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To direct, fund, promote and communicate horticultural research, which increases the quality and value of ornamental plants, improves the productivity and profitability of the nursery and landscape industry, and protects and enhances the environment.

Soybean Oil Controls Two-Spotted Spider Mites on Burning Bush[1]

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Abstract

Summer sprays of soybean (*Glycine max* (L.) Merrill) oil were evaluated for efficacy against two spotted spider mites (*Tetranychus urticae* Koch) (TSSM) on burning bush (*Euonymus alatus* Thunb.). Single sprays of 1, 2, or 3% soybean oil or 1% SunSpray reduced TSSM populations by 97–99% compared to water-sprayed controls. Single sprays of 2 or 3% soybean oil were not phytotoxic but suppressed photosynthesis for a short time. In a second experiment, a single spray of 0.75, 1.0, or 1.5% soybean oil reduced the TSSM population by > 95%, compared to the water control. A second spraying of 0.25–1.5% soybean oil resulted in ≥ 93% control of TSSM compared to the water control. A third spray provided little additional TSSM control. Predaceous mites were not initially disrupted by a single spray of soybean oil or SunSpray Ultra- fine spray oil. A single spray of ≤ 1.5% soybean did not significantly reduce photosynthesis. Soybean oil had efficacy against TSSM similar to that of SunSpray and had similar effects on photosynthesis. Soybean oil was less phytotoxic and caused less defoliation of stressed plants than did SunSpray in one experiment but not in two other experiments. Results show that soybean oil could be used in an integrated pest management program for managing spider mites on ornamentals.

Index words: *Tetranychus urticae*, *Euonymus alatus*, botanical oil, horticultural oil, integrated pest management, organic mite control, photosynthesis, phytotoxicity.

Species used in this study: 'Compact' dwarf burning bush (*Euonymus alatus* Thunb. Sieb.'Compactus').

Chemicals used in this study: soybean oil; SunSpray Ultra-Fine oil, Avid.

Significance to the Nursery Industry

This research shows that summer sprays of soybean oil effectively controlled populations of two-spotted spider mites with minimum phytotoxicity to burning bush plants (*Euonymus alatus* Thunb. Sieb.'Compactus'). A single spray of 0.75 or 1.0% or two sprays of 0.25 or 0.5% soybean oil gave effective mite control. Insects and especially mites often develop resistance to synthetic pesticides, making control difficult. No insect species has been reported to develop resistance to vegetable or petroleum oils. Furthermore, soybean oil did not greatly reduce predaceous mite populations. Thus, soybean oil is especially useful for reducing mite populations during the summer. Soybean oil also has the advantages of being a renewable agricultural product and is readily available. This product is very safe to the applicator and to the environment.

Introduction

Petroleum oils have been used in agriculture for pest control for more than 100 years (14) and have been described as being among the best available miticides (11). Mites are especially difficult to control because they frequently develop resistance to miticides. Oils are the only widely used class of miticides to which mites have not developed resistance, even after long-term use (1, 15). Oil sprays may be less disruptive than synthetic pesticides to beneficial predaceous insects and mites (6), thereby making oils particularly useful components in integrated pest management (IPM) programs.

Crutchfield, economist and section leader of Environmental Quality Valuation in the United States Department of Agriculture, suggested in the 1992 Yearbook of Agriculture that agriculture should promote environmental quality by supplying 'environmentally friendly' products that substitute for petroleum products (5). The Environmental Protection Agency (EPA) issued a rule in 1996 that 'establishes an exemption from regulation … for certain pesticides' (17). Several botanical oils, including soybean (*Glycine max* (L.) Merrill), corn (*Zea mays* L.), and garlic (*Allium sativum* L.) oils were exempted from normal pesticide registration because they were relatively nontoxic to humans, non-persistent in the environment, and had no significant adverse effects on the environment. EPA has encouraged the use of environmentally-friendly, renewable resources that can substitute for petroleum products and synthetic pesticides (17).

DeOng and associates (7) reported that cottonseed (*Gossypium* sp.), linseed (*Linum usitatissimum* L.), and castor (*Ricinus communis* L.) oils controlled insects, but were more phytotoxic than petroleum oil. Rock and Crabtree (15) reported that cottonseed oil controlled winter eggs or adult females of European red mite (*Panonychus ulmi* Koch) but was slightly phytotoxic to apple leaves. Butler and Henneberry (4) showed that soybean, corn, sunflower (*Helianthus annuus* L.), safflower (*Carthamus tinctorius* L.), peanut (*Arachis hypogaea* L.), and cottonseed (*Gossypium hirsutum* L.) oils provided between 97 and 99% control of two-spotted spider mites (*Tetranychus urticae* Koch) (TSSM) on several vegetable crops.

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The TSSM are among the most abundant and destructive spider mites on nursery crops (12). Feeding injury by TSSM often causes unacceptable plant appearance (16) and reduces plant photosynthesis (13), which may slow plant growth. However, sprays used to control mites may also reduce photosynthesis. Ayers and Barden (2) found that petroleum oil sprays generally reduced net photosynthetic rates (Pn); however, many synthetic pesticides also had a similar impact on Pn rates. However, Ferree and Hall (8) reported that superior (petroleum) oil sprays had little effect on apple leaf Pn.

