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Control of San Jose Scale, Terrapin Scale, and European Red Mite on Dormant Fruit Trees with Soybean Oil

C.D. Pless[1], D.E. Deyton[2], and C.E. Sams[3]
The University of Tennessee, Knoxville, TN 37901-1071

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Abstract. **Emulsions of degummed soybean (*Glycine max* L.) oil were compared to a petroleum oil emulsion for efficacy against winter populations of San Jose scale [*Quadraspidiotus perniciosus* (Comstock); Homoptera: Diaspididae] and European red mite [*Panonychus ulmi* (Koch); Acari: Tetranychidae] on dormant apple (*Malus domestica* Borkh.) trees and terrapin scale [*Mesolecanium nigrofasciatum* (Pergande); Homoptera: Coccidae] on dormant peach [*Prunus persica* (L.) Batsch.] trees. In laboratory tests, more than 94% of San Jose scale was killed on stems dipped for 1 second in 5.0% or 7.5% soybean oil or 5.0% petroleum oil. Mortality of terrapin scale exceeded 93% on peach stems dipped for 1 second in 7.5% soybean oil or 5.0% petroleum oil. No European red mite eggs survived on apple stems dipped for 1 second in 2.5%, 5.0%, or 7.5% soybean oil, or 5.0% petroleum oil. In field tests, >95% of San Jose scale died on apple trees sprayed with one application of 2.5% petroleum oil or 5.0% soybean oil; two applications of these treatments or 2.5% soybean oil killed all San Jose scales. One or two applications of 2.5% petroleum oil or 5.0% soybean oil killed 85% and 98%, respectively, of the terrapin scales on peach trees. Soybean oil shows promise as a substitute for petroleum oil for winter control of three very destructive fruit tree pests.**

Oils are reported to be the only widely used class of insecticides/miticides to which no species of insects or mites are known to have developed resistance, even after many decades of continuous use in orchards (Chapman, 1967; Rock and Crabtree, 1987). Oils also pose little human health hazard, and they are less expensive than competitive pest control products (Chapman, 1967; Hesler and Plapp, 1986). Petroleum oils have been used in agriculture for pest control for >200 years (Lawson and Weires, 1991), and they are considered to be the best pesticides available to control mites, scale insects, and certain other pest species present on dormant fruit trees (Chapman, 1967; Johnson, 1980). Petroleum oils affect only insects that are present at the time of application; those moving to treated plants subsequent to application are not affected by oil residues (Johnson, 1980).

Plant oils also have been commonly used as insecticides (Hesler and Plapp, 1986), and they have been especially effective for controlling pests in stored seeds and foods (Giga and Munetsi, 1990; Hill and Schoonhoven, 1981; Ran et al., 1988; Salas, 1985; Salas and Hernandez, 1985; Shelke et al., 1987). Various formulations of crude plant oils, commercial formulations of insecticidal oils and household cooking oils, [including soybean, safflower (*Carthamus tinctorius* L.), sunflower (*Helianthus annus* L.), corn (*Zea mays* L.), and peanut (*Arachis hypogaea* L.) oils] have provided safe and economical control of several pests of vegetables and cotton (*Gossypium hirsutum* L.) (Butler et al., 1988, 1991, 1993; Butler and Henneberry, 1989, 1990, 1991a, 1991b).

Currently, there is no effective alternative to petroleum oil as a dormant spray for controlling pests that overwinter on fruit trees. Therefore, management of several major pests depends on the continual application of a single product derived from a nonrenewable resource. Use of plant oils as fruit tree insecticides/miticides has not been researched extensively; however, there is continued interest in evaluating petroleum oil formulations to control insects and mites on fruit trees (Lawson and Weires, 1991).

