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Horticultural mineral oil applications for apple powdery mildew and codling moth, *Cydia pomonella* (L.)

Dario E. Fernandez[1], E.H. Beers*, J.F. Brunner, M.D. Doerr, J.E. Dunley

Tree Fruit Research & Extension Center, Washington State University, 1100 N. Western Avenue, Wenatchee, WA 98801, USA

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Abstract

Horticultural mineral oil (Orchex 796) was tested in two treatment regimes, either a three-spray early season program targeting apple powdery mildew, *Podosphaera leucotricha* (Ell. & Evherh.) Salm. (Oil/Disease treatment) or a six-spray program targeting both generations of codling moth, *Cydia pomonella* (L.) (Oil/CM treatment), on apple, *Malus domestica* Borkhausen. These treatments were compared with a check, which received no post-bloom applications of oil. Apple powdery mildew shoot infestation was suppressed only in 1 year of the study (1999) by the Oil/Disease treatment, but no differences in fruit damage were found. The six-spray program of horticultural mineral oil produced the highest percentage of clean fruit, and the lowest level of codling moth-damaged fruit, but only one out of the 3 years of the study. Even in the best treatment in this year, codling moth damage was unacceptably high. *Campylomma verbasci* (Meyer-Dür) fruit damage was reduced by the oil sprays timed for mildew, probably because of the petal fall spray included in this treatment. Rosy apple aphid, *Dysaphis plantaginea* (Passerini), densities were suppressed (1 year only) by both oil treatments, while apple aphid, *Aphis pomi* De Geer, populations were not influenced by oil treatments at any time during the study. White apple leafhopper nymphs, *Typhlocyba pomaria* McAtee, and tetranychid mite populations were consistently suppressed by both oil treatment regimes, with generally higher levels of suppression occurring with the higher number of applications, despite the lack of specific timing. The same was true of apple rust mite, *Aculus schlechtendali* (Nalepa), and the western predatory mite, *Galandromus occidentalis* (Nesbitt).

Keywords: Horticultural mineral oil; Mating disruption; Integrated pest management

1. Introduction

There has been a resurgence in interest in horticultural mineral oil in the past decade for a variety of agricultural uses (Beattie et al., 2002). Its pesticidal effects cover a broad range of arthropod pests and include acute mortality, repellency, and oviposition deterrence (Zwick and Westigard, 1978; Davidson et al., 1991; Fernandez et al., 2001). Horticultural mineral oil has been used as an adjuvant to enhance the activity of other pesticides (Zabkiewicz, 2002), although it is incompatible with a wide range of orchard pesticides and foliar nutrients. Recent investigations have elucidated the mode of action against plant diseases (Northover and Schneider, 1996), and oils have shown promise against mildew diseases of grape, cherry, and apple (Northover and Schneider, 1996; Grove, 1999; Grove and Boal, 2002).

Use of oil in the dormant or delayed dormant period is standard practice in Washington apples, but post-bloom use has been restricted because of concerns over incompatibility with other pesticides, fruit and foliar phytotoxicity, and reduction in fruit yield or quality (Spuler, 1927; Willett and Westigard, 1988). The availability of more highly refined oils has reduced these concerns, making post-bloom use more attractive. Regulatory actions that have reduced the use of broad-spectrum organophosphate insecticides in apple pest management have left a void that, ideally, would be filled by safer, more selective materials such as oil.

Several factors favor the use of horticultural mineral oil, including low cost, low mammalian toxicity, and few deleterious environmental effects. It is one of the few

*Corresponding author. Tel.: 509 663 8181(x)234; fax: 509 662 8714.
E-mail address: ebeers@wsu.edu (E.H. Beers).
[1]Current address: INTA EEA Alto Valle, Ruta Nacional 22, Km 1182, (8332) General Roca, Rio Negro, Argentina.

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pesticide groups to which resistance has never been documented (Willett and Westigard, 1988), possibly because of the physical mode of action. For this reason, oil use is frequently mentioned in resistance management schemes.

