vacuum seeders tested to drop multiple seeds, with less errors made in the form of misses or skips. Visual observation by the authors of the vacuum plates during operation of the vacuum seeders indicated that the seed was being singulated with few misses and multiples. The loss in uniformity must have occurred as the plate rotated down to the release point, with seed not being released or being released erratically, resulting in nonuniform spacing. Further testing must be done to pinpoint where precision is being lost with the vacuum seeders.

Conclusions

The Stanhay belt seeder uniformly seeded spherical (cabbage) and nearly spherical (onion) seeds but could not singulate elongated seeds (carrot and cucumber) as well as the vacuum seeders. Although the vacuum seeders singulated elongated seed better than the belt seeder, none of the seeders singulated or spaced cucumber and carrot seed adequately. Seeding uniformity of all seeders with spinach seed was also insufficient.

The belt seeder had the lowest PREC value with all seeds tested, indicating that the belt seeder was more effective than the vacuum seeders at spacing the seeds uniformly within the target area when outliers were removed. Evaluating the data using Kachman and Smith's (1995) criteria cast doubt on our previous assumptions that vacuum seeders were effective at seed singulation and precision seed spacing.

Overall, the belt seeder was the most uniform and precise of the seeders tested. Seeding uniformity of the belt seeder was good when seeding spherical and nearly spherical seed. When seeding elongated or angular seeds with the belt seeder, multiple seed drops and reduced seed spacing uniformity should be expected.

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Evaluating Biorational Pesticides for Controlling Arthropod Pests and their Phytotoxic Effects on Greenhouse Crops

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Additional index words. greenhouse pests, horticultural oils, insecticidal soap, neem extract (Margosan-O and Azatin), phytotoxicity, plant growth

Summary. **Horticultural oil and insecticidal soap were as effective as conventional insecticides and miticides in controlling a variety of sap-feeding insects and mites on common greenhouse crops. Neem extract (Margosan-O or Azatin) was less consistent and provided intermediate to good control of a variety of sap-feeding insects and mites on common greenhouse crops. Except for purple heart (*Setcreasea purpurea* K. Schum. & Sydow) and wax ivy (*Hoya carnosa* R. Br.), repetitive sprays of horticultural oil, insecticidal soap, and neem extract (Azatin) did not seem to cause any noticeable phytotoxicity or effect the growth of 52 species or cultivars of bedding plants and 13 species of foliage plants examined in this study. Repetitive sprays of horticultural oil and insecticidal soap significantly affected plant height and final quality of some poinsettia cultivars evaluated in this study.**

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The concern over the use of toxic chemicals for controlling greenhouse pests is increasing, with more emphasis being placed on the use of softer more environmentally friendly pesticides as part of integrated pest management (IPM) practices. A benefit of materials such as horticultural oils, insecticidal soaps, and neem is that they have been shown to be relatively easy on beneficial organisms (predators and parasitoids) because of their short-term residual activity and because they kill the beneficial if contacted directly, thus facilitating their incorporation into an integrated pest management program (Davidson et al., 1991; Gibbons, 1992; Hepburn, 1989; Hoelmer et al., 1990). In spite of their potential effectiveness in controlling important greenhouse pests, there is still a reluctance on the part of many growers to incorporate horticultural oils, insecticidal soaps, and botanical insecticides into IPM programs. This may be due to concerns about phytotoxicity and stunting of plant growth or lack of confidence in the efficacy of these products, which might lead to customer dissatisfaction and loss of marketability.

A group of studies were conducted to evaluate 1) efficacy of these materials in controlling common greenhouse pests, 2) potential phytotoxicity after repeated sprays on a wide variety of greenhouse crops, and 3) potential effects on plant growth after repetitive spray applications.

Materials and methods

Pesticides tested were horticultural oil (SunSpray UF), insecticidal soap (M-Pede or Safers), neem extract (Margosan-O or Azatin), acephate (Orthene 75SP), fenopropathrin (Tame 2.4 EC), cyfluthrin (Tempo 2EC), fluvalinate (Mavrik), bifenthrin (Talstar 10WP), dienochlor (Pentac), and abamectin (Avid). Rates are listed in Table 1. All pesticides were applied to all plant surfaces with a hand-held, pump-up sprayer to the point of runoff.

Unless otherwise stated, each plant served as a single replication with five to forty-eight replications per treatment per study, and sample leaves or growing tips were randomly selected for evaluating the insecticidal and miticidal efficacy and for the growth measurement studies. Studies were conducted at greenhouses located at The Morton Arboretum, Lisle, Ill., and College of DuPage (COD), Glen Ellyn, Ill. The aforementioned greenhouses were equipped with horizontal airflow fans (HAF) and good air circulation. No whitewash was used but, 50% shadecloth was present on the COD greenhouse.

Arthropods tested

APHIDS. Wandering Jew ivy (*Tradescantia fluminensis* Vell.) and German ivy (*Senecio mikanioides* Otto) plants heavily infested with melon aphid (*Aphis gossypii* Glover) growing in 4-inch (10-cm) pots were selected for study.

Chrysanthemums (*Chrysanthemum ×morifolium* Ramat.), cineraria (*Senecio cruentus* Masson), and pansies (*Viola tricolor* var. *hortensis* DC.) infested with green peach aphid (*Myzus persicae* Sulzer) growing in 4-inch (10-cm) diameter and 2.5-gal (4-L) pots were used.

