Herbicide-Treated Mulches for Weed Control in Nursery Container Crops[1]

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Abstract

Weed control is the largest expense faced in the nursery and landscape industries. Nursery growers spend $967 to $2,228/A, depending on species, for supplemental hand weeding in addition to three to four yearly herbicide applications. Herbicide-treated mulches have utility in addressing many current nursery/landscape weed control issues such as non-target herbicide losses, leaching and off-site herbicide movement, and reduction of weed control costs. The objectives of this study were to compare seven types of mulches, including Douglas fir nuggets, pine nuggets, shredded hardwood, shredded Cypress, PennMulch™, rice hulls, and cocoa shells sprayed with Surflan [aqueous solution (AS) (oryzalin) at 1.12 (0.5×) and 2.24 (1×) kg ai/ha (1.0 and 2.0 lb ai/A)] and SureGuard [(water dispersible granular (WDG) (flumioxazin) at 0.19 (0.5×) and 0.38 (1×) kg ai/ha (0.17 and 0.34 lb ai/A)] to determine efficacy on common chickweed (*Stellaria media*), annual bluegrass (*Poa annua*) and spotted spurge (*Chamaesyce humistrata)* and phytotoxicity to Golden vicary privet (*Ligustrum* x*vicaryi*), creeping juniper (*Juniperus horizontalis* 'P.C. Youngstown'), and wintergreen boxwood (*Buxus microphylla* 'Wintergreen') at 45 and 115 days after treatment (DAT). The herbicide-treated mulches were compared to untreated mulches, over-the-top sprays of the herbicides and a combination spray of Surflan + SureGuard each applied at the 1× rate, described above, an industry-standard granular formulation Rout (oxyfluorfen + oryzalin) at 3.41 kg ai/ha (3.0 lb ai/A), an industry standard non-chemical alternative Geodisc™, and an untreated control. The experiment was conducted in 2001 and repeated in 2002. In 2001, 17 of 43 treatments provided commercially acceptable visual ratings at 45 DAT; 14 were herbicide treated mulches. Four of five treatments in 2001 providing acceptable control at 115 DAT were herbicide treated mulches. In 2002, three treatments providing commercially acceptable control at 45 DAT were: PennMulch™ + 0.5× Surflan, PennMulch™ + SureGuard, and Rout. Rout was the only treatment providing commercially acceptable control at 115 DAT in 2002. Golden vicary privet exhibited the greatest phytotoxicity in both years. In 2001–2002, the over-the-top sprays of Surflan + SureGuard were the most phytotoxic treatments to Golden vicary privet when averaged across 45 and 115 DAT. The data indicated a significant herbicide × mulch interaction and that some combinations, such as hardwood + SureGuard or pine nuggets + SureGuard, increased and extended efficacy and reduced phytotoxicity versus mulches or herbicides applied alone.

Index words: Geodisc™, PennMulch™, ricehulls, pine bark, hardwood bark, container production, ornamental herbicides, mulch.

Species used in this study: common chickweed (*Stellaria media*); annual bluegrass (*Poa annua*); spotted spurge (*Chamaesyce maculata*); Golden Vicary privet (*Ligustrum* x*vicaryi*); creeping juniper (*Juniperus horizontalis* 'P.C. Youngstown'); wintergreen boxwood (*Buxus microphylla* 'Wintergreen').

Herbicides used in this study: Rout (oxyfluorfen + oryzalin) 2-chloro-1-(3ethoxy-4-nitrophenoxy)-4-(trifluormethyl) benzen + 3,5-dinitro-N^4-N^4-dipropylsulfanilamide; Surflan AS (oryzalin) 4-(dipropylamino)-3, 5-dinitrobenzenesulfonamide; SureGuard WDG (flumioxazin) 2-[7-fluoro-3, 4-dihydro-3-oxo-4-(2-propynyl)-2H-1, 4-benzoxazin-6-yl]-4, 5, 6, 7-tetrahydro-1H-isoindole-1, 3(2H)-dione.

Significance to the Nursery Industry

Effective weed control is essential in nurseries and landscapes and is the largest expense for these industries. Producers often spend $967 to $2,228/A, depending on species, for supplemental hand weeding in addition to three to five yearly herbicide applications (22). Problems associated with herbicide use in nurseries include proper calibration, leaching, spray-drift, herbicide run-off, the need for multiple applications, and product expense. Any method that would reduce herbicide use, hand weeding, crop damage, and the incidence of the problems previously discussed would be of great significance to the industry. We have tested several innovative weed control products in trials from 1998, 2000–2002; however, herbicide-treated mulches have shown the most promise in terms of reducing phytotoxicity while increasing and extending efficacy. Data presented in this paper suggest that mulches may be acting as slow release carriers for the preemergence herbicides. In turn, this decreases the number of herbicide applications needed via extension of duration. Increased efficacy would reduce supplemental handweeding costs and alleviate herbicide waste problems resulting in environmental and economic gains.

Introduction

Weeds are deleterious and troublesome in landscapes and nursery production, and the markets for nursery crops demand container-grown plants that are weed-free (28). Nurseries can spend between $500 and $4000 per acre for manual removal of weeds, depending on weed species present (21). Based on an hourly wage of $14.75, it costs $1,367 to hand weed 1000 3-liter pots over a 4-month period (6).