Soybean oil was used in our studies because it is the most abundant botanical oil available in the United States (10). Our objectives were to determine if soybean oil sprays 1) were as effective as a petroleum oil in controlling TSSM, 2) were phytotoxic to burning bush foliage, and 3) influenced Pn rates of foliage.

Materials and Methods

Oils. Degummed soybean oil (Central Soya, Fort Wayne, IN) was used throughout the trials. Crude soybean oil, which was used in earlier trials, is less uniform among batches than degummed soybean oil. Soybean oil treatments were formulated by premixing the oil with Latron B-1956 Spreader-Sticker (Rohm and Haas, Philadelphia, PA) at a 10:1 ratio of soybean oil to Latron. Soybean oil is not refined by distillation, as are the petroleum oils; thus, formulations are not described by distillation range. This formulation has a viscosity of 152 centipoise at 25C (77F) (3). The TNsoy1 formulation soybean was agitated and allowed to set for 30–60 min prior to mixing with water in the spray tank. The spray solution was continually agitated in the spray tank by shaking.

SunSpray Ultra-Fine (Sun Company Inc., Philadelphia, PA) petroleum oil was used as a standard to compare with the soybean oil treatments. It is a paraffinic oil with a 92% minimum unsulfonated residue and a 50% distillation point at 212C (414F) (6).

Treatment application. Treatments were sprayed onto plants with a Stihl SR-400 backpack mist blower (Stihl Inc., Virginia Beach, VA). Sprays were applied until runoff, with emphasis of saturating upper and lower leaf surfaces.

Photosynthesis measurement. The top fully expanded leaf of each plant was tagged before spraying, and Pn rates were measured periodically with an ADC-3 model portable infrared gas analyzer (ADC Inc., Hoddenson, UK). The photosynthetic rates (Pn) were measured between 10:00 AM and 2:00 PM when light was >800 $mol \cdot m^{-2} \cdot s^{-1}$ photosynthetic photon flux.

Experiment 1. Research was conducted in early autumn of 1996 to evaluate the effects of soybean oil on 1) mite control efficacy and 2) Pn rates of burning bush foliage. In August 1996, twenty-five two-year-old plants in #1 containers (2.8 liter) were obtained from a commercial nursery. Plants were placed in a randomized complete block design (RCBD) in a greenhouse at the University of Tennessee, Knoxville (UTK), until infested with TSSM. Pre-counts of TSSM were made prior to spraying to ensure high populations. Plants were sprayed on September 20 with the water control; 1, 2, or 3 soybean oil (by vol); or 1% SunSpray. Twenty leaves per plant were randomly selected, removed at the petiole, and immediately brushed with a mite brushing machine (Leedom Enterprises, MiWuk Village, CA) on the seventh and fourteenth days after treatment (DAT). Mites were preserved in 70% ethanol and later counted using a dissecting scope and a counting grid.

The effects of oils on photosynthesis were measured 1 and 11 DAT. The Pn rate of a newly expanded leaf on each plant was measured as described above.

Experiment 2. A second trial was conducted to evaluate the efficacy of lower concentrations of soybean oil for the control of TSSM and to determine the effects of repeated oil sprays on photosynthesis. Forty two-year-old burning bush plants were obtained from a commercial nursery on May 6, 1998, and repotted into #3 containers (7.4 liter). In a greenhouse at UTK, plants were arranged in a RCBD with five replications and eight treatments. To ensure mite infestation, one TSSM-infested raspberry leaflet was placed in the center of each burning bush plant on May 28. By June 11 all burning bush plants were heavily infested with TSSM**.** Plants were sprayed on June12, 17, and 22 as described in Expt.1 with a water control or 0.25, 0.5, 0.75, 1.0, or 1.5% soybean oil. Treatments of 1.0 or 1.5% SunSpray sprays were also included in the experiment. Twenty leaves per plant were collected on the fourth day after each spray (June 16, 21, and 26), placed into white paper containers with lids, and stored at 6C (43F) in a cooler for 1 to 3 days. Leaves were brushed as in Expt. 1 and mites preserved in 70% ethanol until TSSM and the predaceous mites (probably *Phytoseiulus persimilis*) were counted.

Phytotoxicity was observed on June 16 (4 DAT), and plants were rated using a five-point rating scale. Defoliation was evident; therefore, a five-point rating scale was created to rate treatment effects on defoliation: 1 = no defoliation, 2 = slight defoliation (≤ 30%), 3 = moderate defoliation (31% to 60%), 4 = severe defoliation (≥ 61%), but no shoot dieback and 5 = 100% defoliation with shoot dieback. The Pn rates of a newly expanded leaf and a tagged mature leaf were measured on June 12, 13, 16, 18, 20, and 22 and on July 23 using the ADC analyzer.