Although plant-oil treatments could potentially be competitive with petroleum oils for controlling several destructive pests, only a few studies have been conducted to evaluate efficacy of plant oils as insecticides on fruit crops. Taschenberg (1952) found cottonseed oil to be slightly superior to peanut oil or linseed oil for control of eggs of grape berry moth (*Endopiza viteana* Clemens). Rock and Crabtree (1987) found cottonseed oil to be a less effective miticide than petroleum oil when applied to winter eggs or adult females of European red mite (ERM). In the same study, cottonseed oil also had poor ovicidal activity against redbanded leafroller (*Argyrotaenia velutinana* Walker) and tufted apple bud moth [*Platynota idaeusalis* (Walker)]. Cottonseed oil was slightly phytotoxic when used as a postdormant treatment.

To our knowledge, no studies evaluating the miticidal or insecticidal activity of soybean oil applied to fruit trees have been reported. We conducted laboratory and field studies in 1993 to compare the relative insecticidal/miticidal efficacies of soybean oil and petroleum oil sprays applied to fruit trees infested with overwintering populations of three selected pests. Two destructive species, San Jose scale (SJS) and ERM, attack apple and peach trees and overwinter on their host trees. SJS has traditionally been an important pest throughout the apple-growing regions of the United States (Chapman, 1967; Reissig et al., 1985) and the world (Gentile and Summers, 1958). SJS is especially serious in temperate and subtropical regions (Gentile and Summers, 1958). This insect has been known to be a pest of tree fruit in Tennessee since about 1896 (Chambliss, 1897). ERM can be even more difficult than SJS to control. One or more chemical treatments are generally required to prevent serious damage by ERM in orchards (Lienk, 1972). A third species used in our studies, terrapin scale (TS), is a pest of peach and plum (*Prunus* sp.) in Tennessee.

Materials and Methods

Oil dips. Stems from dormant 'Golden Delicious' and 'Delicious' apple trees infested with SJS and from 'Red Haven' peach trees infested with TS were collected on 26 Jan. 1993 from commercial orchards near Morristown, Tenn. 'Red Haven' peach stems containing ERM eggs were collected on 9 Mar. from the same locality. Stems were transported in coolers to the Univ. of Tennessee, Knoxville. Ten apple stems (replicates) were dipped for 1 sec in one of the following treatments: 1) water emulsions of 2.5%, 5.0%, or 7.5% (v/v) degummed (slightly refined) soybean oil (SO) (Archer-Daniels Midland, Chattanooga, Tenn.) containing 0.6% (v/v) Latron AG 44M emulsifier (Rohm and Haas, Philadelphia); 2) 5.0% (v/v) petroleum oil (PO) (Drexel Chemical Co., Memphis, Tenn.); 3) 0.6% Latron AG 44M emulsifier; or 4) controls, which received no treatment. Stems were trimmed to 25 cm long by removing their bases. The basal 1 cm of the treated stems was submerged in water, and the stems were incubated for 2 weeks in a chamber at 23C. After incubation, 10 overwintering SJS ("black-cap" stage of first instar) per stem were examined microscopically and assessed for viability.

Peach stems containing TS were treated by the same methods as those used to treat apple stems, except that an additional treatment of 2.5% (v/v) PO was included, and stems were trimmed to 35 cm in length before their incubation. After incubation, viability of adult female (overwintering stage) TS (= 36 per stem) was determined.

Peach stems containing ERM eggs were dipped on 11 Mar. in the same oil concentrations as were the apple stems. Stems were cut

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[1]Professor, Dept. of Entomology and Plant Pathology.
[2]Associate Professor, Dept. of Plant and Soil Science.
[3]Professor, Dept. of Plant and Soil Science.

into sections ≈4 to 8 cm long. Eggs on each stem section were counted, and the sections were partitioned into groups (treatment units) so that each group contained about the same number of eggs (= 87). Mite egg viability was assessed by methods similar to those described by Lawson and Weires (1991). Stem segments were impaled onto insect pins that had been driven through 10 × 12-cm white posterboard containing a thin coat of Stiky Stuff (Olson Products, Medina, Ohio) to trap newly hatched mites and facilitate their counting. Treatments were replicated three times in a completely randomized design. All treatment groups were incubated at ≈27C, 77% relative humidity, and 16-h light/8-h dark cycle. Eggs were examined every 2 to 3 days until hatch was complete (29 Mar.), and all mite larvae were counted. The number of mite eggs and percentage of surviving scale insects were analyzed using SAS least squares analysis (SAS Institute, 1985). Percentage data of surviving insects in laboratory trials were transformed to arcsin square root before analysis.