Before spraying, at 0 days posttreatment (0 DPT) and at 3 and 7 DPT, one leaf (wandering Jew ivy) or a 1-inch-long (2.5-cm) growing tip (German ivy, chrysanthemums, pansies, and cineraria) was examined, and the total number of live aphids was recorded. Aphids that were shriveled, discolored, or that did not exhibit movement after repeated prodding were considered dead. Greenhouse temperature at the time of application was ≈70 °F (21 °C) to 75 °F (24 °C) with 55% relative humidity and partly cloudy skies.

CITRUS MEALYBUG. Jade (*Crassula argentea* Thunb.), pothos (*Scindapsus pictus* Hassk.), and coleus 'Vicks' (*Coleus×hybridus* Voss.) plants infested with citrus mealybug (*Planococcus citri* Risso) growing in 3-inch (8-cm), 4-inch (10-cm), and 6-inch (15-cm) pots, respectively, were used for study. Before spray application (0 DPT) and at 3 and 11 DPT, a 1-inch-long (2.5-cm) growing tip was selected and examined, and the total number of live immature and adult mealybugs was recorded. Immature and adult mealybugs that were shriveled, darkened, and failed to exhibit movement after repeated prodding were considered dead. Greenhouse conditions were as described for aphid evaluations.

GREENHOUSE WHITEFLY. Buckthorn (*Rhamnus cathartica* L.) seedlings and poinsettia (*Euphorbia pulcherrima* Willd. 'V-14 Glory') plants growing in 6-inch (15-cm) pots and infested with the greenhouse whitefly (*Trialevrodes vaporariorum* Westwood) were chosen for evaluation.

Treatments were applied to buckthorn seedlings three times at weekly intervals. Before spraying (0 DPT) and 1 week after the last spray, two leaves were randomly selected from each buckthorn seedling and a 0.75 × 1.25-inch (1.9 × 3.2-cm) area of each leaf was randomly selected and sampled. Whitefly nymphs and pupae within the leaf sample are were examined for mortality. Nymphs and pupae that were shriveled or desiccated were considered dead.

Treatments were applied to poinsettias at 3- to 4-d intervals for six to seven applications to control immature whiteflies. Before spraying (0 DPT), 14

Table 1. Application rates for insecticides and miticides evaluated in these studies.

Treatment	Rates	Company
SunSpray UF spray oil	2% by volume/gal (L)	Mycogen Corp., San Diego
M-Pede insecticidal soap	2% by volume/gal (L)	Mycogen Corp. San Diego
Margosan-O	0.16 fl oz/gal (4.7 $mL \cdot L^{-1}$)	Grace-Sierra, Milpitas, Calif.
Azatin	0.16 fl oz/gal (4.7 $mL \cdot L^{-1}$)	AgriDyne, Salt Lake City, Utah
Orthene 75SP	0.05 oz/gal (1.4 $g \cdot L^{-1}$)	Valent Corp. Walnut Creek, Calif.
Tame 2.4 EC	0.002 fl oz/gal (0.05 $mL \cdot L^{-1}$)	Valent Corp. Walnut Creek
Tempo 2EC	0.002 fl oz/gal (0.05 $mL \cdot L^{-1}$)	Mobay Corp. Kansas City, Mo.
Mavrik	0.004 fl oz/gal(0.10 $mL \cdot L^{-1}$)	Sandoz Corp. Des Plaines, Ill.
Talstar 10WP	0.5 oz/gal (14 $g \cdot L^{-1}$)	FMC Corp. Philadelphia
Avid	0.008 fl oz/gal (0.2 $mL \cdot L^{-1}$)	Merck Inc. Rahway, N.J.
Pentac	0.016 fl oz/gal (0.4 $mL \cdot L^{-1}$)	Sandoz Corp. Des Plaines

d after the first treatment application and 1 week after the last application, one leaf was selected and a 0.5 × 1.25-inch (1 × 3.2-cm) area of each leaf was used as the sampling area. Mortality was determined as described above.

Two-spotted spidermite. Spidermite (*Tetranychus urticae* Koch) infested marigolds (*Tagetes patula* L. 'Janie Bright Yellow') growing in 4-inch (10-cm) pots were used. Before spraying (0 DPT) and at 3, 6, and 11 DPT, one leaf was selected from each plant and the total number of live, immature, and adult mites was recorded. Mites that were shriveled or distorted were considered dead. Greenhouse temperature at the time of application was 75 °F (24 °C) with 50% relative humidity.

Phytotoxicity and growth studies

Bedding plants. Pesticide rates are listed in Table 1. Fifty-two species and cultivars of common bedding plants were evaluated: impatiens (*Impatiens balsamina* L. 'Accent', 'Impulse', 'Super Elfin', 'Blitz'), begonia (*Begonia semperflorens-cultorum* Hort. 'Cocktail', 'Vodka', 'Olympia'), marigold (*Tagetes patula* L. 'Inca', 'Perfection', 'Hero'), petunia (*Petunia* ×*hybrida* Vilm.-Andr. 'Carpet' and 'Dream'), coleus (*Coleus* ×*hybridus* Voss. 'Wizard Mix'), *Dianthus barbatus* L. 'Telstar', snapdragon (*Antirrhinum majus* L. 'Tahiti'), vinca (*Vinca minor* L. 'Cooler'), and geranium (*Pelargonium* ×*domesticum* L. 'Pinto Quick Silver').