Experiment 3. A third experiment was conducted to determine if soybean oil and SunSpray differed in phytotoxicity to plants grown in the more stressful environment of a greenhouse versus those grown outdoors. Fifty burning bush plants in #1 containers (2.8 liter) were obtained from a commercial nursery. The plants were relatively free of mites and were sprayed with the miticide Avid (Merck and Co., Inc., Rahway, NJ) on July 6, 1998, to minimize TSSM effects on the plants. In a greenhouse at UTK, twenty-five plants were randomly selected and placed in a RCBD with five replications and five treatments inside a greenhouse. The remaining twenty-five plants were randomized in a RCBD with five replications and five treatments outside the greenhouse. Plants were sprayed as described in Expt.1 with water, 1% soybean oil, 1.5% soybean oil, 1% SunSpray, or 1.5% SunSpray on August 13, 18, and 24 with the treatments. The Pn rates of a newly expanded leaf on each plant were measured on August 13, 17, 19, 23, 25 and 31 as well as September 4 and 7. Foliage phytotoxicity was rated on August 24 and 26 using the scale in Expt. 2.

Data analysis. Data were analyzed by regression analysis with soybean oil concentration as the independent variable

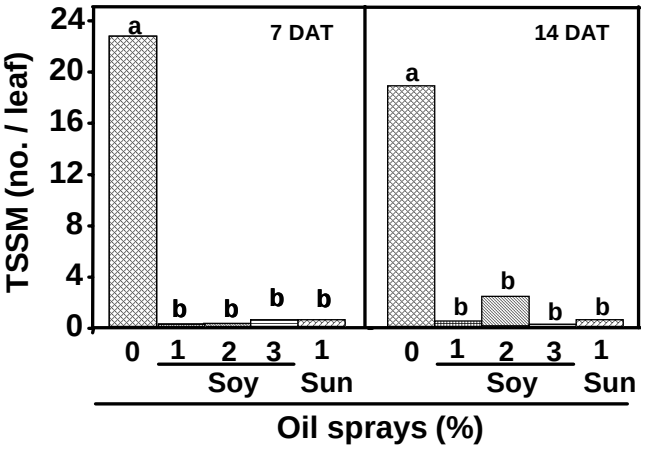

Fig. 1. Effects of soybean oil (Soy)and SunSpray (Sun) sprays on two-spotted spider mites (TSSM) on burning bush leaves 7 and 14 days after treatment (DAT). Letters represent mean separation with Duncan's Multiple Range Test ($P \leq 0.05$). Sprays were applied September 20, 1996.

and mite count data as the dependent variable using REG and NLIN procedures (SAS Institute, Cary, NC). The effects of soybean oil and SunSpray were also analyzed using the GLM procedure, and mean separation was performed with Duncan's Multiple Range Test.

Results and Discussion

Experiment 1. Spraying 1–3% soybean oil reduced mite populations (Fig. 1). Visual examinations indicated that adult mites were killed and eggs were discolored and shrunken within 2 DAT. By 7 DAT, plants sprayed with 1, 2, or 3% soybean oil, or 1% SunSpray had TSSM populations that were reduced by 97–99% compared to the water control (Fig. 1). At 14 DAT, TSSM populations on oil treated plants were still 87–98% lower than those on the control. The 1% rate of soybean oil was as effective as higher rates of soybean oil or 1% SunSpray for reducing TSSM populations.

The oil sprays decreased leaf photosynthesis at 1 DAT (Fig. 2). Soybean oil concentration was negatively correlated with Pn rates ($y = 10.6 – 0.64x$, $r^2 = 98.6$). At 1 DAT, plants treated with 1% SunSpray had lower Pn rates than plants sprayed with 1–3% soybean oil and Pn rates 30% below those recorded for the water control. By 11 DAT the Pn rates of plants sprayed with 1–3% soybean oil or 1% SunSpray were not different from Pn rates of water-sprayed plants.

No phytotoxicity was observed throughout the study. The sprays were applied in September when temperatures were moderate (< 32C, 90F). Although a single spray of 3% soybean oil was applied without visible phytotoxicty, the spray reduced photosynthesis for at least one day.

In conclusion, the lowest tested rate of a single spray of 1% soybean oil controlled TSSM as well as higher rates of soybean oil or 1% SunSpray with little effect on photosynthesis and no phytotoxicity. The highest rate of 3% soybean oil did not cause phytotoxicity but did reduce photosynthesis.