The objective of this experiment was to test two seasonal oil programs, targeting the most prevalent disease of apple in the arid western US, apple powdery mildew, *Podosphaera leucotricha* (Ell. & Evherh.) Salm. (Grove, 1999), and the most destructive insect pest of apple, codling moth, *Cydia pomonella* (L.). While these were the primary targets, we anticipated that the oil applications would affect many other arthropods present in the orchard; thus, densities of a wide spectrum of apple pests and natural enemies also were assessed.

2. Materials and methods

This experiment was conducted in a 0.45-ha block of apples planted in 1995 in an experimental orchard near Orondo, WA. Prior to the beginning of the experiment, the block was managed using conventional pesticides. The block was composed of four cultivars of apple, Oregon Spur, Golden Delicious, Gala, and Fuji on EM.7A rootstock. The trees were planted 4.5 m between rows and 4 m between trees and maintained in a free-standing central leader system (ca. 3 m tall and 2 m wide). Orchard floor management consisted of a weed-free strip beneath the trees maintained with herbicides, and grass sod in the row middles. Trees were irrigated with under-tree impact sprinklers at about weekly intervals throughout the growing season. The experimental design was a split-plot with three oil treatments (main plots), four cultivars (subplots), and four replicate blocks. The plots were three rows × five trees, but samples were taken from the center row only, on one tree of each of the four cultivars (same tree for each sample).

The treatments consisted of varying timing and number of applications of petroleum oil (Orchex 796, Exxon, Houston TX) applied during three growing seasons, 1997–1999. This material is a light (C-23) paraffinic oil with the following properties: distillation range, 20 °C; minimum unsulfonated residue, 92%; viscosity, 77 s Saybolt Universal at 37.8 °C; minimum paraffinic-based molecules, 60%; 50% distillation point, 267 °C; pour point, −6 °C; molecular weight, 330; API gravity, 35.1. The treatments were (1) oil applications directed primarily against apple powdery mildew (Oil/Disease treatment), (2) oil directed at direct pests, primarily codling moth (Oil/CM treatment), and (3) check. All post-bloom oil applications were made at a rate of 1% (v:v) in an airblast application made at 2100 l/ha. The check did not receive any post-bloom oil applications.

The Oil/Disease treatment received three applications per season. The first application was applied at petal fall. The second application was made about 2 weeks after the first, and the third spray was applied at the same time as the second cover spray for codling moth (Table 1). The timing of the Oil/CM treatment was based on the phenological development of codling moth (degree-days [DD] accumulated between 10 and 31 °C, horizontal cut-off) using the method of Welch et al. (1978). The primary target of these applications was the egg stage. The program consisted of six oil applications, three during each of the first two generations of codling moth. The first application against the first generation was applied at about 250 DD (50% adult flight, 2% egg hatch), and the first application for the second generation was timed for 1250 DD (Table 1). Subsequent applications were at about 200 DD intervals.

The check was left untreated in the first year of the study (1997) to help build populations of codling moth. This occurred more rapidly than anticipated, and pressure was so high by the end of the first year of the test (72–82% fruit damage) that some additional form of codling moth suppression was used over the entire block during subsequent years. In 1998 and 1999, the mating disruption product codlemone (Isomate-C plus, Pacific Biocontrol, Vancouver, WA) was applied to the entire study block at a rate of 1000 dispensers/ha. To further reduce the extremely

Table 1
Application dates of horticultural mineral oil (Orchex 796) to four cultivars of apples, 1997–99

	1997		1998		1999	
Timing	Oil/Disease	Oil/CM	Oil/Disease	Oil/CM	Oil/Disease	Oil/CM
Delayed dormant	31 March	31 March	31 March	31 March	30 March	30 March
Petal fall	13 May		4 May		10 May	
1st cover		20 May		11 May		2 June
PF + 14 d	28 May		15 May		25 May	
2nd cover	9 June	9 June	22 May	22 May	14 June	14 June
3rd cover		23 June		11 June		25 June
4th cover		22 July		14 July		29 July
5th cover		5 August		20 July		6 August
6th cover		19 August		29 July		19 August

All applications made at 1% v:v (2100 l/ha), except the delayed dormant, which was 1.5%.

high codling moth pressure of the 1997 season, two applications of diflubenzuron (Dimilin 25W, Uniroyal Chemical, Middlebury CT) were made during the first generation (30 April and 8 May 1998) and one application of fenoxycarb (Comply 25WP, Novartis, Greensboro NC) was made early in the second generation (6 July 1998). In 1999, mating disruption, but no insect growth regulators, was applied.