Plugs were transplanted into flats containing 1204 inserts (48 cells per flat) with a soilless mix and were grown in the greenhouse with 50% shadecloth. The plants were watered as needed with a constant liquid feed of a 15–16–17 fertilizer at 150 ppm N. Daytime greenhouse temperatures averaged 74 °F (23 °C) with a night temperature of 61 °F (16 °C) and ≈50% relative humidity. Temperatures at the time of spraying ranged from 68 °F (20 °C) to 82 °F (28 °C). Once the plants were well established, treatments were applied weekly for 6 weeks.

Plants were monitored weekly for signs of phytotoxicity and flower damage using the rating scale below. At the completion of the six sprayings, six plants per cultivar were randomly selected and their height was measured to the nearest 0.04 inch (1.0 mm). All plants and flowers were rated for appearance using a rating scale of 0 to 5 with 0 = no apparent damage; 1 = slight yellowing of the flowers or foliage; 2 = light burn of flower or leaf edge; 3 = flower, leaf edge, and growing tip burn; 4 = stunting and extensive dieback of flowers and leaves; and 5 = death.

Bedding plant seedlings. In a related study, three petunia cultivars ('Mariner', 'Summer Madness', and 'Red Madness'), three marigold cultivars ('Perfection Yellow', 'Perfection Orange', and 'Dainty Marietta'), and five impatiens cultivars ('Accent Mix', 'Accent White', 'Super Elfin Blush', 'Super Elfin Orange', and 'Blitz White') were treated at label and two-times label rate for 4 weeks at weekly intervals. The two-times label rate was included to determine an upper range of plant tolerance for these particular treatments. Plants were situated inside a plexiglass greenhouse growing in eight packs with six packs per flat. There were 48 single plant replications per treatment. At the beginning of the study, petunias and impatiens were in the three-leaf stage 0.75 to 1.25 inches (2 to 3 cm) and marigolds were in the four-leaf stage 2 to 3 inches tall (5 to 8 cm).

Temperature at the time of application was from 68 °F (20 °C) to 82 °F (28 °C) and relative humidity was 60% to 70% with partly cloudy to clear skies. A minimum overnight temperature of 63 °F (17 °C) was maintained throughout the study. Plants were watered using overhead irrigation with a hose and watering wand. A 15–15–17 fertilizer at 200 ppm N was used. Throughout the study, plants were examined every 3 to 4 d for evidence of phytotoxicity. Three days after the last (fourth) spray, a final phytotoxicity evaluation for foliage and flowers was conducted and height measurements were taken. Plants were evaluated using the same rating scale as described above.

Foliage plants. Thirteen common species of foliage plants growing in 4-inch (10-cm) pots were used in this study. Species evaluated included purple heart (*Setcreasea purpurea* K. Schum. & Sydow), Wandering Jew ivy (*T. fluminensis*), Peperomia ivy (*Peperomia obtusifolia* L.), *Z. pendula*, English ivy (*Hedera helix* L.), Swedish ivy (*Plectranthus australis* R. Br.), wax ivy (*Hoya carnosa* L.f.), German ivy (*Senecio mikanioides* Otto), philodendron (*Philodendron bipennifolium* Schott), pothos ivy (*Epiprenum aureum* Linden & Andren), goldfish plant (*Columnea microphylla* Klotzch & Hanst.), weeping fig (*Ficus benjamina bipennifolium* Schott), and jade (*Crassula argentea* Thunb.). The plants were grown in a glass greenhouse fitted with 50% shadecloth with a mean temperature of 64 °F (18 °C) and 55% relative humidity.

Treatments were applied at weekly intervals for 6 weeks. Plants were examined weekly throughout the study for evidence of phytotoxicity. Following the sixth and final spray, the most recent fully developed leaf on each plant was marked. To evaluate the effect of the treatments on plant growth, 1 month after the last spray, 10 plants per species for each treatment were randomly selected and the number of newly developed nodes distal to the marked leaf was counted and recorded.

Poinsettias. Six poinsettia cultivars were evaluated: 'Annette Hegg', 'Angelica White', 'Freedom Red', 'Jolly Red', 'Red Sails', and 'Supjibi'.

Before being potted, cuttings were inspected for all life stages of whiteflies, including eggs. All cuttings with two or more whitefly nymphs were dipped in a 1% SunSpray UF horticultural oil and flagged. No adults were observed. Flagged cuttings were inspected 7 days posttreatment for egg and immature whitefly mortality. After being flagged, cuttings were immediately transplanted into 4-inch (10-cm) plastic pots and placed on benches on 10 × 10-inch (23 × 23-cm) spacings. After transplanting and again 1 month later, all pots were drenched with Banrot 40WP at 9 oz (255 g) per 100 gal (380 L) of water. No other applications were used. Fertilization with 15–16–17 was initially applied at a rate of 350 ppm N. After pinching, fertilizer rates were dropped to 250 ppm N to avoid a postpinch rapid growth flush. Plants were watered with clear water only and no fertilizer the last 2 weeks of the schedule to allow for hardening off just before sale.

Soil tests were conducted throughout the cropping cycle to monitor for nutrient deficiencies and pH levels. No black cloth was used for flower initiation. Daytime greenhouse temperatures averaged 75 °F (24 °C) and overnight temperatures averaged 68 °F (20 °C).