Oil sprays. Dormant 'Golden Delicious' and 'Delicious' apple trees in a commercial orchard near Morristown, Tenn., that were infested with SJS were sprayed to runoff on 9 Feb. 1993 with emulsions of 1.25%, 2.5%, or 5% degummed SO plus 0.6% Latron AG 1956 (Rohm and Haas), or 2.5% PO. Control trees received no treatment. Dormant 'Red Haven' peach trees infested with TS received the same treatments, except that the lowest concentration of SO was excluded. Treatments of apple were randomized in an incomplete-block design with six blocks, each containing four treatments (single-tree units) and with five replications of oil treatments and four of the control. Treatments of peach were randomized in an incomplete-block design with six blocks, each containing three treatments (single-tree units) and with five replications of 2.5% PO and 2.5% SO and four of control and 5.0% SO. Ten stems were collected from each tree on 23 Mar., and insect mortality was determined by examining 10 black cap SJS on each apple stem and all TS on each peach stem. All trees were retreated in a late dormant stage on 25 Mar. Ten additional stems from each peach and apple tree were randomly collected on 6 and 13 Apr., respectively, and TS and SJS viability were determined the following day. On 24 June, 10 fruit were collected from each apple tree, and SJS on each fruit were counted. All percentage data in field trials were transformed to arcsin square root before analysis. Field data were analyzed with the General Linear Mixed Models statistical program (Blouen and Saxon, 1990).

Results and Discussion

Oil dips. Only 4% and 6% of SJS that received no treatment and 0.6% emulsifier, respectively, died (Fig. 1). All oil treatments except 2.5% SO killed >94%, and the least effective oil treatment resulted in 84% control of SJS. Since the emulsifier alone in water did not kill many of this species of scale insect, we believe that in this case the primary insecti-

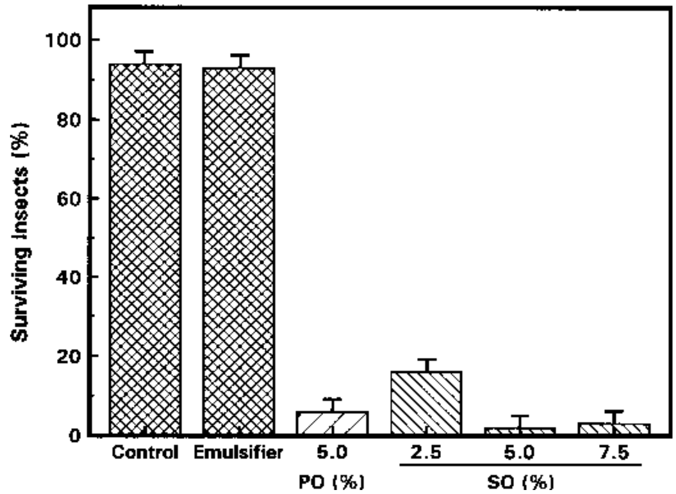

Fig. 1. Control of black-cap stage of San Jose scale on dormant apple stems with water-emulsion dips containing emulsifier (0.6% Latron AG 44M); 2.5%, 5.0%, or 7.5% degummed soybean oil (SO); or 5.0% petroleum oil (PO). Vertical lines represent one SE.

