Mineral Oil Inhibition of White Apple Leafhopper (Homoptera: Cicadellidae) Oviposition[1]

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Abstract Various rates, types and residue ages of horticultural mineral oils were tested for inhibition of oviposition by white apple leafhopper, *Typhlocyba pomaria* McAtee, in laboratory bioassays. The numbers of nymphs produced from females exposed to treated apple leaf surfaces were used to determine the behavioral effect. No differences in effect were found among the three oils tested (Orchex 796, Orchex 692, and Orchex 892). Inhibition of oviposition was found in concentrations of Orchex 796 as low as 1% vol:vol (2-fold reduction in nymphs), with complete inhibition at 4%. The inhibitory effect of this material at 1% vol:vol persisted for at least 3 d, with no difference between the 7-d-old residues and the check.

Key Words *Typhlocyba pomaria*, oviposition behavior, repellent

Petroleum distillates have been used for pest control since the 1870s (Davidson et al. 1991), but their popularity has waxed and waned over that period. Early products, such as the kerosene emulsions, were highly phytotoxic. The potential for plant injury remains a concern, even though the relationship between the oil properties (parafinicity, unsulfonated residue, distillation range, viscosity, etc.) and phytotoxicity have been well studied in the intervening years. By the time issues of efficacy and phytotoxicity were reasonably well settled, the advent of highly effective synthetic organic pesticides had replaced oil compounds as the primary pest controls in agriculture. Their use on apples was confined to the prebloom period (Willett and Westigard 1988) when phytotoxicity risks were minimal and benefits were clearly established.

Two issues in particular have reawakened the interest in the use of oils as a pest control tool. First, the health and environmental risks associated with the use of broad-spectrum synthetic pesticides have become a focus of public attention, and the Food Quality and Environmental Protection Act of 1988 has accelerated activity to restrict use of these compounds. From an operational viewpoint, resistance has effectively terminated the utility of several synthetic pesticides for many pests (Denholm and Rowland 1992). Oils represent a class of pesticidal compounds for which there are no documented cases of resistance. This may be because of the modest selection pressure they exert, the limited use pattern, or the inherent difficulty in developing resistance to a mode of action that is thought to be primarily physical in nature.

Studies with oil have primarily focused on their direct toxicity, especially ovicidal

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activity. The primary use on tree fruits has been against overwintering eggs of European red mite, *Panonychus ulmi* (Koch), and various aphid species, as well as the overwintering forms of San Jose scale, *Quadraspidiotus perniciosus* (Comstock) (Beers et al. 1995). Surprisingly little attention has been given the behavioral effect of oils on motile arthropods, despite the well-established and widely applied principle of oviposition deterrence of pear psylla, *Cacopsylla pyricola* Foerster (Zwick and Westigard 1978, Weissling et al. 1997). The use of one to two applications of oil in the prebloom period on pear to delay and compress the oviposition activity helps to synchronize subsequent generations and is widely practiced in Washington (Beers and Brunner 1989). With the exception of codling moth, *Cydia pomonella* L. (Riedl et al. 1995), behavioral effects on other tree fruit pests have not been reported and consequently little used as a tactic in pest management programs.

The objective of the experiments reported here was to determine the effect of mineral oil residues on the oviposition of white apple leafhopper, *Typhlocyba pomaria* McAtee, a common indirect pest of apple in Washington. Several rates and types of oil were tested for oviposition deterrence.

Materials and Methods

Small dormant apple trees ≈0.75 m in height (EMLA 111 liners, Treco Co., Woodburn, OR) were potted in individual 3.8-liter pots with peat-vermiculite-perlite mix and grown in a greenhouse. Trees were fully leafed out at the time the experiment began. The trees were watered twice weekly and treated as needed for apple powdery mildew, *Podosphaera leucotricha* (Ellis & Everhard) Salmon, with myclobutanil (Rally 40W, 10 g/100 liter, Rohm and Haas, Philadelphia, PA) and triflumizole (Procure 50WS, 30 g/100 liter, Uniroyal Chemical, Middlebury, CT), and for phytophagous mites with fenbutatin oxide (Vendex 50WP, 60 g/100 liter, DuPont, Wilmington, DE) and hexythiazox (Savey 50WP, 11 g/100 liter, Gowan Co, Yuma, AZ).

The oils used in these tests were narrow distillation range types with various mean carbon chain lengths (Orchex 892, mean carbon chain length of 25 (C-25); Orchex 796, (C-23); Orchex 692, (C-21); Exxon Co., Houston, TX). These oils are sold as base products to various agricultural chemical dealers that formulate them as pesticides sold under different labels.

