Behavioral and Electrophysiological Responses of Leafroller Moths to Selected Plant Extracts

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ABSTRACT The behavioral and electrophysiological responses of the obliquebanded leafroller, *Choristoneura rosaceana* (Harris), and the redbanded leafroller, *Argyrotaenia velutinana* (Walker), to crude extracts of *Arctium lappa, Bifora radians, Humulus lupulus, Xanthium strumarium,* and *Verbascum* spp. were studied under laboratory conditions. Plant materials were dried and ground before extraction with methanol. Plant extract residues were mixed in acetone to give 20% (wt:wt) suspensions after evaporation of excess methanol. All five plant extracts elicited significant electroantennogram (EAG) responses from both males and females of each species. EAG responses to *X. strumarium* were generally the highest for both species. The behavioral responses of male and female obliquebanded leafrollers to the plant extracts were compared with responses to pheromone [(Z)11–14:Ac] and a solvent control. Significantly more male and female obliquebanded leafrollers were attracted to *X. strumarium* compared with pheromone on filter paper, *H. lupulus*, *Verbascum* spp., and the control. Compared with the control, there was no significant attraction to pheromone on filter paper, *A. lappa*, *H. lupulus*, and *Verbascum* spp. The oviposition-deterring effect of plant extracts on female obliquebanded leafrollers was studied in dual-choice bioassays. *B. radians* elicited the highest oviposition deterring effect with no eggs laid on this treatment. *A. lappa* was also effective and reduced oviposition to 2.9% of that observed in the controls. The number of eggs laid on *X. strumarium* (14.4%) and *Verbascum* spp. (21.2%) treatments were not significantly reduced relative to the control; however, oviposition was reduced by three-fold by these two treatments. The results show that certain crude plant extracts induce behavioral effects on male and female obliquebanded leafrollers. Further studies are needed to determine the active ingredients and their potential use in pest management strategies aimed at managing these pest species in tree fruit production.

KEY WORDS plant extract, *Choristoneura rosaceana, Argyrotaenia velutinana,* olfactometer, choice bioassay

THE OBLIQUEBANDED LEAFROLLER, *Choristoneura rosaceana* (Harris) (Lepidoptera: Tortricidae), is a tortricid moth native to North America and is widely distributed from British Columbia to Nova Scotia and south to Florida (Chapman et al. 1968). The obliquebanded leafroller has an extremely wide host range; however, its host preference is limited to woody plants including Rosaceae. It is an established pest of pome fruits throughout North America, particularly apples. The redbanded leafroller, *Argyrotaenia velutinana* (Walker) (Lepidoptera: Tortricidae), is sympatric with the obliquebanded leafroller and native to temperate eastern North America (Chapman 1973). The host range of this species is even broader than that of the obliquebanded leafroller; it feeds on leaves of diverse plant species excluding conifers. Redbanded leafroller larvae feed on many unrelated plants, including most common fruits, vegetables, weeds, flowers, ornamentals, and shrubs (Hull et al. 1995). Among the fruits, redbanded leafrollers prefer apples and are a common pest in the apple-growing areas of the midwestern and eastern United States and eastern and western Canada (Howitt 1993, Hull et al. 1995). Its pest status has been associated with commercial use of pesticides and nutrient adjuvants in upper midwestern orchards (Strickler and Whalon 1985)

The obliquebanded leafroller and the redbanded leafroller are closely related species, sharing the major components of their pheromone blends: (*Z*)11–14:Ac and (*E*)11–14:Ac in a 98:2 ratio for obliquebanded leafroller and 93:7 ratio for redbanded leafroller (Roelofs and Arn 1968, Roelofs and Tette 1970, Roelofs et al. 1975, Cardé and Roelofs 1977, Hill and Roelofs 1979). In addition, both species' antennae respond to green leaf volatiles and terpenoids as measured by electroantennograms (EAGs) (Stelinski et al. 2003a). Such plant volatiles are likely important cues used by males and females of both species for host-plant location.