2.1. Sampling

In all, about 50 terminals per tree (200 per replicate) were sampled to determine the level of infestation by powdery mildew. Terminals were classified as either infested (if any mildew was observed) or not infested by inspection of the distal three open leaves.

Rosy apple aphid (*Dysaphis plantaginea* [Passerini]) was sampled by walking around the tree periphery for 5 min and counting the number of colonies. Apple aphid (*Aphis pomi* De Geer) populations were sampled every other week by counting the number of infested leaves on two shoots per tree (eight shoots per replicate). Apple aphid predators (coccinellids, lacewings, *Deraeocoris* sp., *Campylomma verbasci*, cecidomyiids, and syrphids) were sampled on the same shoots by counting the total number of predators per shoot. White apple leafhopper (*Typhlocyba pomaria* McAtee) nymphs were sampled from late April through mid-June (first generation), and from mid-July through early September (second generation). The upper and lower surfaces of 10 leaves per tree (40 per replicate) were examined in situ, and the number of nymphs counted. Phytophagous (Tetranychidae, Eriophyidae) and predatory (Phytoseiidae, Stigmaeidae) mites were sampled every 2–3 week by collecting 40 mature leaves (10 per tree on each of the four cultivars) per replicate. Cluster leaves were sampled at the beginning of the season, and mid-shoot leaves during the mid- and late-season. The leaves were collected in paper bags and kept cool until processing (within 24 h). Mites were removed from the leaves with a leaf brushing machine (Leedom Enterprises, MiWuk Village, CA). Motile and egg stages of European red mite (*Panonychus ulmi* (Koch)), twospotted spider mite (*Tetranychus urticae* Koch), McDaniel spider mite (*Tetranychus mcdanieli* McGregor), western predatory mite (*Galandromus occidentalis* (Nesbitt)), a stigmaeid predatory mite, *Zetzellia mali* Ewing, and motile stages of apple rust mite (*Aculus schlechtendali* [Nalepa]) were counted under binocular microscopy.

A fruit sample was evaluated just before harvest each year to determine damage or presence of direct and indirect pests. Classes of damage assessed included codling moth, leafrollers (primarily *Pandemis pyrusana* Kearfott), a zoophytophagous mirid, *C. verbasci* (Meyer-Dür), aphid honeydew and leafhopper tarspots (excrement droplets), European red mite eggs, San Jose scale, *Quadraspidiotus perniciosus* (Comstock), and fruit russeting by apple powdery mildew. A maximum of 60 fruits (30 from the upper half of the canopy and 30 from the lower half) from each sample tree (240 fruits per replicate) was examined.

2.2. Data analysis

Data were analyzed using PROC GLM (SAS Institute, 1982). The treatment effect was examined using a TEST statement using Block $\times$ Trt as the error term. Levene's (1960) test was used to determine the homogeneity of variances, and data were transformed [log $(y+0.5)$] when necessary. Percentage data were transformed using arcsine[sqrt $(y/100)$]. Means were separated using Fisher's least significant difference (LSD). Cumulative insect days for motile mites and leafhopper nymphs were calculated following the method of Ruppel (1983) with modifications to account for two discrete leafhopper generations.

The primary focus of this study was to determine the effect of the oil treatment regimes on insect and disease pests. The cultivar differences were of lesser importance, and were included primarily to broaden the scope of the test, especially because of the differences in mildew susceptibility. Probability values for the main effects Trt (oil treatment) and Cult (cultivar), as well as the Trt $\times$ Cult interaction are calculated, but only the treatment means, standard errors, and mean separation statistics are given in the tables. Cultivar differences, where applicable, are described in the text.