Experiment 2. When sampled 4 days later (June 16), a single spray of 0.25% or 1.5% soybean oil made on June 12 reduced the populations of TSSM by 70% to 97%, respectively (Fig. 3). The numbers of TSSM were significantly related to soybean oil concentration in an decreasing asymptotic manner ($y = 13.76^{-4.4x}$, $r^2 = 99.5$). A single spray of ≥ 0.75% soybean oil reduced the TSSM population by > 95%, compared to the water control. The TSSM populations on water sprayed plants declined from 13.8 to 9.0, and finally to 1.2 TSSM/leaf, on June 16, 21, and 26, respectively, perhaps due to washoff by water spray or due to natural population decline. A similar decreasing asymptotic relationship of soybean oil concentration to TSSM populations ($y = 8.97^{-10.2x}$, $r^2 = 99.5$) existed on June 21 (4 days after the second spray). A second spraying of 0.25–1.5% rate of soybean oil resulted in ≥ 93% control of TSSM populations compared to the water control (9.0 TSSM/leaf). Plants sprayed twice with 0.75–1.5% soybean oil 5 days apart had ≤ 0.1 TSSM/leaf. By June 26 (4 days after the third spray), plants sprayed with 0.25–1.5% soybean oil had < 0.1 TSSM/leaf compared to 2.1 TSSM/leaf on water sprayed plants. Sprays of 1.0% or 1.5% soybean oil tended to reduce TSSM populations to lower levels than SunSpray, but when compared with contrast statements (SAS 6.12, 1996), the effects of the oils were not different ($P = 0.39$).

Predaceous mite populations were more variable than TSSM populations, and the effects of the oils were more difficult to determine. Predaceous mites were not disrupted greatly by the first oil application (Fig. 4). On June 16 (43 DAT), there were scattered distributions of predaceous mites with only plants sprayed with 0.25% soybean oil differing from the water-treated plants. However, on June 21 and 26 the oil-sprayed plants had fewer predaceous mites than the water-sprayed plants. Similar to the effect on TSSM populations, the soybean oil concentration was significantly related in an decreasing asymptotic manner to the number of predaceous mites after the second and third sprays. Predaceous mites were reduced by soybean oil on June 21 ($y = 1.83^{-5.84x}$, $r^2 = 99.9$) and June 26 ($y = 1.57^{-9.53x}$, $r^2 = 99.9$). This decrease in predaceous mites may have been due to direct kill by in-

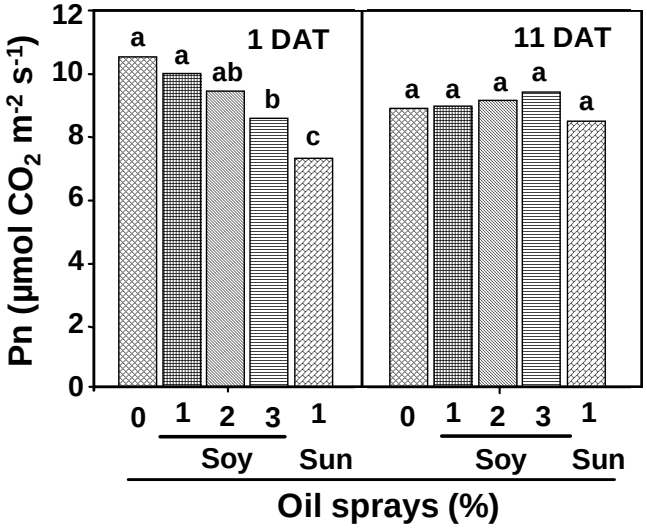

Fig. 2. Effects of soybean oil (Soy)and SunSpray (Sun) sprays on net photosynthetic (Pn) rates of burning bush leaves at 1 and 11 days after treatment (DAT). Letters within dates represent mean separation by Duncan's Multiple Range Test ($P \leq 0.05$).