Several plant extracts have been identified containing secondary plant compounds, including waxes, ter-

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Table 1. Plants used in EAG, olfactometer, and oviposition studies

Family name	Scientific name	Tissue used
Apiaceae	*Bifora radians*	Whole plant
Asteraceae	*Arctium lappa*	Whole plant
Asteraceae	*Xanthium strumarium*	Fruit
Canabinaceae	*Humulus lupulus*	Flower bud
Scrophulariaceae	*Verbascum spp*	Whole plant

penes, steroids, alkaloids, phenolics, and cardiac glycosides (Duke 1990), which affect various behaviors of insects belonging to different families (Mordue et al. 1998, Ge and Weston 1995, Blaney et al. 1988, Mancebo et al. 2000, Bruno et al. 2003). The plant derived compounds could be used in "push-pull" methods of pest control (Miller and Cowles 1990, Pickett et al. 1997). As part of this strategy, plant-derived repellents, antifeedants, or oviposition deterrents impart the "push" by moving pests away from the targeted crop (Kahn et al. 2001, Bartelt et al. 2004, Mauchline at al. 2005). The plant species used in this study (Table 1) were chosen because they are known to produce secondary compounds such as monoterpenes, sesquiterpenes, and triterpenes (Heywood et al. 1977, Katsiotis et al. 1990, Latrasse et al. 1991, Baser et al. 1998), which affect the behavior of arthropods (Kradyova et al. 2000, Krupke et al. 2001, Jones et al. 2003). These plants occur in the North American range of both leafroller species considered in this study despite their collection in Tokat, Turkey. In Turkey, these plant species are associated with apple orchard agro-ecosystems, but tortricid moths have not been observed feeding on them (A.G., unpublished data). In addition, some of these plants are insect anti-feedants and repellents (Çetinsoy et al. 1998, Johri et al. 2004, Pons 2004). Therefore, we chose to evaluate the effects of these plant species on two important leafroller pests of apples in North America.

The objectives of this study were to determine whether (1) the selected plant extracts investigated elicit EAG responses in male and female obliquebanded leafrollers and redbanded leafrollers; (2) the plant extracts elicit behavioral responses from male and female obliquebanded leafrollers using a laboratory olfactometer; and (3) the plant extracts impact choice of oviposition site by female obliquebanded leafrollers in two-choice bioassay chambers.

Materials and Methods

Insects. Obliquebanded leafrollers were drawn from a 4-yr laboratory colony originally collected as first- and second-generation pupae from apple orchards in southwestern Michigan. Redbanded leafrollers came from a long-established laboratory colony maintained at Geneva, NY, by W. Roelofs. Moths were reared at 24°C on a pinto bean diet (Shorey and Hale 1965) under a 16:8 (L:D) photoperiod. Male and female pupae of each species were segregated in 1-liter plastic cages containing a 5% sucrose solution in plastic cups with dental cotton wick protruding from their lids. After emergence, moths were incubated for 24 h at above-described conditions and subsequently transferred into 1-liter cups.

Plant Extracts. Five natural product sources were used per study. The plants (Table 1) were all collected from sandy lime soil during spring and summer of 2002 in Taşlıçiftlik, Tokat, in a temperate region of Turkey, where the altitude is 600 m. Samples were dried at room temperature for 3 wk in the dark and subsequently were ground in a mill (M 20 IKA Universal Mill; IKA Group, Wilmington, NC). Ground plants were stored in 2,000-ml glass jars at 18 ± 2°C in the dark. Fifty-gram samples were placed into 1,000-ml Erlenmeyer flasks with 500 ml of methanol (Sigma, St. Louis, MO). Flasks were covered with aluminum foil, placed on a horizontal shaker (HS 260 Basic; IKA Group), and shaken (120 oscillations/min for 24 h) in the dark. The suspension was filtered through two layers of cheese cloth, transferred into a 250-ml evaporating flask, and dried in a rotary evaporator (RV 05 Basic 1B; IKA Group) at 32 ± 2°C. The resulting residue was weighed and mixed with acetone to yield a 20% (wt:wt) plant suspension.