A completely randomized experimental design was used with treatments replicated six times. The experimental unit was an individual potted tree. Six trees per treatment were sprayed with mineral oil at different rates and times, and six trees per bioassay treated with distilled water served as a treatment control. In several of the experiments, an additional group of six trees was neither treated nor exposed to leafhoppers; this served as a control for a pre-existing leafhopper population (eggs) on the dormant trees. All treatments were sprayed to drip with a pressurized handheld sprayer (Model 71967, Ace Hardware Corp., Oak Brook, IL) and allowed to dry for several hours. The trees were then moved from the greenhouse, placed in a growth room [25.6°C; 16:8 (light:dark)], and covered with cages.

The cages were made using rigid wooden rings for the top, covered with cardboard and a piece of 0.9 × 0.35 m of nylon organdy cloth to provide the body of the cage. A 0.80 m strip of hook and loop fastener (Velcro®, Velcro USA Inc., Manchester, NH) was sewn to the long edges of the fabric, and the cloth piece was attached to the wooden ring forming a tube. Aluminum wire (3 mm) was attached to the pot to hold

the cage up and minimize contact with the tree. The bottom of the cage was secured with an elastic band around the pot over the fabric.

Bioassays were performed with field-collected adults from the first generation (June and July) from 1996 through 1999. Adult leafhoppers were collected from heavily-infested 'Delicious' apple orchards at Washington State University's experimental farms. These orchards were not treated with insecticides during the time of season that collections were made. Adults were collected with a hand-held vacuum (Black & Decker Dust Buster® modified by Bioquip, Gardena, CA), powered by a 12 volt NiCd battery. Leafhoppers were stunned with CO_2 and aspirated into vials in lots of ten individuals. In 1996 and 1997, both sexes were used in experiments while in 1998 and 1999 only females were used. In 1998, an unusually high degree of parasitism by *Aphelopus typhlocyba* Musebeck (Hymenoptera: Dryinidae) was noted, and parasitized individuals were not used in tests. Adults were stored at 3.3°C no more than 48 h before introduction into cages. One vial of leafhoppers was introduced into each caged tree by suspending the vial upside down over a small Petri dish (50 × 9 mm) allowing the adults to exit the vial with minimal disturbance. During the experimental period trees were watered by a tube inserted in the side of the pot. Female leafhoppers were allowed to oviposit for 3 d, after which time all leafhoppers in the cages were removed. The numbers of adult leafhoppers that were dead, alive, and that remained in the vial or in the Petri dish were recorded. Trees were checked weekly and the number of newly-hatched leafhopper nymphs counted and removed from the cages. Cages remained closed between each inspection. Evaluations were continued until no new nymphs were found for two consecutive weeks.

The variables analyzed were total number of viable adults (that is, those that could have contributed to oviposition) and the nymphs per viable adult. Leafhopper eggs are inserted deeply into plant tissues and cannot be visually assessed without extensive leaf clearing and staining. Therefore, production of nymphs was used as an indirect measure of oviposition. Data were tested for homogeneity of variance using Levene's (1960) test. The data were transformed as needed by $(\ln(y + 0.5))$ due to non-homogeneity of variances. The data were analyzed using PROC GLM of SAS (1989), and means were separated using Fisher's Least Significant Difference.

Results and Discussion

There was some variability in the number of leafhopper adults found alive, dead, and dead in vials or Petri dishes in the bioassays; however, the difference in the number of viable (live) adults between treatments within a single bioassay was not significant (data not shown). Approximately 7 to 10 adults per cage were recovered after the 3-d exposure period in all treatments. In no case was the number of adults recovered from the oil-treated trees significantly less than the number recovered from the control tress indicating that the oil residues were not toxic to the adults.

In Test 1 and 2, 4% and 2% concentrations of oil were evaluated, and both were effective in reducing the number of nymphs produced (Fig. 1A, B). The 4% oil concentration completely inhibited the production of nymphs, while the 2% concentration reduced nymph numbers by about 90%. In Test 3, a broader range of oil concentrations was examined (Fig. 1C). While there was a trend for greater suppression of nymphs at the higher oil concentration, differences among treatments were not significant, even at the 4% concentration. In Test 4, 0.5%, 1%, and 1.5% concentrations were compared with an untreated control. The two highest concentrations sup-