3. Results and discussion

The percentage of shoots with mildew was high in 1998, and increased in 1999 (Table 2). Differences in cultivar susceptibility ($P<0.0001$, 1998 and 1999) were the most striking result, with Gala and Golden Delicious having the highest levels of shoot mildew (about 97% in 1999), Fuji an intermediate level, and Delicious having consistently the lowest level (27–35%). No differences due to treatment occurred in 1998, but in 1999, under severe pressure, the Oil/Disease treatment provided some suppression of apple powdery mildew. In three of the four cultivars, the reduction in the Oil/Disease treatment was about 5% relative to the percentage in the check; Fuji showed the greatest reduction in mildewed shoots relative to the check (15%).

Rosy apple aphid populations were low in 1997 and 1999, but substantially higher in 1998 (Table 2). In the latter case, although there were striking numerical differences in treatment means, no statistically significant differences occurred, due in part to the highly variable spatial distribution of this pest. The highest populations occurred in Golden Delicious, intermediate on Fuji and Gala, and none were detected on Delicious. In two cultivars, Golden Delicious and Fuji, the lowest populations occurred in the Oil/Disease treatment; however, the reverse was true for Gala. Despite numerical difference, the cultivar effect was not significant in any year. In 1999, the check had significantly higher numbers of rosy apple

Table 2
Powdery mildew infestation and aphid densities (± standard error), 1997–99

Treatment	1997	1998	1999
% shoots with apple powdery mildew			
Oil/Disease	—	48.13±7.45a	69.13±7.11b
Oil/CM	—	49.88±7.45a	74.38±6.83ab
Check	—	51.13±6.27a	76.00±6.94a
Rosy apple aphid colonies/5 min			
Oil/Disease	0.25±0.25a	1.38±0.80a	0.69±0.24b
Oil/CM	0±0a	4.94±2.97a	0.50±0.18b
Check	0±0a	10.63±8.22a	1.44±0.42a
Apple aphid-infested leaves/shoot			
Oil/Disease	0.25±0.05a	0.58±0.11a	0.26±0.06a
Oil/CM	0.32±0.06a	0.48±0.06a	0.40±0.11a
Check	0.29±0.06a	0.54±0.12a	0.26±0.09a
Motile predators/apple aphid-infested shoot			
Oil/Disease	0.06±0.01b	0.05±0.02a	0.06±0.03a
Oil/CM	0.05±0.02b	0.07±0.02a	0.05±0.04a
Check	0.12±0.01a	0.07±0.02a	0.03±0.01a

Means within columns and years not followed by the same letter are significantly different (Fisher's LSD, $P \leqslant 0.05$).

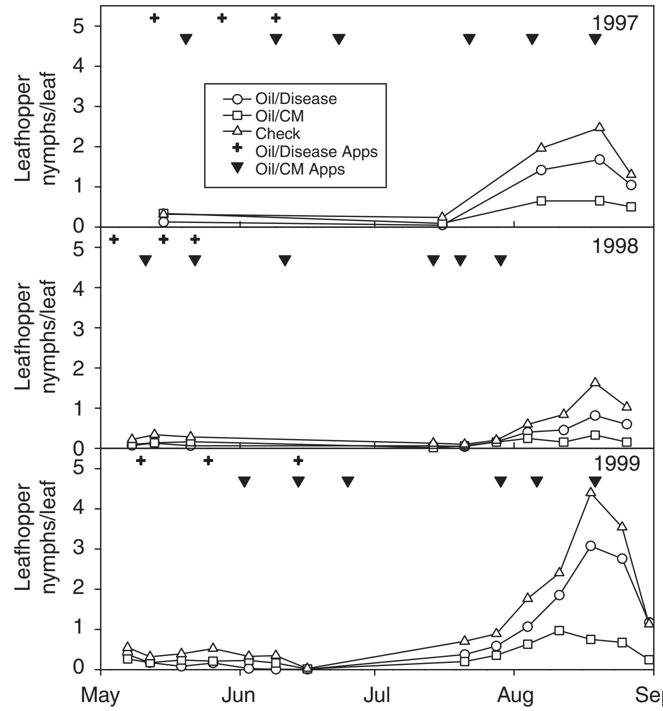

Fig. 1. Seasonal densities of white apple leafhopper nymphs relative to petroleum oil application dates, 1997–1999.

aphid colonies. The first oil application (petal fall) in the Oil/Disease treatment was early enough to potentially affect rosy apple aphid colony establishment, and this possibility merits further investigation.