EAGs. The EAG system and test protocols have been detailed by Stelinski et al. (2003a, b). Two milligrams of plant extracts (Table 1) or pheromone [(Z)11–14:Ac (lot # 10010); Shin Etsu, Tokyo, Japan] was diluted in acetone (20 μl total solution) and pipetted onto 1.4 by 0.5-cm strips of Whatman no. 1 filter paper. After 5 min in a fume hood for solvent evaporation, treated strips were inserted into disposable glass Pasteur pipettes. EAGs were measured as the maximum amplitude of depolarization elicited by 1-ml puffs of air through EAG cartridges directed over live insect preparations.

Male and female obliquebanded leafrollers and redbanded leafrollers were 2–4 d old when used for EAGs. Insects were restrained on a wax-filled, 3.5-cm-diameter petri dish by placing clay (10 by 3 mm) over their thorax and abdomen. The terminal two segments of the antenna destined for recording were removed with fine scissors, and the recording electrode was placed over the severed end. The reference electrode was inserted into the neck. For each sample tested, EAGs were recorded from 10 moths of each sex. Control stimulations (using filter paper impregnated with 20 μl of acetone solvent) were "puffed" before and after each stimulus presentation. Two puffs of each volatile treatment and control spaced 12 s apart were administered to yield duplicate depolarization amplitudes for each replicate moth. The experiment was conducted in a randomized complete block design with chemical and moth sex as factors. Ten replicates were conducted for each moth sex and species combination.

Olfactometer Study. Male or female obliquebanded leafrollers used in this study were 1–3 d old. They were reared as described above. Discs, 55 mm in diameter, were cut from the sticky liners of pheromone traps (LPD Scenturian Guardpost; Suterra, Bend, OR) intended for catching Lepidoptera. Each sticky disc was cleaned with acetone and placed into a sterile 90-mm

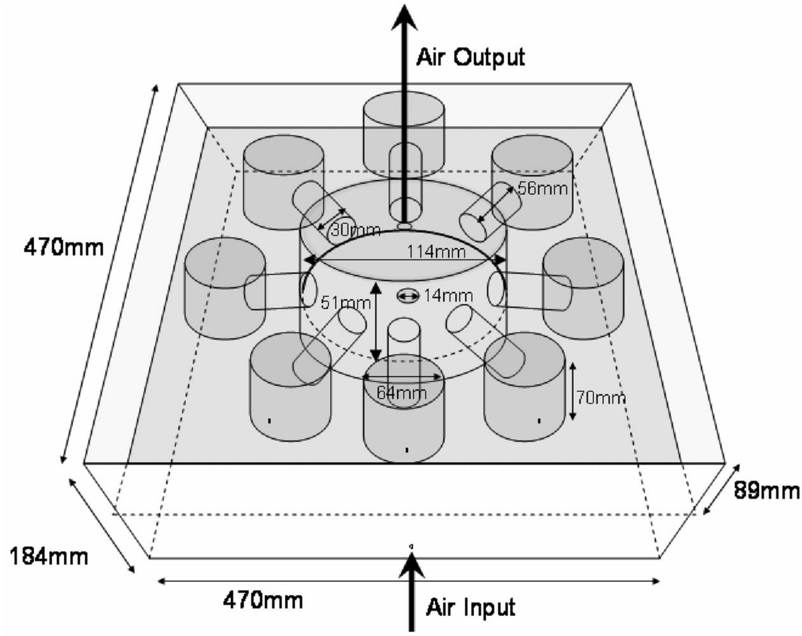

Fig. 1. Diagram of eight-arm olfactometer used to assay responses of male and female obliquebanded leafrollers, *C. rosaceana*, modified from Liu and Sengonca (1994).

disposable petri dish. Twenty-millimeter-diameter discs, cut from Whatman no. 1 filter paper, were placed centrally on top of the 55-mm sticky discs. Twenty-five microliters of each plant extract, diluted in acetone (20% wt:wt), was applied to the central filter paper disc. In the control treatment, 25 μl of acetone was applied to the disc. In the positive control, 25 μl of the pheromone component (Z)11–14:Ac was applied. In addition to positive control and negative or nontreatment control discs, a three-component obliquebanded leafroller pheromone in a rubber septum was also used as a standard. The septa were loaded with 0.485 mg of (Z)- and 0.015 mg (*E*)-11-tetradecenyl acetates and 0.026 mg of (Z)-11-tetradecenol (Hill and Roelofs 1979). After completing applications, the treated discs were left to dry in a fume hood for 15 min.