Beginning 9 weeks after plants were transplanted, spray treatments of horticultural oil (2%), insecticidal soap (2%), and neem extract (Azatin) 0.17 fl oz/gal (4.7 $mL \cdot L^{-1}$) were applied either weekly or twice per week for 9 weeks. Plants were monitored twice a week for evidence of phytotoxicity. At the comple-

Table 2. Effects of various insecticides on immature and adult melon aphids on greenhouse grown plants at College of DuPage greenhouses, Glen Ellyn, Ill., 1993.

	Mean number of live immature and adult melon aphids[z]					
	Wandering Jew ivy[y]			German ivy[y]		
Treatment	0 DPT[x]	3 DPT	7 DPT	0 DPT	3 DPT	7 DPT
SunSpray UF oil 2% by volume/gal (L)	16 a	0 a	2 a	25 a	0 a	0 a
M-Pede 2% by volume/gal (L)	14 a	1 a	4 a	23 a	0 a	0 a
Margosan-O 0.16 fl oz/gal (4.7 mL·L–1)	19 a	1 a	1 a	26 a	2 a	1 a
Orthene 0.05 oz/gal (1.4 g/L)	18 a	0 a	0 a	---	---	---
Tame 2.4E 0.002 fl oz/gal (0.5 $mL \cdot L^{-1}$)	---	---	---	22 a	0 a	0 a
Control	19 a	25 b	20 b	21 a	30 b	35 b

[z]Values within columns followed by the same letter are not significantly different ($P < 0.05$; Student-Neuman-Keuls multiple comparison test).
[y]Five and ten single-plant replications per treatment for wandering Jew ivy and German ivy, respectively.
[x]DPT = days posttreatment.

tion of the spray schedule, all plants were rated for appearance and saleability using a scale of 1 to 5, with 1 = excellent, 2 = good, 3 = average, 4 = poor, and 5 = dead. All plants of each treatment group and each cultivar were measured to the nearest 0.04 inch (1.0 mm) for total height midway through the cropping cycle and at the end of the cropping cycle. No attempt was made to monitor for nutrient levels through tissue analysis or to measure respiration rates following spray applications.

Statistical analysis

Data were subjected to a one-way ANOVA. Means were compared using the Student-Neuman-Keuls (SNK) multiple comparison test (Duncan, 1955). Data were analyzed using SigmaStat for Windows (Jandel Scientific, 1992).

Results and discussion

Insecticidal efficacy studies

APHIDS. Horticultural oil (SunSpray UF) and insecticidal soap (M-Pede) were as effective at controlling the melon aphid and green peach aphid (GPA) as the synthetic organophosphate insecticide acephate (Orthene) and the synthetic pyrethroid insecticide fenopropathrin (Tame) used at 3 and 7 DPT (Table 2). Neem extract (Margosan-O) was as effective as the other treatments at controlling melon aphids on wandering Jew ivy, German Ivy, and chrysanthemum, but failed to provide adequate aphid control on *Cineraria* and pansy (Tables 2 and 3). Bethke and Parrella (1991) found horticultural oil and insecticidal soap tank-mixed with acephate (Orthene) to be effective in controlling GPA on chrysanthemums. In studies by Redak and Bethke (1993), insecticidal soap provided some measure of control of cotton aphid on chrysanthemum, but actual aphid numbers were not significantly different from the controls. The short-term control of horticultural oil, insecticidal soap, and neem extract (Margosan-O) of aphids on pansy could be a function of plant structure and aphid colonizing behavior. A study by Vehrs et al. (1992) revealed that the GPAs tend to frequent the upper leaves of chrysanthemums and continue to move upward as the plant grows compared to the cotton aphid (*Aphis gossypii* Glover). We strived for thorough spray coverage in all applications, but, it is possible that some GPAs may have been missed or escaped contact with the treatments due to their location on the plant, plant growth habits, or plant structure. These factors may have facilitated or enhanced the quick population rebound observed by 7 DPT (Table 3). Failure of neem extract (Margosan-O) to control aphids on cineraria may have been affected by the type of host plant (Schmutterer, 1990). Lowry et al. (1993) found that neem provided better control of green peach aphid (*M. persicae*) on pepper than rutabaga. Soil drenches of neem extract (Margosan-O) reduced numbers of leafhoppers on marigold and chrysanthemums but not on zinnias (Jacobson, 1990).

Resistance by the GPA to synthetic pyrethroids is well known (Hussey et al., 1969; Robb et al., 1986) and may explain the failure of cyfluthrin (Tempo 2E) to control aphids on cineraria in this study. No phytotoxicity was observed on any of the treated plants.

CITRUS MEALYBUG. Control of citrus mealybug by horticultural oil, insecticidal soap, and neem extract (Azatin) was variable (Table 4). Horticultural oils provided excellent control of citrus

Table 3. Effects of various insecticides on immature and adult green peach aphid on greenhouse grown plants, College of DuPage greenhouses, Glen Ellyn, Ill., 1993.