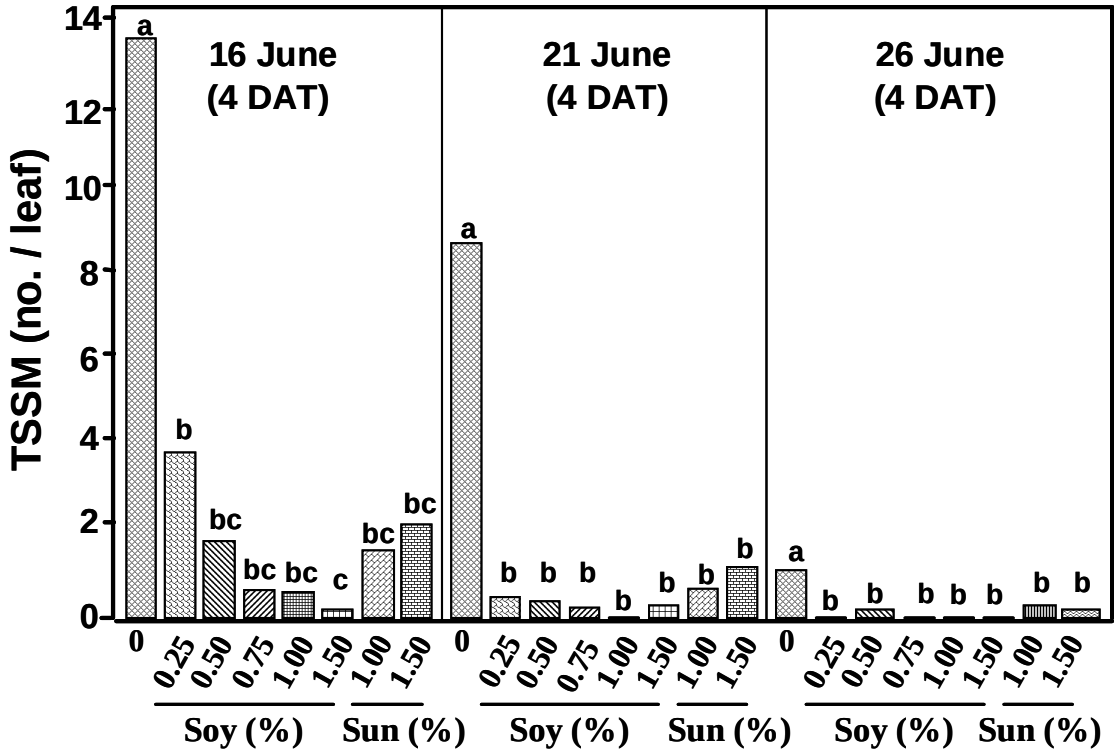

Fig. 3. **Effects of soybean oil (Soy) and SunSpray (Sun) (4 days after treatment (DAT) on June 12, 17, and 22, 1998) on two-spotted spider mites (TSSM) on burning bush. Letters represent mean separation within each date with Duncan's Multiple Range test ($P \leq 0.05$).**

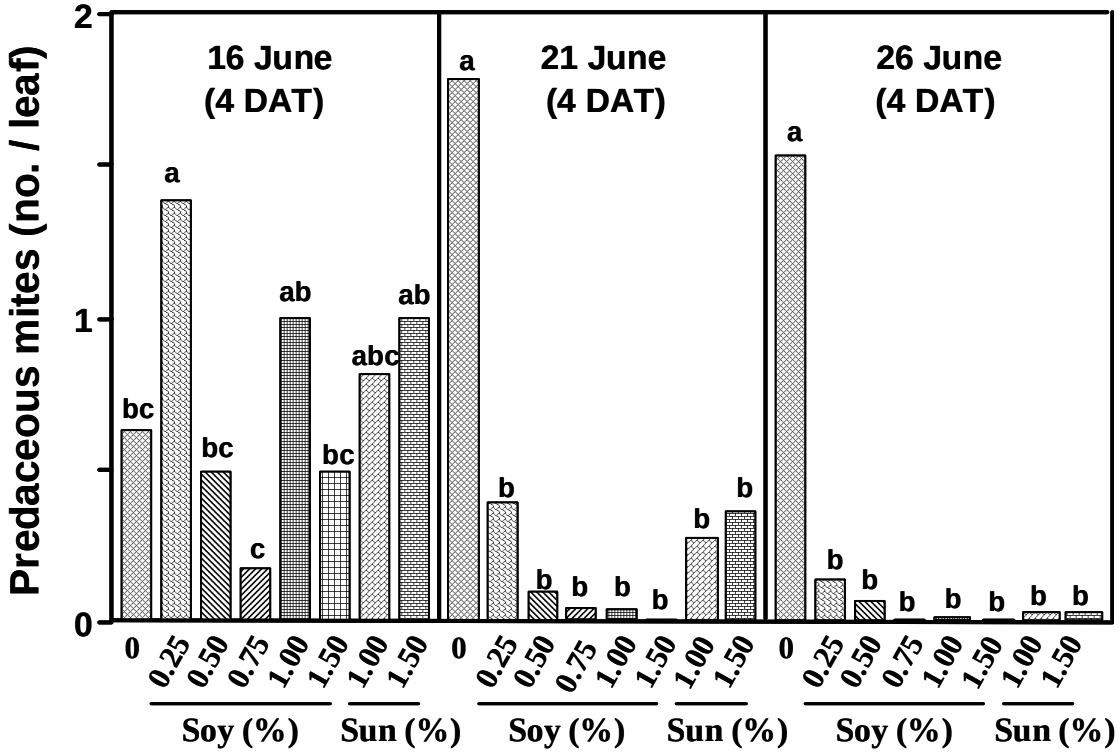

Fig. 4. **Effects of soybean oil (Soy) and SunSpray (Sun) (4 days after treatment (DAT) on June 12, 17, and 22, 1998) on predaceous mites on burning bush. Letters represent mean separation within each date with Duncan's Multiple Range test ($P \leq 0.05$).**

