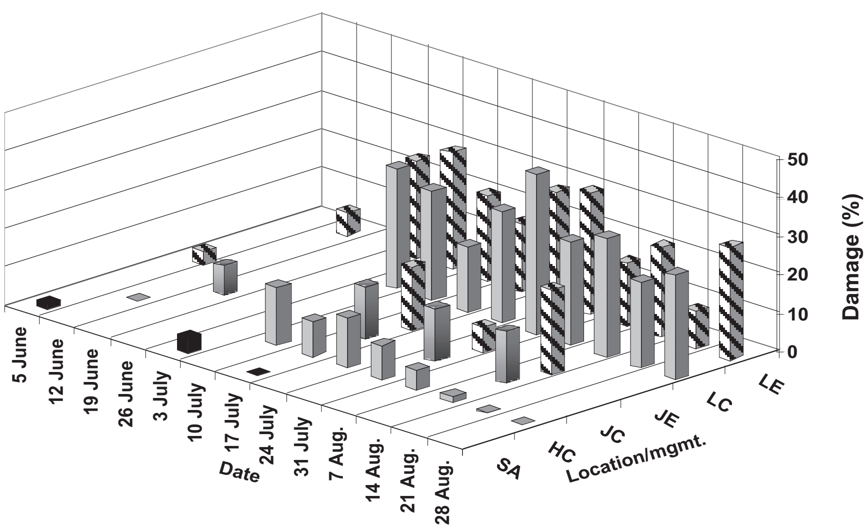

Fig. 4. A comparison of the percentage of grape clusters with one or more berries damaged by grape berry moth larvae in 2003 in four Arkansas vineyard locations, each under one of three pest management programs (Location/mgmt.): Lowell Exosex mating disruption (LE), Lowell conventional (LC), Judsonia Exosex mating disruption (JE), Judsonia conventional (JC), Hindsville conventional (HC), and Searcy abandoned (SA).

conventional farms (organophosphate insecticides).

Only in the Hindsville vineyard did a difference in insecticide use (Table 1) contribute to significantly less arthropod diversity (Table 2) and significantly more carabid density (Table 3) in the edge (more insecticide) than the vineyard center (less insecticide).

Percent parasitism of grape berry moth larvae varied more among conventionally managed vineyards (3.6% to 48.6%) than those integrating early season insecticide sprays with mating disruption (15.6% to 25%). However, Seaman et al. (1990) observed a maximum of only 20% parasitism of grape berry moth larvae but found no significant difference in percent parasitism among wild, organically managed and conventionally managed grapes. They also had no evidence as to what factor(s) affected parasitism. Further study is needed to determine if a pest management program integrating early season insecticide sprays followed by mating disruption will support more arthropod diversity and carabid abundance, and enhance parasitism of grape berry moth eggs and larvae.

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