	Mean number of live immature and adult green peach aphids[z]								
	Cineraria[y]			Pansy[y]			Chrysanthemum[y]		
Treatment	0 DPT[x]	3 DPT	7 DPT	0 DPT	3 DPT	7 DPT	0 DPT	3 DPT	7 DPT
Sun Oil 2% by volume/gal (L)	25 a	0 a	0 a	33 a	6 a	19 a	41 a	0 a	0 a
M-Pede 2% by volume/gal (L)	25 a	0 a	0 a	22 a	3 a	21 a	39 a	0 a	1 a
Azatin 0.16 fl oz/gal (4.7 $mL \cdot L^{-1}$)	25 a	24 b	23 b	37 a	4 a	14 a	39 a	5 a	4 a
Tempo 0.002 fl oz/gal (0.05 $mL \cdot L^{-1}$)	25 a	27 b	35 b	---	---	---	45 a	23 b	17 b
Control	25 a	30 b	37 b	43 a	36 b	21 a	44 a	46 c	50 c

[z]Values within columns followed by the same letter are not significantly different ($P < 0.05$; Student-Neuman-Keuls multiple comparison test).
[y]Seven, eight, and six single-plant replications per treatment for cineraria, pansy, and chrysanthemum, respectively.
[x]DPT = days posttreatment.

Table 4. Effects of various insecticides on immature and adult mealybugs on greenhouse plants, College of DuPage greenhouses, Glen Ellyn, Ill., 1993.

	Mean number of live mealybugs[z]						
	Jade[y]		Pothos vine[y]		Vicks[y] coleus		
Treatment	0 DPT[x]	4 DPT	0 DPT	4 DPT	0 DPT	11 DPT	21 DPT
Sun Oil 2% by volume/gal (L)	22 a	0 a	34 a	1 a	37 a	1 a	0 a
M-Pede 2% by volume/gal (L)	24 a	24 b	42 a	9 a	47 a	5 a	0 a
Azatin 0.16 fl oz/gal (4.7 $mL \cdot L^{-1}$)	23 a	23 b	34 a	11 a	66 a	6 a	0 a
Tempo 2E 0.002 fl oz/gal (0.05 $mL \cdot L^{-1}$)	---	---	---	---	61 a	3 a	0 a
Control	20 a	21 b	44 a	47 b	66 a	29 b	14 b

[z]Values within columns followed by the same letter are not significantly different ($P < 0.05$; Student-Neuman-Keuls multiple comparison test).
[y]Six , six, and 14 single-plant replications per treatment for jade, pothos vine, and coleus 'Vicks', respectively.
[x]DPT = days posttreatment.

mealybug on jade and pothos vine by 4 DPT and coleus 'Vicks' by 11 DPT (Table 4). Horticultural oils have been also shown to act as a repellant discouraging egg deposition and feeding by certain sap-feeding insects (Davidson et al., 1991) It is supposed that the residual oil film my inhibit scale crawlers from attaching to plant tissue (Davidson et al., 1991). Since soft scales and mealybugs have similar feeding behavior and habits, it is possible that the horticultural oil treatment also acted as a repellant, inhibiting mealybug crawler attachment and colonization. Insecticidal soap and neem extract (Azatin) failed to control citrus mealybug on jade plants (Table 3) but were effective in controlling citrus mealybug on pothos vine and coleus 'Vicks' by 4 and 11 DPT, respectively (Table 4). Failure of mealybug control on jade plants is a mystery but could be due in part to the heavy leaf cuticle and plant structure of jade plants, which may have contributed to increased plant repellency and runoff of the insecticidal soap and neem extract (Margosan-O) treatments enhancing mealybug survival, establishment, and colonization. A related but more remote explanation could be due to only one application of insecticidal soap and neem extract (Margosan-O). Most control recommendations call for multiple applications due to an extended crawler emergence period of 14 to 21 d. Lack of an insecticidal soap residual and the slowing action of neem extract (Margosan-O) may partially explain the lack of acceptable mealybug control on jade plants.

Horticultural oil, insecticidal soap, and neem extract (Margosan-O) were as effective as the synthetic pyrethroid cyfluthrin (Tempo 2E) at controlling citrus mealybug on coleus 'Vicks' (Table 4). No phytotoxicity was observed on any of the treated plants.

Greenhouse whitefly. Compared to the pyrethroid insecticides cyfluthrin (Tempo 2E), fluvalinate (Mavrik), and bifenthrin (Talstar 10WP), horticultural oils (SunSpray UF), insecticidal soap (M-Pede), and neem extract (Margosan-O) provided comparable control of greenhouse whitefly on buckthorn seedling plants by 21 DPT and on poinsettia plants by 15 DPT (Table 5). Compared to horticultural oils and insecticidal soap, mortality for whiteflies on poinsettia plants treated with neem extract (Margosan-O) was slower not reaching horticultural oil and insecticidal soap control levels until 35 DPT (Table 5).

Our results agree with Bethke and Redak (1991), who found that greenhouse whitefly nymphs infesting *Gerbera* and lantana plants were reduced using insecticidal soap but were not always significantly different from the untreated plants. In addition, Gill and Healy (1990) found horticultural oils and insecticidal soap to be as effective as synthetic chemicals in controlling whitefly on poinsettia ('Annette Hegg'). They found neem extract to take longer at controlling whiteflies and that repeated applications were needed. No phytotoxicity was observed on any of the treated plants in our study.

Two-spotted spidermite. Treatments of horticultural oils, insecticidal soap, and neem extract (Margosan-O) were as effective at controlling the two-spotted spidermite on marigolds by 3 DPT as the standard miticides abamectin (Avid), fenopropathrin (Tame 2.4E), and dienochlor (Pentac) (Table 6). These results are consistent with find-

Table 5. Effects of various insecticides on immature greenhouse whiteflies on greenhouse grown plants, The Morton Arboretum greenhouses, Lisle, Ill., 1990.