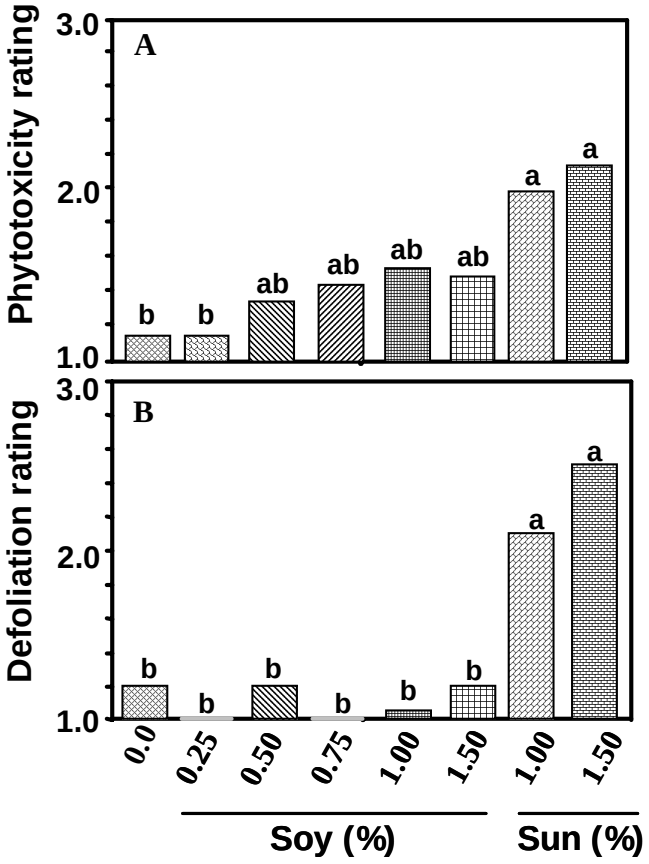

Fig. 5. **A) Phytotoxicity and B) defoliation of mite-infested burning bush plants four days after spraying water, soybean oil (Soy) or SunSpray (Sun). Phytotoxicity rating scale: 1 = no visible damage; 2 = slight yellowing on some leaves; and 3 = moderate yellowing on most leaves . Defoliation ratings scale: 1 = no defoliation; 2 = ≤ 30% defoliation; and 3 = 31 to 60% defoliation. Letters represent mean separation by Duncan's Multiple Range Test ($P \leq 0.05$).**

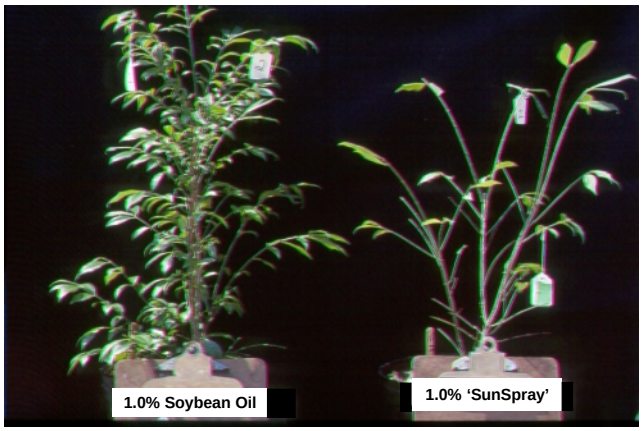

Fig. 6. **Burning bush plants on June 22 that had been sprayed with 1% soybean oil or 1% SunSpray on June 12, 16, and 21.**

terference with gas exchange. However, since there were few differences in predaceous mite numbers after the first spray it is more probable that numbers declined due to migration from oil-treated plants. Number of predaceous mites on plants sprayed with soybean oil did not differ from the number on SunSpray sprayed plants ($P = 0.44$).

Phytotoxicity and defoliation were noted on June 16, 4 DAT and 1 day before the second spray (Fig. 5). The plants had been kept in a greenhouse with fans and cooling pads. The fans malfunctioned at 2 DAT, and maximum daytime temperatures were ≥ 40C (104F) for two days. Soybean oil sprays tended to cause slight foliar phytotoxocity, though not statistically significant, but did not cause defoliation. Later data are not available, but plants sprayed with SunSpray were almost completely defoliated, while soybean oil-sprayed plants had minor defoliation by the end of the experiment (Fig. 6).

The oil sprays again influenced photosynthesis (Fig. 7). The first oil sprays on 12 June did not significantly affect leaf Pn rates on 1 or 4 DAT. The Pn rates of plants sprayed with 0.75% soybean oil tended to be low before spraying (June 12) and throughout the trial. All second-time oil sprays reduced Pn rates ($P \leq 0.01$) on June 18 (1 DAT), but the rates were not significantly lower ($P \leq 0.05$) than Pn of control plants on June 20 (3 DAT). All third-time oil sprays had reduced Pn rates ($P \leq 0.05$) by June 22 (1 DAT) but not at 2 DAT, when compared to Pn rates of control plants. Multiple applications of oil are feasible and produce only short term reductions in photosynthesis. The Pn rates of SunSpray-treated plants tended to be slightly lower than those of soybean oil-treated plants at similar concentrations but were not significantly different when compared by contrast statements.