Apple aphid populations were low in all 3 years of the study, never exceeding an average of one infested leaf per shoot. No differences among seasonal average treatment means occurred in any year (Table 2). In 1997 only, the aphid predator complex was significantly lower in the two oil treatments in relation to the check, but no differences occurred in succeeding years.

White apple leafhopper densities were moderate in 1997, with a peak population in the check at 2.5 nymphs/leaf (Fig. 1). Populations were lower in 1998, with a peak of 1.6 nymphs/leaf, and highest in 1999, with a peak of 4.5 nymphs/leaf. Peak nymph populations always occurred in late August, or mid-way through the second generation, and were about six-fold higher than the peak in the first generation. The check had the highest number of cumulative leafhopper days in all 3 years (Table 3). The Oil/CM treatment (six applications) suppressed the populations to the greatest extent. However, the Oil/Disease treatment (three applications) also provided significant suppression of seasonal nymph populations in all years. Despite this, the peak of the second generation was suppressed in all cases relative to the untreated check (data not shown). Differences in cumulative insect days were discernable in the latter treatments even though the oil applications were made only during the first generation.

Tetranychid mite populations were very low in 1997, never exceeding 0.10 mites/leaf in any treatment. The densities began to increase in 1998, but were still too low to be of economic concern. However, the seasonal mite populations were significantly lower in the two oil treatments relative to the check (Table 3). There were no detectable differences between the oil treatments, although the Oil/Disease treatment received no oil in mid- to late-summer, the typical time for mite population increase in Washington. The highest populations occurred in 1999, with a peak of about 4.5 mites/leaf (check) in late-July. The population was composed primarily (96%) of European red mite. As in 1998, both of the oil treatments suppressed mite populations relative to the check, but were not statistically different from each other.

Predatory mite densities were highest in the check and lowest in the Oil/CM treatment (six oil applications) in all 3 years of the study (Table 3). Although the two oil treatments had predatory mite-day accumulations that were significantly different from each other only in 1999, the trend for predatory mite densities to be inversely related to the number of oil applications was the same in all 3 years. The same trend was apparent in the apple rust mite populations in 1997 and 1999, but the populations in 1998 were too low to detect differences.

There was a trend for codling moth damage to be lowest in the Oil/CM treatment in 1997–1998, but statistical differences became apparent only in 1999 (Table 4). The damage was extremely high in 1997, apparently overwhelming any potential benefit of the oil. Conversely, the additional pesticides applied during 1998, while substantially reducing the damage, also did not allow any detection of statistical differences. In 1999, when mating disruption

Table 3
White apple leafhopper and mite cumulative insect days (± standard error), 1997–99

Treatment	1997[a]	1998[a]	1999[a]
Cumulative leafhopper nymph days			
Oil/Disease	46.9±2.0b	12.9±1.1b	77.7±4.6b
Oil/CM	23.5±2.1c	8.7±0.8c	34.8±2.4c
Check	69.4±2.7a	25.2±1.9a	116.7±6.1a
Cumulative tetranychid mite days			
Oil/Disease	0.4±0.0a	1.5±0.8b	28.8±3.5b
Oil/CM	0.5±0.4a	0.6±0.3b	27.2±8.1b
Check	5.4±0.8a	3.8±1.4a	153.7±36.0a
Cumulative predatory mite days			
Oil/Disease	67.3±1.1b	33.8±2.8a	103.6±14.8b
Oil/CM	53.4±4.5b	13.8±1.9b	38.9±4.9c
Check	107.5±8.2a	66.7±5.0a	160.5±12.7a
Cumulative apple rust mite days			
Oil/Disease	876±294ab	0.4±0.3a	928±398b
Oil/CM	547±25b	0±0a	123±39c
Check	4086±1083a	0.1±0.1a	1580±317a

Means within columns and years not followed by the same letter are significantly different (Fisher's LSD, $P \leqslant 0.05$).
[a]Data transformed $\log(x+0.5)$ prior to analysis due to unequal variances.