	Mean number of live immature whiteflies per 6 cm^2[z]					
	Buckthorn seedlings[y]				Poinsettia plants[y]	
Treatment	0 DPT[x]	21 DPT	0 DPT	15 DPT	28 DPT	35 DPT
Sun Oil 2% by volume/gal (L)	27 a	5 a	556 a	34 a	---	---
M-Pede 2% by volume/gal (L)	151 a	6 a	423 a	59 a	---	---
Margosan-O 0.16 fl oz/gal (4.7 $mL \cdot L^{-1}$)	110 a	11 a	456 a	149 a	100 a	30 a
Tempo 2E 0.002 fl oz/gal (0.05 $mL \cdot L^{-1}$)	121 a	49 a	413 a	143 a	70 a	16 a
Mavrik 0.004 fl oz/gal (0.10 $mL \cdot L^{-1}$)	---	---	411 a	158 a	104 a	42 a
Talstar 10WP 0.5 oz/gal (14 $g \cdot L^{-1}$)	---	---	384 a	93 a	36 a	15 a
Control	81 a	294 b	440 a	478 b	361 b	282 b

[z]Values within columns followed by the same letter are not significantly different ($P < 0.05$; Student-Neuman-Keuls multiple comparison test).
[y]Seven and five single replications per treatment for buckthorn seedlings and poinsettia plants, respectively.
[x]DPT = days posttreatment.

Table 6. Effect of various insecticides and miticides on immature and adult two-spotted spidermites on *Tagetas patula* plants, The Morton Arboretum greenhouses, Lisle, Ill., 1990.

Treatment	Mean number of live mites[z,y]			
	0 DPT[x]	3 DPT	6 DPT	11 DPT
Sun UF Oil 2% by volume/gal (L)	23 a	0 a	0 a	1 a
M-Pede 2% by volume/gal (L)	25 a	0 a	0 a	0 a
Margosan-O 0.16 fl oz/gal (4.7 $mL·L^{-1}$)	21 a	0 a	0 a	4 a
Avid 0.008 fl oz/gal (0.2 $mL·L^{-1}$)	28 a	0 a	0 a	0 a
Pentac 0.016 fl oz/gal (0.4 $mL·L^{-1}$)	17 a	0 a	0 a	0 a
Tame 2.4E 0.002 fl oz/gal (0.8 $mL·L^{-1}$)	31 a	0 a	0 a	0 a
Control	26 a	29 b	14 b	11 b

[z]Values within columns followed by the same letter are not significantly different ($P < 0.05$; Student-Neuman-Keuls multiple comparison test).
[y]Five single-plant replications per treatment.
[x]DPT = days posttreatment.

ings reported by Merchant (1993) in which marigolds infested with two-spotted spidermites were effectively controlled up to 14 DPT using 2% horticultural oil and 2% insecticidal soap. No phytotoxicity was observed on any of the treated plants in this study.

Phytotoxicity studies

BEDDING PLANTS. No obvious phytotoxicity was observed on flowers or foliage. All plants appeared healthy and were in a saleable condition by the end of the study.

Taking together all 52 cultivars of bedding plants, six weekly treatments of horticultural oils, insecticidal soap, and neem extract (Azatin) did not significantly affect plant height. (Table 7). Mean plant height within individual cultivars treated with horticultural oils, insecticidal soap, or neem extract (Azatin) was not significant (Table 7).

After two weekly sprays of 2% and 4% rates (by volume) of horticultural oils (SunSpray UF), the three petunia cultivars showed evidence of slight phytotoxicity. Plant foliage had a light brown flecking and water-soaked leaves. By the end of the study, the plants had recovered and no further phytotoxicity was observed. By the end of four insecticidal soap sprays, the flowers of 'Summer Madness' and 'Red Madness' petunias were slightly bleached and appeared variegated. The foliage appeared unaffected. 'Mariner' petunias treated with horticultural oils had light burning of the leaf margins and water-soaked foliage by the end of the study. No damage to the flowers was apparent.

No evidence of phytotoxicity was observed on either foliage or flowers of any of the marigold or impatiens cultivars in this study. Treatments did not appear to affect final plant height, as treated plants for all cultivars were the same height as untreated plants.

Table 7. Final plant height measurements of greenhouse bedding plants after being treated with repetitive sprays of horticultural oil, insecticidal soap, and neem extract (Azatin), College of DuPage greenhouses, Glen Ellyn, IL, 1993.

Species[y]	Mean plant ht (cm)[z]			
	Azatin	M-Pede	Oil	Untreated
Impatiens	11.6	11.4	11.4	11.9
Petunia	19.8	21.7	20.1	20.5
Marigold	19.7	19.1	19.1	18.9
Begonia	17.5	19.5	17.0	19.9
Coleus	21.0	23.3	21.0	21.1
Dianthus	13.9	16.7	18.7	17.9
Salvia	24.9	29.0	33.3	31.1
Vinca	19.9	20.3	19.7	18.2
Snapdragon	12.0	11.0	13.0	12.4
Geranium	25.1	24.7	24.9	21.8

[z]None of the treatments across rows were significantly different from the untreated control ($P < 0.05$, Student-Newman-Keuls multiple comparison test).
[y]Twenty-four single-plant replications per treatment per species.

Table 8. Final growth measurements of greenhouse foliage plants after being treated with repetitive sprays of horticultural oil, insecticidal soap, and neem extract (Azatin), College of DuPage greenhouses, Glen Ellyn, Ill., 1993.