The treated discs and rubber septum with pheromone were transferred into an eight-arm wheel olfactometer using clean forceps (Fig. 1). The wheel olfactometer was connected to a vacuum pump set at 100 mmHg, which suctioned air into the olfactometer through a hydrocarbon trap (Alltech item no. 14633; Alltech Associates, Deerfield, IL). For each replicate, 10 obliquebanded leafroller males or females were released into the central release point of the olfactometer. Each replicate was conducted at 24°C and at a 16:8 L:D photo regimen. Counts of obliquebanded leafrollers in each olfactometer arm were made after 24 h. The experiment was conducted as a randomized complete block design with six replicates.

Antioviposition Study. Experiments were conducted using plastic 1-liter bioassay cups 140 mm in height and 110 mm in diameter. Four windows (30 by 30 mm) were cut in each bioassay cup 90° apart around its circumference, 60 mm above its bottom. They were covered with fine mesh. Acetone-cleaned wax paper (50 by 100 mm) was attached to the interior wall of each bioassay cup. In the control treatment, 10 -μl of acetone was applied to each side of wax paper and spread with a sterile bent glass rod "hockey stick." In each treatment, 100 μl of each acetone suspension of plant extract (20% wt:wt) was applied to each side of the wax paper and spread onto the wax paper with a sterile glass hockey stick. The wax papers were left to dry in a fume hood for 15 min. In choice bioassays, the cups contained one acetone-treated wax paper and one plant extract–treated wax paper placed 30 mm from the edge of bioassay cups suspended by string from the top of the cup. A 5% sucrose solution was provided within bioassay cups. Five female and three male obliquebanded leafroller adults (1 d after emergence) were transferred into each bioassay cup. The number of individual eggs within egg masses was counted and removed every 24 h for 7 d. Freshly treated wax paper was replaced daily. The experiment was replicated six times.

Data Analysis. EAG data were subjected to analysis of variance (ANOVA), and differences in pairs of means between treatments were separated using Tukey's multiple comparisons test (SAS Institute 2000).

For the olfactometer test, the number of male insects attracted by each treatment was expressed as a percentage of the total number of insects tested in each replicate. The resulting preference values for the treatments totaled 100%. The data were normalized using arcsine transformation (Zar 1999). The trans-

Table 2. EAG responses of male and female obliquebanded leafrollers to various plant extracts and pheromone

Treatment	EAG responses (mV ± SE)[a] on stimulation with 1 ml of air through stimulus cartridge		
	Males	Significance	Females
Control	0.48 ± 0.06d	NS	0.16 ± 0.02c
Pheromone	4.87 ± 0.32a	*	0.45 ± 0.06ab
B. radians	1.36 ± 0.10bc	*	0.56 ± 0.06a
X. strumarium	2.25 ± 0.19b	*	0.61 ± 0.08a
H. lupulus	0.94 ± 0.10c	NS	0.47 ± 0.05b
A. lappa	1.36 ± 0.10bc	*	0.35 ± 0.05b
Verbascum spp.	1.24 ± 0.11bc	*	0.32 ± 0.04b

[a] Means within columns followed by the same letter are not significantly different ($P = 0.01$, Tukey's multiple comparisons test). Paired values within rows marked with an asterisk are significantly different ($P < 0.01$), whereas those marked NS are not.

Table 3. EAG responses of male and female red banded leafrollers to various plant extracts and pheromone

Treatment	EAG responses (mV ± SE)[a] on stimulation with 1 ml of air through stimulus cartridge		
	Males	Significance	Females
Control	0.36 ± 0.07d	NS	0.14 ± 0.02b
Pheromone	5.42 ± 0.40a	*	0.43 ± 0.06a
B. radians	1.44 ± 0.05c	*	0.47 ± 0.08a
X. strumarium	2.26 ± 0.20b	*	0.49 ± 0.08a
H. lupulus	0.96 ± 0.09c	NS	0.52 ± 0.05a
A. lappa	1.54 ± 0.04c	*	0.44 ± 0.04a
Verbascum spp.	1.26 ± 0.09c	*	0.43 ± 0.06a

[a] Means within columns followed by the same letter are not significantly different ($P = 0.01$, Tukey's multiple comparisons test). Paired values within rows marked with an asterisk are significantly different ($P < 0.01$), whereas those marked NS are not.

formed data were analyzed using single-factor ANOVA (Minitab Release 14; McKenzie and Goldman, 2005) ($P = 0.05$) followed by Tukey's test ($P = 0.05$). Two-sample *t*-tests (Minitab Release 14; McKenzie and Goldman 2005) were performed to test effects of sex on attractiveness of plant extracts and pheromone.