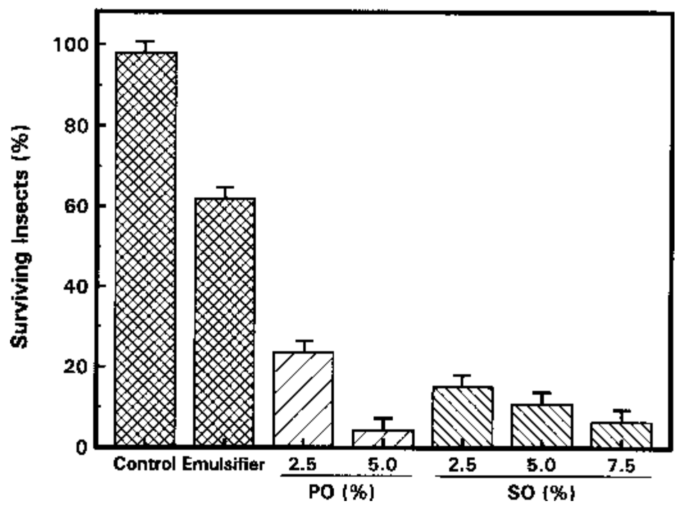

Fig. 2. Control of adult female terrapin scale on dormant peach stems with water-emulsion dips containing emulsifier (0.6% Latron AG 44M); 2.5%, 5.0%, or 7.5% degummed soybean oil (SO); or 2.5% or 5.0% petroleum oil (PO). Vertical lines represent one SE.

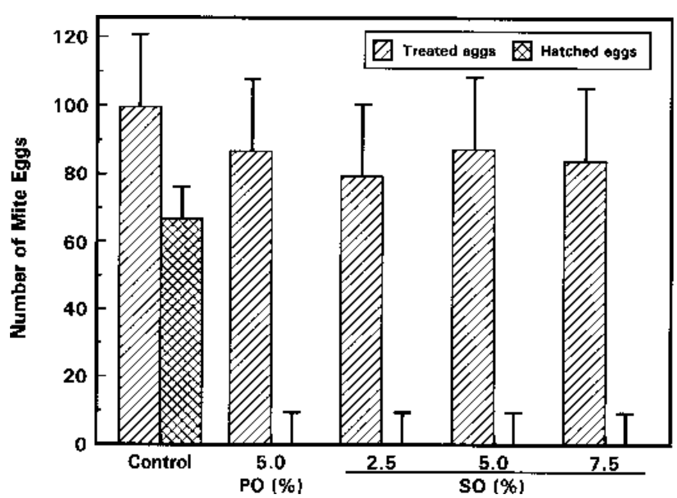

Fig. 3. Control of European red mite eggs on dormant peach stems with water-emulsion dips containing 2.5%, 5.0%, or 7.5% degummed soybean oil (SO) or 5.0% petroleum oil (PO). Eggs were treated on 3 Mar., and egg hatch was evaluated on 29 Mar. Vertical lines represent one SE.

cidal agent in the SO treatments was the oil itself. In TS populations, however, significant (38%) control did occur following treatment with emulsifier alone. This control is assumed to be due to the emulsifier; however, a water control was not included in this experiment. All oil treatments resulted in high levels of death of TS (Fig. 2); dips of 5% PO and 7.5% SO resulted in similar levels (>93%). The 2.5% and 5% SO emulsions killed 84% and 88%, respectively.

About 67% of the nontreated ERM eggs remained viable and hatched by the end of the post-treatment incubation period (Fig. 3). None of the eggs that had been treated with either PO or SO hatched, indicating that both types of oil are potentially very effective ERM ovicides. In a separate field study (data not shown), ERM control was erratic, perhaps due to non-uniform coverage or inappropriate timing of sprays, indicating that additional field studies will be required to determine the relative efficacies of the two types of oils for practical ERM control. Previous studies (Chapman and Lienk, 1966; Chapman and Pearce, 1949; Lienk, 1972) indicate that critical timing of field applications of PO is essential for satisfactory control of ERM. Lawson and Weires (1991) reported that field spray applications of PO and insecticidal soap killed considerably fewer overwintering ERM eggs than did laboratory dip treatments. They attributed better control in the laboratory to better coverage of stems with dips than with sprays.