Species[z] (Common name)	Mean number of new nodes 30 DPT[y]			
	Oil	M-Pede	Azatin	Untreated
Purple Heart	0.54 a	1.35 b	1.30 b	1.10 b
Peperomia Ivy	0.95 a	1.15 a	0.90 a	1.00 a
English Ivy	3.30 a	2.95 a	3.83 a	3.00 a
Weeping Fig	0.87 a	0.80 a	0.50 a	0.67 a
Swedish Ivy	2.75 a	2.20 a	2.10 a	2.45 a
Jade	0.18 a	0.40 a	0.20 a	0.20 a
Wax Ivy	0.85 b	1.05 b	0.20 a	0.90 b
Pothos Ivy	1.40 a	0.95 a	1.00 a	1.25 a
Goldfish Plant	2.13 a	2.20 a	1.67 a	1.60 a
German Ivy	1.93 a	2.20 a	2.10 a	1.63 a
Philodendron	0.83 a	1.20 a	1.20 a	1.20 a
Wandering Jew	1.43 a	1.70 a	1.95 a	1.63 a
Z. pendula	2.00 a	2.07 a	2.00 a	2.00 a

[z]Forty single-plant replications per species per treatment.
[y]DPT = days posttreatment. Values across rows followed by the same letter are not significantly different ($P < 0.05$; Student-Newman-Keuls multiple comparison test).

FOLIAGE PLANTS. No obvious phytotoxicity was observed on 10 of 13 different species of commonly grown foliage plants after six weekly applications of horticultural oils, insecticidal soap, and neem extract (Azatin). Three species, including wandering Jew ivy, and *Z. pendula*, and purple heart, exhibited slight distortion and curling of the newly formed leaves. Plants grew out of the damage within 1 to 2 weeks after termination of treatments.

Within species, there was no significant difference in growth for treated and untreated plants except for purple heart and wax ivy treated with horticultural oils and neem extract (Azatin), respectively (Table 8). Purple heart plants treated with horticultural oils had significantly fewer nodes (0.54) than insecticidal soap, neem extract (Azatin), and untreated plants (1.10 to 1.35 nodes) (Table 8). Wax ivy plants treated with oil or soap and untreated plants exhibited significantly more new nodes per plant (0.85 to 1.05) as compared to neem-treated (Azatin) wax ivy plants with 0.2 nodes per plant (Table 8).

Poinsettias

Phytotoxicity. Taken together, all poinsettia cultivars treated with horticultural oil and insecticidal soap exhibited some degree of leaf burn and leaf drop of upper and lower leaves throughout the study. Neem extract (Azatin) treated plants and untreated plants showed no evidence of leaf burn or leaf drop throughout the entire study.

'Angelica White' poinsettias sprayed with insecticidal soap weekly and biweekly showed evidence of burning on the leaf margins within 1 week after the initial spray. By 2 weeks after the initial spray 'Angelica White', 'Annette Hegg', 'Red Sails', and 'Freedom Red' poinsettias sprayed biweekly continued to exhibit leaf burn and drop of upper and lower leaves.

Gill and Healy (1990) observed that after four biweekly applications of 2% insecticidal soap, 'Annette Hegg Dark Red' poinsettias exhibited a golden bronzing or russeting of the undersides of the foliage. New leaves were not damaged. Similar damage appeared on plants receiving four weekly applications, but leaves on the upper half of the plants appeared normal (Gill and Healy, 1990).

'Angelica White' poinsettias treated with 2% horticultural oil exhibited yellow leaves and leaf burn 1 week after initial spraying. All plants for all six cultivars had a bright sheen just on the leaves for 24 to 48 h posttreatment, but it was not considered detrimental to the plant.

Two weeks after the initial spray, 'Angelica White', 'Annette Hegg', 'Red Sails', and 'Freedom Red' poinsettias sprayed biweekly with 2% horticultural oil experienced drop of upper and lower leaves and some leaf burn.

Results in this study are different from Gill and Healy (1990), who found no evidence of phytotoxicity on 'Annette Hegg Dark Red' poinsettias after nine weekly applications. Poinsettias leaves had darkened, green greasy spots on the undersides of the leaves however after 18 biweekly sprays (Gill and Healy, 1990).

Except for 'Angelica White' and 'Jolly Red', the remaining four cultivars recovered and were saleable by the end of the study. 'Jolly Red' poinsettias treated with insecticidal soap and horticultural oils showed poor bract development.

No evidence of phytotoxicity or leaf burn was observed on any of the six cultivars treated with neem extract (Azatin) or the untreated plants. In fact, neem extract (Azatin) treated plants had a superior appearance compared to untreated plants by the end of the study.

Growth effects midseason. Overall, spray schedule (weekly versus biweekly) had no significant effect on plant height for all six poinsettia cultivars treated.

Taken together, plants sprayed once or twice per week with neem extract (Azatin) had significantly greater growth than horticultural oil, insecticidal soap and untreated plants. Within poinsettia cultivars, only 'Supjibi' exhibited significant growth effects with untreated plants growing less than treated plants midway through the cropping cycle.

Growth effects end of season. Within cultivars, treatments (neem extract, insecticidal soap, horticultural oils, untreated) had a significant effect on final plant height (Table 9). Overall, all six cultivars sprayed with horticultural oils and insecticidal soap either once or twice per week were significantly shorter than plants treated with neem extract (Azatin) or untreated plants.