For the oviposition choice test, egg counts were presented as a percentage. Within replicates, the cumulative number of eggs laid on each treatment was divided by the total number of eggs laid on each treatment. Therefore, the resulting preference values for the treatments totaled 100%. The data were normalized using arcsine transformation (Zar 1999) and were subjected to paired *t*-tests ($P = 0.05$) (Minitab Release 14; McKenzie and Goldman 2005).

Results

EAG Studies—Obliquebanded Leafroller. The EAG responses of male obliquebanded leafrollers were significantly ($F = 12.7$; df = 1,63; $P < 0.01$) higher than those of females for each treatment except for the control and *Humulus lupulus.* The EAG response of male obliquebanded leafrollers to pheromone significantly ($F = 8.5$; df = 9,63; $P < 0.01$) exceeded that to any of the plant extracts tested (Table 2). The highest EAG responses to a plant extract recorded from male obliquebanded leafrollers were to *Xanthium strumarium;* these were significantly ($F = 8.5$; df = 9,63; $P < 0.01$) higher than those recorded for *H. lupulus* (Table 2). The EAG responses of male obliquebanded leafrollers to all of the plant extracts were significantly ($F = 8.5$; df = 9,63; $P < 0.01$) higher than that to the control (Table 2).

The EAG responses of female obliquebanded leafrollers to all of the plant extracts tested were significantly ($F = 17.6$; df = 9,63; $P < 0.01$) higher compared with the control (Table 2). The highest EAG responses from female obliquebanded leafrollers were recorded for *Bifora radians* and *X. strumarium;* these responses were significantly ($F = 17.6$; df = 9,63; $P < 0.01$) higher compared with *H. lupulus, Arctium lappa,* and *Verbascum* spp. (Table 2).

EAG Studies—Redbanded Leafroller. The responses of male redbanded leafrollers were significantly ($F = 18.5$; df = 1,63; $P < 0.01$) higher compared with females for each treatment except for the control and *H. lupulus.* The EAG responses of male redbanded leafrollers to pheromone were significantly ($F = 7.2$; df = 9,63; $P < 0.01$) higher compared with all of the plant extracts tested (Table 3). *X. strumarium* elicited significantly ($F = 7.2$; df = 9,63; $P < 0.01$) higher EAG responses from male redbanded leafrollers compared with all of the other plant extracts tested (Table 3). The responses of female redbanded leafrollers to all of the plant extracts tested were significantly ($F = 13.0$; df = 9,63; $P < 0.01$) higher than the control but did not differ significantly ($F = 0.5$; df = 9,63; $P > 0.1$) among themselves (Table 3).

Olfactometer Studies—Obliquebanded Leafroller. There was a significant treatment effect of the plant extracts tested on the behavior of obliquebanded leafroller males ($F = 7.61$; df = 7,47; $P < 0.001$). *X. strumarium* appeared to be the most attractive extract, capturing an average 24.3% of the insects released. Significantly more male obliquebanded leafrollers were attracted to *X. strumarium* than to pheromone on paper, *H. lupulus, Verbascum* spp., or the control (Table 4). Compared with the control, there was no

Table 4. Behavioral responses of male and female obliquebanded leafrollers to various plant extracts and pheromone

Treatment	Percent attraction (mean ± SEM)[a]		
	Males	Significance	Females
Control	0.80 ± 0.80c	NS	1.14 ± 1.12b
Pheromone on paper	4.05 ± 1.66bc	NS	1.14 ± 1.12b
Pheromone mixture in septum	20.16 ± 0.07ab	*	5.28 ± 2.58b
B. radians	18.49 ± 0.64ab	NS	10.79 ± 1.53ab
X. strumarium	24.32 ± 0.50a	NS	29.67 ± 0.40a
H. lupulus	1.64 ± 0.97c	NS	2.57 ± 1.25b
A. lappa	11.74 ± 1.12abc	NS	11.06 ± 1.31ab
Verbascum spp.	4.46 ± 1.56bc	*	14.04 ± 0.47ab

[a] Means within columns followed by the same letter are not significantly different ($P = 0.01$, Tukey's multiple comparisons test). Paired values within rows marked with an asterisk are significantly different ($P < 0.01$), whereas those marked NS are not.