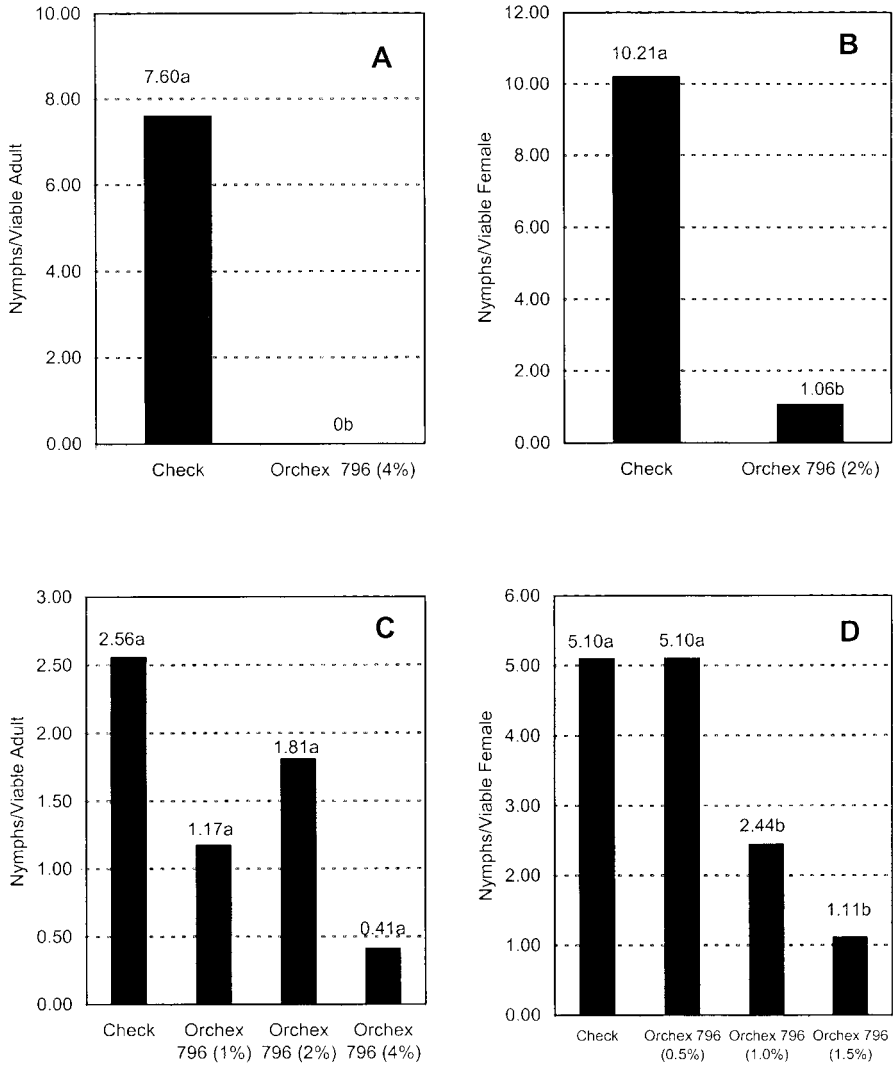

Fig. 1. Effect of various concentrations of Orchex 796 on the production of nymphs from female leafhoppers exposed to fresh residues, 1996-1999.

pressed the numbers of nymphs by 2- and 4.6-fold, respectively (Fig. 1D). There was no significant reduction in nymphs produced at the 0.5% oil concentration in comparison to the control treatment. Although direct comparisons between different tests cannot be made, overall there appears to be a positive correlation between increasing oil concentration and reductions in the number of nymphs recovered. The differences between Tests 3 and 4 were use of unsexed adult leafhoppers in the former and only female leafhoppers in the latter. The high degree of variation in results in Test 3 was

probably due to use of unsexed leafhoppers. Leafhopper age could also affect results of these tests. The age of leafhopper adults was not known and variation in age of females and their potential to lay eggs could have contributed to variability of test results. The collection period of adults in the field should be limited in future studies as a means of restricting the variable age structure used in tests of this type.

Test 5 examined the effect of oils with different average carbon chain lengths in the distillation range on leafhopper oviposition. All oils were tested at a concentration of 2%, and there was no significant difference in the production of nymphs between the oil treatments nor were they different in relation to the control (Fig. 2).

Test 6 examined the effect of oil (2% concentration) residue age on leafhopper oviposition. While there were no statistical differences among treatments including the untreated control, there was a distinct tendency for fewer nymphs in all oil residues ages, including those that were 14-d-old (Fig. 3A). In a second test on residual deterrent effects, oil was used at a 1% concentration. The deterrent effect was significant, but lasted only a few days. The 0- and 3-d-old residues showed an approximate 2-fold reduction in nymphs produced compared to the untreated controls but the 7-d-old residue had no effect (Fig. 3B).