In a related study, 'V-14 Glory' poinsettia plants sprayed 14 times at 3- to 4-d intervals with horticultural oils and insecticidal soap grew ≈0.5-inch and 0.6-inch (1.4 and 1.5 cm) less in overall height, respectively, than untreated plants. Plants repeatedly sprayed with neem extract (Margason-O) grew

Table 9. Mean plant height of six poinsettia cultivars sprayed weekly (W) and biweekly (BW) with horticultural oil, insecticidal soap, and neem extract (Azatin), College of DuPage greenhouses, Glen Ellyn, Ill., 1993.

		Mean plant ht (cm)[z,y]			
Cultivars	Spray schedule[x]	Azatin	M-Pede	Oil	Untreated
Annette Hegg	W	24.2 b	21.2 a	23.1 a	24.0 b
	BW	24.7 b	20.0 a	21.6 a	26.3 b
Red Sails	W	21.7 b	18.2 a	15.9 a	19.5 b
	BW	20.1 b	16.5 a	15.6 a	20.6 b
Supjibi	W	18.5 b	15.7 a	18.4 a	19.3 b
	BW	19.6 b	15.4 a	15.6 a	18.4 b
Angelica White	W	23.4 b	19.3 a	19.9 a	22.7 b
	BW	20.7 b	19.0 a	18.7 a	23.1 b
Freedom Red	W	23.0 b	19.2 a	19.6 a	21.7 b
	BW	22.8 b	19.0 a	18.7 a	23.8 b
Jolly Red	W	18.0 a	16.8 a	14.8 a	17.4 b
	BW	18.0 a	17.7 a	16.4 a	18.4 b

[z]Values across rows followed by the same letter are not significantly different ($P < 0.05$; Student-Newman-Keuls multiple comparison test).
[y]Twenty-four single-plant replications per cultivar per treatment.
[x]W = plants sprayed one time per week; BW = plants sprayed two times per week.

Table 10. Quality ratings for six poinsettia cultivars sprayed weekly (W) and biweekly (BW) with horticultural oil, insecticidal soap, and neem extract (Azatin), College of DuPage greenhouses, Glen Ellyn, Ill., 1993.

Cultivar	Spray schedule[x]	Mean quality rating[z,y]			
		Azatin	M-Pede	Oil	Untreated
Annette Hegg	W	1.8 a	2.9 b	3.9 b	1.8 a
	BW	1.3 a	2.7 b	3.2 b	1.3 a
Red Sails	W	1.1 a	2.5 b	3.5 b	1.2 a
	BW	1.2 a	3.7 b	3.6 b	1.0 a
Supjibi	W	1.3 a	3.3 b	3.0 b	1.2 a
	BW	1.3 a	3.5 b	3.6 b	1.3 a
Angelica	W	1.2 a	3.6 b	3.7 b	1.5 a
	BW	1.2 a	4.2 b	4.1 b	1.4 a
Freedom Red	W	2.9 a	3.9 b	3.6 b	2.1 a
	BW	1.4 a	4.0 b	4.0 b	2.0 a
Jolly Red	W	1.3 a	3.2 b	3.5 b	1.1 a
	BW	1.3 a	3.6 b	4.0 b	1.2 a
Mean		1.5 a	3.6 b	3.7 b	1.4 a

[z]Represents the saleable quality of twenty-four single plant replicates per treatment using the following scale: 1 = excellent; 2 = good; 3 = average; 4 = poor; 5 = dead.
[y]Values across rows followed by the same letter are not significantly different ($P < 0.05$; Student-Newman-Keuls multiple comparison test).
[x]W = Plants sprayed one time per week; BW = Plants sprayed two times per week.

≈0.2 inch (0.5 cm) less in height than untreated plants.

The initial dipping of whitefly infested cuttings in 1% horticultural oil provided effective control of immature stages of whitefly by 7 DPT.

Overall quality rating. Overall, treatments significantly affected quality ratings (Table 10). Final ratings, just before sale, for all six cultivars for all treatments (horticultural oils, insecticidal soap, neem extract, untreated) revealed that plants treated with horticultural oils and insecticidal soap had significantly lower quality ratings (3.6 and 3.7, with 3 = average) (Table 10). Plants treated with neem extract (Azatin) and untreated plants had significant higher quality ratings of ≈1.5 (2 = good) (Table 10). Spray schedule (weekly versus biweekly) had no significant affect on overall final quality ratings.

Conclusions

Our study demonstrates that horticultural oil and insecticidal soap were as effective as conventional insecticides and miticides in controlling a variety of sap-feeding insects and mites on common greenhouse crops. Neem extract (Margosan-O or Azatin) was less consistent and provided intermediate to good control of a variety of sap-feeding insects and mites on common greenhouse crops. Except for purple heart and wax ivy, repetitive sprays of horticultural oil, insecticidal soap, and neem extract (Azatin) did not appear to result in any noticeable phytotoxicity nor effect the growth of the bedding and foliage plants examined in this study. Repetitive sprays of horticultural oil and insecticidal soap significantly affected plant height and final quality of some poinsettia cultivars evaluated in this study. Horticultural oil, insecticidal soap, and neem extract (Margosan-O or Azatin) appear to be compatible with a comprehensive integrated pest management program. As with any chemical, caution and judicious use should be exercised in order to prevent plant damage and the development of pest resistance.

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