Table 4
Percentage fruit damaged by various arthropod pests and diseases (± standard error), 1997–99

Treatment	1997[a]	1998[a]	1999[a]
% codling moth			
Oil/Disease	72.8±5.2a	9.4±2.2a	20.8±1.8b
Oil/CM	69.9±3.0a	7.3±2.5a	13.0±1.7c
Check	82.3±3.9a	7.1±1.5a	42.0±3.0a
% *C. verbasci*			
Oil/Disease	0±0a	7.0±2.7b	7.7±1.2a
Oil/CM	0±0a	16.0±3.8a	7.7±1.1a
Check	0±0a	9.7±3.3ab	7.8±1.4a
% aphid honeydew			
Oil/Disease	0±0a	11.1±2.8a	27.5±3.8a
Oil/CM	0±0a	11.3±6.2a	25.2±3.6a
Check	0±0a	8.4±5.6a	34.6±5.7a
% leafhopper tarspot			
Oil/Disease	15.7±3.6a	67.1±8.5a	61.4±5.8a
Oil/CM	7.8±2.4a	51.8±9.5a	30.2±4.4b
Check	14.5±4.4a	59.4±9.1a	70.3±4.9a
% mite eggs			
Oil/Disease	0±0a	0±0a	0±0a
Oil/CM	0±0a	0.2±0.2a	0±0a
Check	0±0a	0.1±0.1a	0±0a
% San Jose scale			
Oil/Disease	0.1±0.1a	0.9±0.5a	0.3±0.3ab
Oil/CM	0.1±0.1a	0.3±0.3a	0.1±0.1b
Check	0±0a	0.7±0.4a	1.1±0.5a
% mildew russeting			
Oil/Disease	2.6±0.8a	9.8±4.4a	0.4±0.3a
Oil/CM	1.8±0.6a	4.6±2.5a	0.7±0.4a
Check	1.2±0.4a	4.0±1.9a	0.6±0.3a
% undamaged fruit			
Oil/Disease	15.4±3.1a	14.7±4.5a	17.0±2.6b
Oil/CM	21.1±3.2a	17.9±5.7a	40.0±3.5a
Check	10.1±2.5a	15.4±4.8a	8.5±1.9b

Means within columns and years not followed by the same letter are significantly different (Fisher's LSD, $P \leqslant 0.05$).
[a]Data transformed $\log(x+0.5)$ prior to analysis due to unequal variances.

was supplemented with oil, there was a measurable reduction in codling moth damage caused by oil applications. However, these levels are much higher than is normal in commercial orchards.

Leafroller fruit damage ranged from 1.5% to 6.6% during the 3 years of the study, but treatment means were never significantly different (data not shown). Injury by *C. verbasci* was not found in 1997, but was moderate (7–16%) in 1998 and 1999. Only in 1998 were there significant differences between treatments, with the Oil/Disease treatment having significantly lower *C. verbasci* damage. There were significant differences in the amount of *C. verbasci* injury among cultivars ($P<0.0001$, 1998 and 1999), with Delicious having ca. 9× less damage than Gala in 1998, and 3× less damage than Golden Delicious in 1999. The relative susceptibility of the cultivars is consistent with that found by other workers (Thistlewood et al., 1989). The amount of aphid honeydew damage varied considerably among years, but there were no treatment differences. The amount of tarspotting on fruit was not consistently related to the leafhopper nymph densities, although in the check, tarspotting tended to be highest in 1999, when the peak nymph density occurred. Only in 1999 were significant treatment differences detected, with the six-application Oil/CM treatment producing the lowest percentage of fruits with tarspots, less than half the amount in the check (Table 4). Despite the higher mite densities in 1999, there was no increase in European red mite eggs in the fruit calyces, and no treatment differences at harvest. San Jose scale fruit damage occurred at low levels in this study (0.03–1.1%). However, there was a gradual increase in damage levels over the course of the study, perhaps because of the withdrawal of broad-spectrum insecticides from the program. Only in 1999 was fruit damage by San Jose scale significantly lower in the Oil/CM treatment compared with the check, 0.1% compared to 1.1%. Fruit russeting caused by powdery mildew never exceeded 10% despite the high disease pressure, and no differences among treatments were found (Table 4). In 1998 and 1999, however, Golden Delicious had significantly higher levels of russeting than the other cultivars ($P<0.0001$). While this cultivar is mildew susceptible, it is also subject to environmental russet, and this may have confounded the evaluations to some extent. Generally, the cultivars Fuji and Gala are thought to be highly mildew susceptible, and Delicious one of the least susceptible cultivars (Grove, 1998; Grove, 1999;

