Attraction of Adult Plum Curculios (Coleoptera: Curculionidae) to Host-Tree Odor and Visual Stimuli in the Field[1]

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ABSTRACT Field tests were conducted to determine if plum curculios, *Conotrachelus nenuphar* (Herbst), responded to host odor and/or visual cues to locate host trees. Experiment 1 investigated the role of odor in host location. Host branchlets (apple leaves and fruit) were compared with non-host branchlets (maple leaves). Significantly more released color-marked plum curculios arrived on screen cages containing apple branchlets than on screen cages containing maple branchlets. Experiment 2 investigated the role of visual cues, with or without host odor, in host tree location. Plum curculios arrived preferentially on 60 cm wide × 130 cm tall sticky green rectangles (intended to mimic the canopy of a small tree) with associated caged apple branchlets than on sticky clear Plexiglas rectangles with caged apple branchlets or on sticky green or clear Plexiglas rectangles with caged maple branchlets. These data suggest that plum curculio adults may use both odor and visual cues to locate host trees during spring migration from overwintering sites.

KEY WORDS *Conotrachelus nenuphar*, host finding, attraction, host odor, apple

The plum curculio, *Conotrachelus nenuphar* (Herbst), is one of the most serious, yet least understood, North American pests of stone and pome fruit east of the Rocky Mountains. Adults quickly infiltrate host trees on warm, humid evenings causing feeding or ovipositional injury to fruit. Migration to apple trees from overwintering sites in nearby woods and hedgerows has been investigated (reviewed in Racette et al. 1992). However, there is no information on host-tree stimuli used by the adults to recognize host trees during spring migration. Information on the chemical and visual ecology of plum curculio adults has been derived through laboratory examinations of adult responses to plant stimuli at distances not exceeding a few centimeters (Butkewich et al. 1987, Butkewich and Prokopy 1993, Prokopy et al. 1995). Here, we determined if plum curculio adults use odor or visual cues, or both, to locate distant (3 m) sources of host tree stimuli under field conditions.

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Materials and Methods

Olfactory Response. Plum curculio adults were tested first (Experiment 1) for olfactory response to wire screen cages (25 cm diam × 50 cm tall) containing either eight fresh-cut host McIntosh apple branchlets with leaves and fruit (7 to 10 mm diam fruit) or eight fresh-cut non-host maple branchlets with leaves. Each cage was attached to a stake so that the cage bottom was 10 cm above ground. The fine mesh screen prevented observation of the cage contents to eliminate visual cues. Cut ends of branchlets were placed in water to maintain turgidity and were replaced every two days. The test was conducted in the center of a large open alfalfa field (280 × 280 m), where treatments were emplaced in four mowed 6-m-diam circles 25 m apart in a straight line extending north to south. Each circle contained four cages of the same treatment in N, E, S and W positions. There were two circles of each treatment type. All cages within a circle contained the same foliage type to minimize effects of wind direction. Each trial lasted two days, following which treatments were rotated among circles in a linear direction until four replicates per circle (eight replicates per treatment) were completed.

Trials began on 17 May at apple tree petal fall, when plum curculio adults were first observed on apple trees in nature, and ended on 24 May. Adults used in tests were collected daily from unsprayed apple trees. They were brought to the laboratory, chilled for 1 min, retained beneath cloth screen, and each was marked with a dot of liquid paper (Opp and Prokopy 1986) on its right elytrum. Mark color was unique to each day of the experiment. Adults were not sexed. Marked adults were kept in a dark, cool environment without food prior to release, which was 4 to 5 h after collection. An equal number of marked adults (17) was released, each day at 1500 h, by placing them under a leafy non-host oak tree branch (40 cm diam) surrounded by decaying grass in the center of each circle. The non-host branch and decaying grass provided a refuge enabling adults to acclimate. Preparation time prohibited trials earlier than 1500 h.

Every 30 min from 1530 to 2200 h on each of the two days of a trial, all cages were examined for adults. Those found were removed and examined for color of mark. Flashlights were used to aid in night inspection of cages. Collection ended at 2200 h. Preliminary trials showed that adults did not move to cages between 2220 h and dawn the following day. Other observations showed that all adults arriving on a cage by crawling or by flight remained at least 30 min, irrespective of presence or absence of apple branchlets in the cage; thus, we were confident that the procedure of removing adults from cages every 30 min accurately reflected the number that arrived.

Visual and Olfactory Response. Plum curculio adults were tested next (Experiment 2) for response to 25 × 50 cm wire screen cages placed in association with 60 cm wide × 130 cm tall rectangles, each supported by a center post. The rectangles were of two types: (1) green-painted wood (intended as a visual mimic for the color, shape and size of the canopy of a small apple tree), or (2) clear Plexiglas (intended to represent open space). Green rectangles were painted with a mixture (1:2) of Sherwin Williams Lemon Yellow F65Y 44 and Bright Blue F65 L 10 paint that approximated the spectral reflectance of apple foliage (Prokopy 1968). The interior-facing side of each rectangle was covered with a thin layer of Tangletrap™ to retain alighting adults. The center post of each rectangle was inserted into a hollow plumbing tile wedged into the ground so that the bottom of each rectangle was 50 cm above ground. Each cage, containing either fresh-cut apple or maple branchlets, was attached to the center post (bottom of cage 10 cm above ground) so that visual and olfactory stimuli were close to one another. A portion of the rectangle (25 cm wide × 10 cm tall) behind the cage was cut away to facilitate air flow through the plant material. Trials began on 25 May and ended on 1 June. All procedures were the same as those described previously except: (1) the fruit on the McIntosh apple branchlets were 11 to 14 mm diam; (2) the treatments consisted of green models with apple branchlets (GA), green models with maple branchlets (GM), clear Plexiglas models with apple branchlets (CA) or clear Plexiglas models with maple branchlets (CM); (3) there were four rather than eight replicates per treatment, and (4) adults were removed every 30 min from the sticky surface of the models as well as from the cages.