The leafhopper nymphs recovered from treated trees in all the tests were either first or second instar, i.e., no more than 6-d-old. The egg development period for this species is relatively long, and the first nymphs were not recovered until the third week following exposure to adults. The early instars are the most susceptible to insecticides (Beers et al. 1993), and the absence of nymph mortality coupled with the lack of residual toxicity of oil supports the hypothesis that the oil treatments acted primarily as a deterrent for the ovipositing females.

The experiments provide strong evidence for oviposition deterrence as an addi-

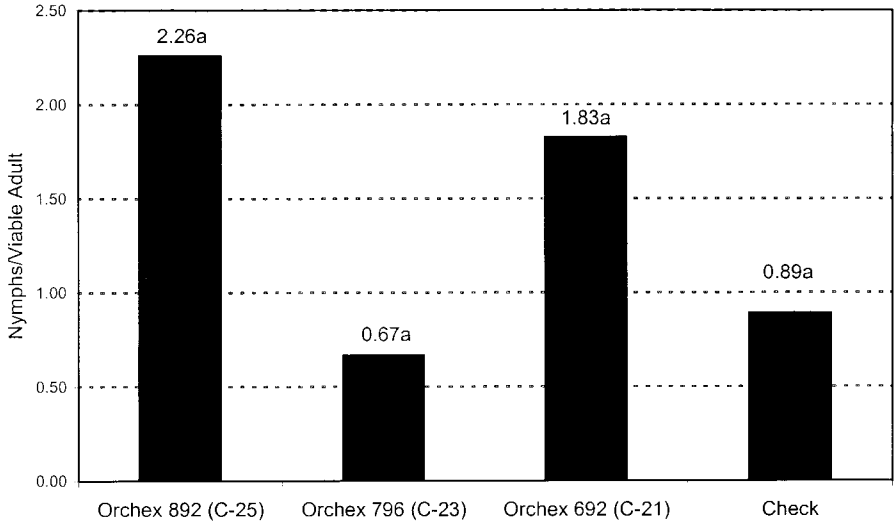

Fig. 2. Effect of three oils of varying weights (carbon chain lengths) on the production of nymphs from females exposed to fresh residues, 1997.

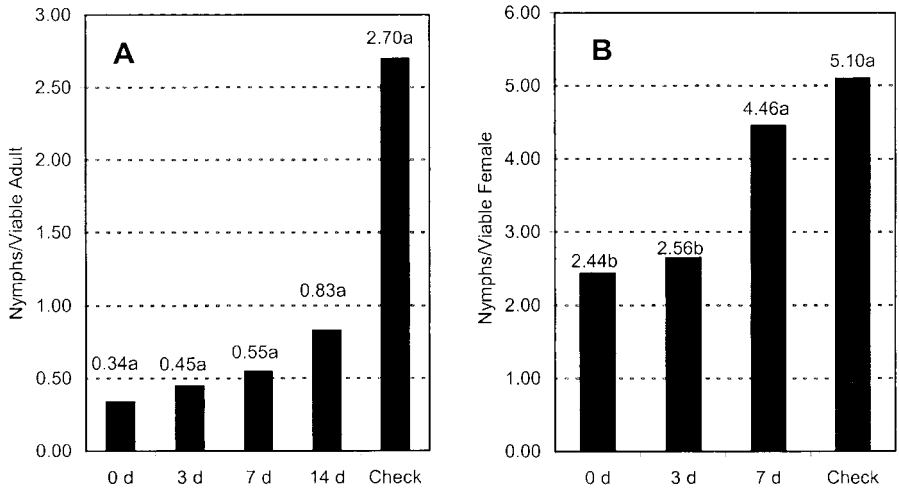

Fig. 3. The effect of varying ages of Orchex 796 residues (A, 2% vol:vol; B, 1% vol: vol) on oviposition inhibition of leafhopper females.

tional means of suppressing leafhopper populations with oil. Although the specific mechanism involved in this effect is not known, chemical and mechanical cues at the leaf surface appear to be of importance for other Heteroptera (Weissling et al. 1997). The effect is not as long-lived as reported for pear psylla, where applications are made during periods of lower temperatures (prebloom) and typically at higher rates. However, the 50% reduction in oviposition found after 3 d in one of the tests may have a significant negative impact on the overall population dynamics. Although only a single application was tested in these experiments, multiple applications may increase the residues of oil and prolong the period of oviposition inhibition.

Acknowledgments

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