Turechek et al., 2004). There was no difference in the percentage of undamaged fruit among treatments, except in 1999 when the Oil/CM treatment had a significantly higher percentage than the other two treatments.

4. Summary

Neither of the two oil treatment regimes was very effective against their primary targets, apple powdery mildew, and codling moth. Suppression of each of the primary target pests occurred in only one out of 3 years of the study, and did not reduce the damage to acceptable commercial levels. The effect on apple powdery mildew is consistent with the results of other researchers (Grove and Boal, 1996; Yoder et al., 2002; Yoder and Cochran, 2004), although a much greater degree of success has been achieved on powdery mildews of stone fruit (Grove and Boal, 2002; Lunden and Grove, 2002). While oil may be useful in a program of other fungicides, it does not appear to be a stand-alone tactic for apple powdery mildew. This is especially true on mildew-susceptible cultivars, but even Delicious, the least susceptible cultivar in this study, had high levels of shoot infection.

The marginal benefit of oil applications against codling moth was consistent with the results of Fernandez et al. (2005). It is also consistent with the conclusions drawn from the laboratory studies of Riedl et al. (1995), who concluded that oil would not be of significant benefit under field conditions. Significant suppression of codling moth would likely require either higher rates or more frequent applications of oil than were used in this study.

While the oil treatments were not effective against their primary targets, they did provide suppression of several secondary pests. The petal fall timing is most likely the one that had the greatest impact on rosy apple aphid populations, although there was insufficient evidence to determine if oil applications will be effective against this pest.

Tetranychid mites and white apple leafhopper nymphs were the pests most consistently suppressed by multiple oil applications, with the level of suppression related to the number of applications. This is consistent with the results of Fernandez et al. (2005) and Agnello et al. (1994). The most encouraging data are the seasonal reduction in densities in the Oil/Disease treatment (three applications), in which no oil was applied during the most critical period (second generation of nymphs and peak mite populations). Apparently, the benefits of early season suppression of these pests carried through later into the summer, when populations generally increase most dramatically. In the case of mites, repellency may play a role after direct mortality effects have dissipated. The same may be true for leafhopper females. Oviposition deterrence has been demonstrated for up to 3 d (Fernandez et al., 2001), so any deterrence in this study should have been a minor effect and only by the third application.

The potential benefits of oil must be weighed against the risks of phytotoxicity, both acute and chronic. Only minor incidences of leaf burn, fruit marking, or fruit finish effects were found in this study (data not shown). Our observations are consistent with a lack of problems in other Washington studies on use of oils in apple (K.E. Williams, unpublished data; L.E. Schrader, unpublished data). The greatest potential problem with use of oil on apple appears to be the depression in photosynthetic rate, which has been found by several workers (Ayers and Barden, 1975; Sharma et al., 1978). This is the proposed mechanism for reductions in fruit size and other yield parameters, which have been reported from both pear (Hilton et al., 2000) and apple (Spuler, 1927). Concerns about reduced yield and incompatibility with other agricultural chemicals continue to restrict oil use during the post-bloom period to relatively few applications, or as an adjuvant for other pesticides.

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