Data Analysis. Numbers of adults sighted per treatment type were compared using Student's "t" test (Olfactory Response) or ANOVA and the least significant difference test criterion (Visual and Olfactory Response), each at the 0.05 level of significance (Sokal and Rohlf 1981). Adults with a color code different from that used at that treatment site and replicate were excluded from the data.

Results

In Experiment 1, plum curculios responded positively to host olfactory cues in the field. Significantly more released adults were recovered on cages containing apple branchlets than on cages containing maple branchlets ($\bar{X} = 4.3 \pm 1.1$ SE vs $\bar{X} = 1.9 \pm 0.6$SE). In all, 25% of adults released into circles containing caged apple branchlets in Experiment 1 were sighted on corresponding cages compared with 11% of adults released into circles containing caged maple branchlets sighted on corresponding cages.

In Experiment 2, results corroborated findings of Experiment 1 and, in addition, showed that plum curculios responded strongest when host visual and olfactory cues were combined. Significantly more adults were recovered on GA than on GM or CM (between which there was no significant difference) (Table 1). The number recovered on CA was numerically but not significantly less than that on GA and was significantly greater than that on CM (Table 1).

For models alone in Experiment 2, the number of adults recovered was significantly greater on GA models than on models of any other treatment (Table 1). For cages alone in Experiment 2, the number of adults recovered was significantly greater on cages of CA than on cages of any other treatment (Table 1).

In Experiment 2, 53% of adults released into GA circles were recovered on corresponding models and cages. This compares with 38, 28 and 21%, respectively, recovered on CA, GM, and CM models and cages.

Table 1. Mean number (± SE) of color-marked released plum curculio adults recovered from tree models and associated cages containing apple or maple branchlets.

	Mean no. adults recovered*		
Treatment**	Models plus cages	Models alone	Cages alone
GA	9.0 ± 1.3 a	8.0 ± 1.3 a	1.0 ± 0.0 b
CA	6.5 ± 1.0 ab	3.8 ± 0.6 b	2.7 ± 0.5 a
GM	4.8 ± 0.8 bc	4.3 ± 1.0 b	0.5 ± 0.3 b
CM	3.5 ± 0.7 c	3.0 ± 0.6 b	0.5 ± 0.3 b

* Means in each column followed by a different letter are significantly different at the 0.05 level.
** G = green model, C = clear model, A = apple branchlets, M = maple branchlets.

Discussion

Our results indicate that, in the field, plum curculio adults respond positively to the odor of caged fruiting apple branchlets, suggesting that adults use olfactory cues to locate host trees during spring migration from overwintering sites. In addition, the largest number of adults was recovered from GA (the visual-odor test combination that most closely mimicked an apple tree), suggesting that visual cues complement odor cues in host-tree location by plum curculio adults.

Color of apple tree foliage alone is important in detection of foliage by *Rhagoletis* flies in experiments where leaf hue, saturation, and brightness are mimicked via artist-pigment combinations (Owens 1982). The characteristic green hue of apple leaves peaks in wavelength reflectance at 550 nm (Prokopy 1968), a reflectance that our green models mimicked closely. The green models could have provided a visual stimulus to plum curculio adults similar to a large mass of apple foliage.

At a distance, some insects visually detect the silhouette of host trees against the sky (Prokopy and Owens 1983). Plum curculio adults migrate toward tall non-host tree silhouettes at woodlot edges when seeking overwintering sites in autumn (Lafleur et al. 1987). Moericke et al. (1975) suggested that as *Rhagoletis* adults fly toward a tree model, the silhouette should appear increasingly larger against the horizon, a phenomenon which, if applicable to plum curculios, may allow them to distinguish the canopy of a potential host tree from the surrounding landscape. In addition, a tree model may become more visually apparent based on hue or intensity contrast against the sky. Thus, a combination of host tree silhouette and foliage hue could play a role in host tree selection by plum curculio adults in an open habitat.

Host recognition by insects has different sensory triggers at different patch levels. For example, at the level of post-alightment acceptance of host fruit for oviposition, *Rhagoletis* flies respond to chemical cues. But at the level of detecting host fruit within a tree, they use visual cues (Prokopy and Roitberg 1984). Plum curculio adults may process visual, olfactory and other stimuli differently at each host patch level encountered (i.e., petiole, branchlet, tree). They detect individual host fruit apparently at a distance of no more than a few centimeters, possibly by chemotaxis (Butkewich and Prokopy 1993). In most flying insects, long range chemo-orientation is thought to involve an optomotor, chemically-induced anemotactic response (Cardé 1984). We suggest, at the tree patch level, that plum curculios arrive near hosts via an anemotactic response (stimulated by olfactory host cues) that is enhanced when combined with visual cues.

Our findings on plum curculio host-tree finding behavior may lead to improved management of this pest. For example, dark-colored pyrimidal traps developed for monitoring populations of pecan weevil, *Curculio caryae* (Horn), (Tedders and Wood 1995) are currently being tested for monitoring plum curculio adults (Schmitt and Berkett 1995, Mitzell et al. 1996, Prokopy et al. 1996). Attraction of pecan weevils to a pyramidal trap is thought to involve resemblance of the trap to the trunk of a host tree, the silhouette of which apparently is attractive to pecan weevils (Raney and Eikenbary 1968, Tedders and Wood 1995). Conceivably, baiting visual host-mimic traps with synthetic odor attractants (Leskey et al. 1996) could lead to a truly powerful trap for monitoring or controlling plum curculio adults.

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