Oil sprays. The first application of 2.5% PO or 5.0% SO resulted in >95% kill of SJS on the stems of apple trees (Fig. 4). Although the first application of lower concentrations of SO caused only 73% to 85% kill, after the second application, 100% control was achieved with all oil applications, except 1.25% SO, which provided 93% control. The number of SJS on apple fruit was significantly reduced by all oil treatments; fruit from trees treated with 2.5% PO or 5.0% SO sprays were blemished by 97% to 98% fewer (= 0.6 to 0.8 per fruit) SJS than fruit from control trees (= 30 per fruit).

The first application of 2.5% PO or 5.0% SO to peach trees killed ≈85% of TS (Fig. 5). After the second application of either of these two treatments, kill of TS exceeded 98%. Two applications of 2.5% SO resulted in only 72% control of this scale insect.

Our laboratory and field studies indicate that applications of SO emulsions are promising treatments for managing three species of destructive fruit tree pests. The impacts of SO and PO treatments on populations of key predators and parasitoids of SJS and ERM, however, need to be evaluated. Additional studies are needed to determine the most efficacious, cost-effective, and environmentally safe rates of SO application for a wide array of fruit tree pests.

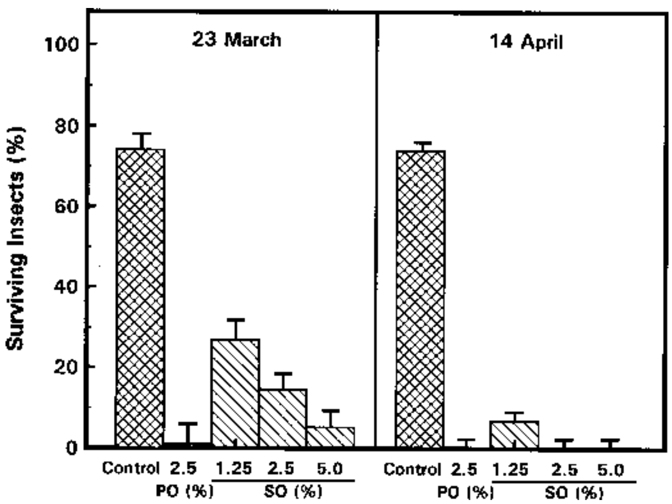

Fig. 4. Control of black-cap stage of San Jose scale in 1993 on dormant apple trees with water-emulsion sprays containing 1.25%, 2.5%, or 5.0% degummed soybean oil (SO) or 2.5% petroleum oil (PO). Treatments were applied on 2 Feb. and 25 Mar.; insect survival was determined on 23 Mar. and 14 Apr. Vertical lines represent one SE.

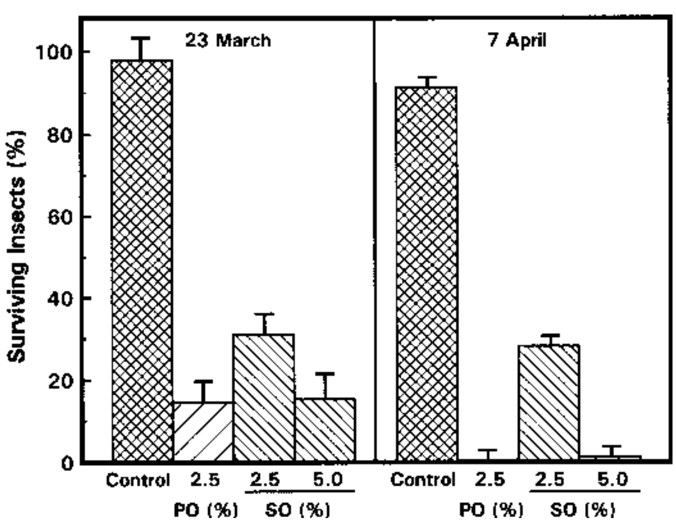

Fig. 5. Control of adult female terrapin scale in 1993 on dormant peach trees with water-emulsion sprays containing 2.5% or 5.0% degummed soybean oil (SO) or 2.5% petroleum oil (PO). Treatments were applied on 2 Feb. and 25 Mar.; insect survival was determined on 23 Mar. and 7 Apr. Vertical lines represent one SE.

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