In summary, as soybean oil concentration of a single spray increased from 0.25% to 1.5%, the population of TSSM was reduced. A single spray of 0.75% soybean oil reduced mite populations by more than 95%. However, two sprays of 0.25 or 0.5% soybean oil 5 days apart also reduced the TSSM population by > 93% compared to water control. Predaceous mites were initially harmed less by oil sprays than were TSSM, which is desirable for an IPM program. Fouche et al. (9) reported that a summer application of Volck Supreme Oil reduced TSSM and European red mites on pear without reducing populations of the western predator mite, *Galandromus occidentalis.*

Oil sprays applied to mite- and temperature-stressed plants caused phytotoxicity and defoliation. To minimize phytotoxicity, Davidson et al. (6) suggested not spraying oils when temperatures were above 32C (90F). The presence of high population densities of TSSM can cause defoliation. Perhaps the high temperatures and presence of a large TSSM population made burning bush foliage more susceptible to oil phytotoxicity. In this study, soybean oil caused less phytotoxicity than SunSpray.

A single spray of oil did not significantly affect photosynthesis; however, the second and third sprays 5 days apart decreased Pn rates. Thus, multiple sprays may reduce photosynthesis for a longer time period than a single spray. Oils were not washed off in the greenhouse and possibly accumulated with the repeated sprays.

Experiment 3. The photosynthesis data for plants grown outdoors and in a greenhouse, as well as for old and new leaves at time of spray, were combined because there were no interactions of treatment and location or of treatment and leaf age (Fig. 8). A single spray of 1 or 1.5% SunSpray or soybean oil did not reduce the Pn rates at 4 DAT (August

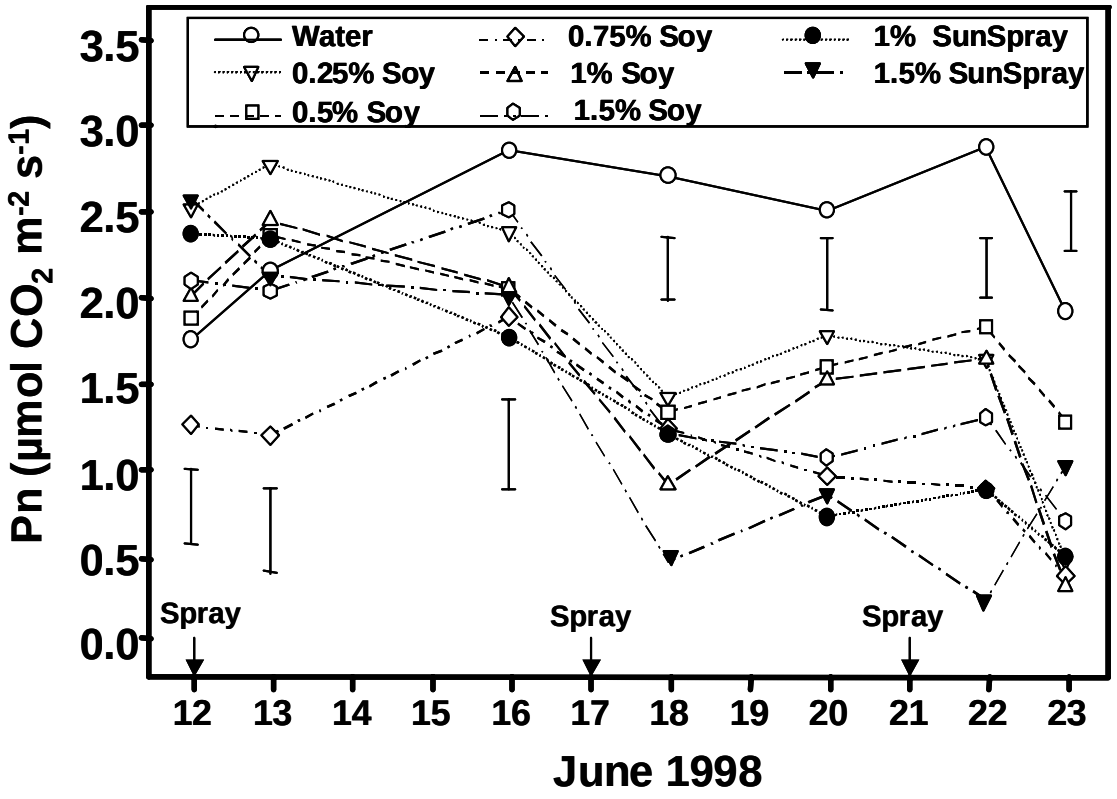

Fig. 7. **Effect of repeated soybean oil (Soy) or SunSpray sprays on net photosynthetic (Pn) rates of burning bush leaves. Vertical bars represent one SE.**