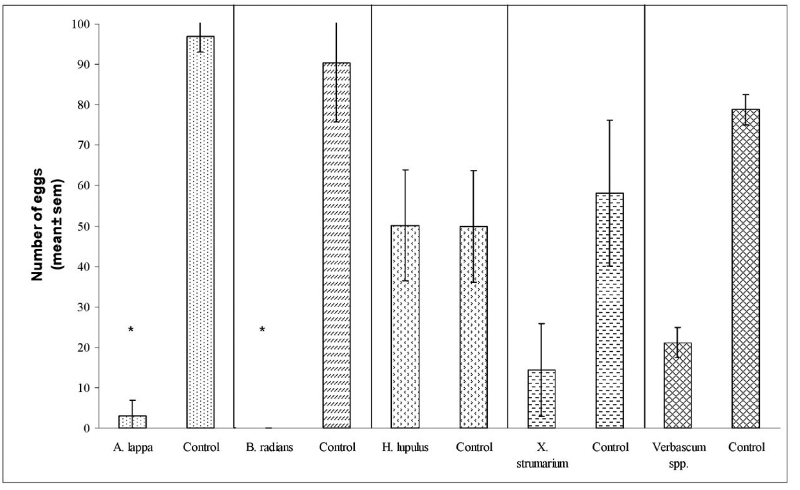

Fig. 2. Numbers of eggs oviposited by female obliquebanded leafrollers, *C. rosaceana*, in choice tests comparing various plant extracts with solvent controls. *Significantly different ($P < 0.05$; paired *t*-test).

significant attraction to pheromone on filter paper, *A. lappa, H. lupulus,* and *Verbascum* spp. There was no significant difference in percent attraction among pheromone in septum, *A. lappa, B. radians,* and *X. strumarium* (Table 4).

The percentage of female obliquebanded leafrollers captured varied from 2.6 (*H. lupulus*) to 29.7% (*X. strumarium*) and only *X. strumarium* was significantly different from the control ($F = 5.31$; df = 7,47; $P < 0.01$). There were no significant differences in the numbers of female obliquebanded leafrollers attracted to *B. radians, A. lappa, H. lupulus,* and *Verbascum* spp; however, significantly more females were attracted to *X. strumarium* than to *H. lupulus.*

The behavioral responses of female obliquebanded leafrollers to the plant extracts were similar to that of males, except in the case of *Verbascum* spp. (Table 4). *Verbascum* spp. extracts captured significantly more females than males. Although more females than males were attracted to *X. strumarium,* this was not significant ($t = -1.23$, df = 10, $P > 0.1$). Significantly ($t = 2.30$, df = 10, $P < 0.05$) more males were attracted to pheromone in septa compared with females. Pheromone on paper and in septa did not attract female obliquebanded leafrollers; 1.1 and 5.3% responded, respectively, and these values did not differ significantly ($P > 0.05$) from the control.

Antioviposition Experiment—Obliquebanded Leafroller Females. Female obliquebanded leafrollers started to lay eggs 1–2 d after adult emergence and continued for up to 7 d. The oviposition behavior of obliquebanded leafroller females was significantly affected by the plant extract suspensions (Fig. 2). Among the tested plant extracts, *B. radians* induced the greatest antioviposition effect given that females did not lay any eggs on *B. radians*–treated wax paper. The total number of eggs laid by females on *A. lappa*--treated wax paper was also significantly lower compared with that on the controls. Although *X. strumarium* and *Verbascum* spp. reduced the number of eggs oviposited by approximately three-fold, neither difference was statistically significant ($t = -1.06$, df = 5, $P > 0.1$ and $t = -2.35$, df = 5, $P > 0.1$, respectively). Females laid as many eggs on *H. lupulus*–treated wax paper as on the controls.