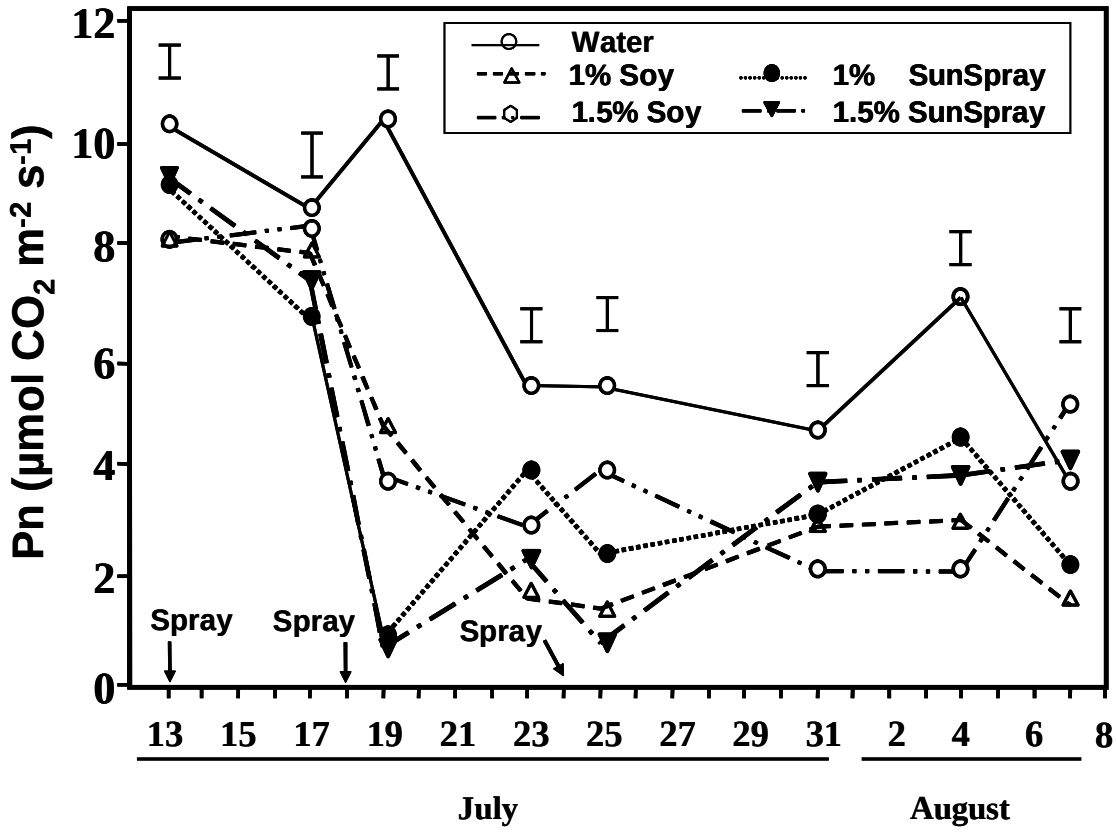

Fig. 8. **Effects of multiple sprays of soybean oil (Soy) or SunSpray on net photosynthetic (Pn) rates of burning bush foliage. Each point is mean of 10 observations. Vertical bars represent one SE.**

17). However, 1 day after a second spray of 1 or 1.5% soybean oil, the Pn rates were <50% below those of water control. The Pn rates of plants sprayed with the second treatment of SunSpray were reduced significantly ($P \leq 0.01$) to <10% of the water controls. Spraying 1 or 1.5% soybean oil or 1.5% Sunspray still reduced Pn rates 5 days after the second spraying. After the third spray on July 24, Pn rates tended to be reduced for 11 DAT. When analyzed over all measurement dates, soybean oil did not affect Pn rates differently than SunSpray ($P = 0.26$).

None of the sprays caused significant phytotoxicity or defoliation of plants grown outdoors or in the greenhouse. However, plants sprayed with 1.5% soybean oil or 1.5% SunSpray and located near the greenhouse exhaust fans had minor phytotoxicity and slight defoliation (10–15%) by September 7. In general, the plants were exposed to less stress than in Expt. 2. The plants had very low mite populations and were exposed to a maximum air temperature of 35C (95F) during the trial.

A treatment of a single spray of 2 or 3% soybean oil during the summer can control TSSM without causing phytotoxicity. However, a single spray of 0.75 or 1.0% soybean oil controlled TSSM and may be an adequate spray rate. The higher rates of soybean oil suppresses photosynthesis for a short time, but the photosynthesis capacity recovers. In Expt. 2, single sprays of ≤ 1.5% soybean did not significantly reduce photosynthesis.

Two sprays of 0.5% or even 0.25% soybean oil 5 days apart may be an alternate approach to controlling TSSM. An advantage of repeated sprays may be that adults or eggs not killed by the first spray may be controlled by the second spray. A disadvantage of repeated sprays may be that accumulated oil may suppress photosynthesis for several days if there is no rain or overhead irrigation between sprays. A third spray extended the time of reduced photosynthesis with little additional TSSM population control.

The spraying of soybean oil to control mites is very feasible and is an environmentally safe alternative to using synthetic pesticides. The soybean oil/Latron B-1956 formulation performed very similarly to SunSpray efficacy against TSSM and effect on photosynthesis. A disadvantage of this soybean oil formulation is that it separates from water in the spray tank more quickly than SunSpray. Thus, better emulsified soybean oil formulations need to be developed. Soybean oil caused less foliar phytotoxicity and defoliation than SunSpray in an experiment in very stressful conditions of high temperatures and mite populations. However, that difference was not confirmed in a later experiment under less stressful conditions.

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