Discussion

All of the plant extract samples elicited significant EAG responses from male and female obliquebanded leafrollers and redbanded leafrollers. Thus, the antennae of these two tortricid species respond to certain constituents of these plant extracts, which may be important in host-plant location or avoidance. There was sexual dimorphism in EAG response to the majority of the plant extracts assayed. Specifically, males of both species showed greater EAG responses to plant extracts compared with females. A previous study has shown that the antennal sensillae of male and female obliquebanded leafrollers and redbanded leafrollers are sensitive to a wide array of green leaf and fruit volatiles that might serve as cues in host-plant finding for these polyphagous herbivores (Stelinski et al. 2003a). It is possible that the plant volatiles evaluated in the previous study are constituents of the plant extracts tested in this study.

Our behavioral assays suggest that male obliquebanded leafrollers exhibit attraction to two of the plant extracts tested: *X. strumariuma* and *B. radians.* Female obliquebanded leafrollers were also attracted to *X. strumariuma.* The highest level of attraction for both sexes was observed with *X. strumariuma,* which also elicited the largest EAG responses. These results suggest that this plant extract may emit odors that are used by obliquebanded leafroller males and females for host-plant location. Future studies will focus on determining whether male redbanded leafrollers exhibit similar responses to *X. strumariuma,* because this insect also showed strong EAG responses to this plant extract.

Recently, a pear-derived kairomone [(*E, Z*)-2,4-decadienoate] has been developed for monitoring both male and female codling moth, *Cydia pomonella* (Light et al. 2001). This lure has outperformed high-load pheromone lures in orchards treated with sex pheromone (Thwaite et al. 2004) and holds promise as an important monitoring tool for both male and female codling moth (Knight and Light 2005). Our results suggest that *X. strumariuma* may produce a kairomone attractive to obliquebanded leafroller males and females that could be developed into a bisexual lure for monitoring this insect. We soon hope to determine whether *X. strumariuma* is attractive to both sexes of redbanded leafrollers. Future work should focus on isolating the kairomone from *X. strumariuma* that is attractive to obliquebanded leafrollers in an effort to develop a potent kairomonal lure for monitoring this important pest in orchards treated with sex pheromone for mating disruption.

The oviposition study showed that female obliquebanded leafrollers distinguished between plant extract–treated versus control wax paper, generally avoiding the extract treatments. This oviposition site avoidance exhibited by females could be related to the odor emitted by the plant extracts or to other cues. Plants belonging to Apiaceae, Asteraceae, Canabinacea, and Secrophyllacea are known to produce monterpenes, sesquiterpene lactones, and triterpenes (Heywood et al. 1977, Latrasse et al. 1991). These secondary chemicals are known to affect insects in various ways including toxic, antifeedant, and repellent effects (Dev and Koul 1997, Prakash and Roa 1997).

Pons (2004) reported that *B. radians* essential oil caused 100% mortality to *Lipaphis pseudobrassicae*, and its toxicities were higher than those of peppermint (*Mentha piperita*) and rosemary (*Rosmarinus officinalis*) essential oils, which are currently used in organic production of vegetable crops in the United States. In our experiment, *B. radians* extract completely deterred oviposition of female obliquebanded leafrollers, and *A. lappa* also significantly reduced the number of eggs laid on the treated paper. Larocque et al. (1999) also reported significant oviposition deterrence for female obliquebanded leafrollers with *Tanacetum vulgare.* The plant extracts used in this study also showed high levels of antifeedant and repellent effects on Colorado potato beetle (*Leptinotarsa decemlineata*) larva (A.G., unpublished data). Oviposition deterrent effects of the currently studied nonhost-plant extracts suggest their potential use for managing this apple pest by using a "push-pull" strategy. The antioviposition effects of *B. radians* have potential for "pushing" female obliquebanded leafrollers away from oviposition sites, whereas the attractiveness of *X. strumariuma* could be exploited against male and female obliquebanded leafrollers. Current work is underway to elucidate and purify the behaviorally active compounds in the crude plant extracts studied here.

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