Weed control by granular, preemergence herbicides is the most common method used by container growers (14), although liquid formulations are sometimes used. One problem associated with herbicide use is the amount of non-target herbicide loss. Non-target herbicide losses are the pri-

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mary contributor to herbicides in runoff water from container nurseries (17). As much as 86% of a granular applied herbicide can be lost by misapplication and non-target loss, depending on pot spacing and species (14). Preemergence herbicides are also limited by the amount of residual provided by the herbicide. Frequent reapplication is necessary to maintain acceptable weed control in containers, so it is likely that the half-life of herbicides on the surface of a soilless media is less than those observed in field soils (16).

Weed control (or suppression) can be obtained in a number of other ways, including organic mulches. Mulches have not been used extensively as weed suppressants in container production. Mulches, however, have been used extensively in the landscape industry because of their aesthetic value (27) and weed suppression (3, 27). Organic mulches can help to alleviate weed competition by inhibition of germination and suppression of weed growth (20). Some mulches, like rice hulls, contain allelopathic chemicals (1). There are a number of organic mulches, with most of them made out of wood shavings or bark. Williams (personal communication) found that pine nuggets applied three inches thick provided excellent weed control; however, Skroch (27) found only 50% reduction in weed counts when the mulch was applied 3.5 inches thick, which is not commercially acceptable. Organic mulches are also biodegradable, which would be beneficial for the environment.

Herbicide-treated mulches could be an answer to long-term weed control that incorporates two control methods. Combining physical (mulch) and chemical control methods could reduce the amount of herbicide applied per year while increasing application uniformity. Herbicide-treated mulches have been investigated in annual plant beds (11), newly established ground covers (9), field grown nursery stock (8), landscape plant areas (12, 8), and containers (10, 22) and have shown promise as an alternative to conventional methods. One hypothesis with mulch and herbicide is that the mulch binds the herbicides and possibly acts as slow release carriers for the herbicides and reduces the leaching potential of the herbicides (22). This, in turn, would decrease the amount of herbicide needed and extend duration. Knight (18) indicated that the application of preemergence herbicides onto organic mulches reduced herbicide leaching by 35–74% compared with bare soil preemergent herbicide applications.

As previously described, there has been much investigation on pre-treated (herbicide-treated) mulch; however there are many mulches and herbicides that have not been researched. The research presented here involves only one mulch previously investigated, which is pine nuggets. The objective of our research was to further investigate the effects of seven common, organic mulches treated with two common preemergence, ornamental herbicides compared to mulches untreated, over-the-top sprays, a granular, a non-chemical alternative Geodisc™ (Texel, U.S.A., Inc., Hendersonville, NC) and untreated control for extent and duration of efficacy and phytotoxicity to three species of container-grown plants.

Materials and Methods

Efficacy. Trials began on June 10, 2001, and were repeated starting June 6, 2002, at The Ohio State University, Columbus, OH. Seven different types of mulch: pine bark nuggets, Douglas fir bark nuggets, shredded cypress, shredded hardwood, PennMulch™ (pelletized newspaper mulch, with 1% nitrogen added, patented by Penn State University, State College, PA) rice hulls, and cocoa shells were laid out on a flat piece of plastic at one unit-layer thickness. Placing the pieces of mulch side by side with minimal overlap on the plastic created a unit-layer thickness. Each year mulches were sprayed with SureGuard (flumioxazin, Valent U.S.A. Corp., Walnut Creek, CA) at 0.38 kg ai/ha (0.34 lb ai/A) (1× rate), and Surflan 4AS (oryzalin, Dow AgroSciences, Indianapolis, IN) at 2.24 kg ai/ha (2 lb ai/A) (1× rate). A second set of mulch-herbicide treatments were sprayed with half the rates listed above (0.5×). Over-the-top spray treatments included Surflan and SureGuard at the rates described above and a combination spray of SureGuard (1×) + Surflan (1×). Carrier volumes were 224 liters/ha (24 gal/A) of water for SureGuard and 271 liters/ha (29 gal/A) for Surflan. Containers (#1) were filled with a soilless potting medium containing 60% pine bark, 20% rice hulls, 10% sand, 5% technigrow (a composted sewage sludge, Kurtz Bros. Inc., Groveport, OH), and 5% aggregate. Herbicides were applied with a CO_2-pressurized backpack sprayer (R&D Sprayers, Opelousa, LA) equipped with 4-8002evs flat fan nozzles (Teejet, Wheaton, IL). Spray pressure was 276 kPa (40 psi) for SureGuard and 345 kPa (50 psi) for Surflan. The treated mulches were allowed to dry for 24 to 48 hours, and then were placed on the pots at one unit-layer thickness. This ranged from 0.3 to 0.6 cm (0.13 to 0.25 in) deep in the pot for all the mulches except the Douglas fir nuggets, where only 3–6 nuggets were placed in each container. Untreated mulches were also put on the containers at one unit-layer thickness to ensure uniformity in the trial. Comparisons were also made to an untreated control (weedy check, no mulch and no herbicide), Rout (oxyfluorfen + oryzalin, The Scott's Co., Marysville, OH) at 3.4 kg ai/ha (3.0 lb ai/A) and Geodisc™. A mixture of 0.06 ml (1/8 tsp) of equal portions by weight of spotted spurge (*Chamaesyce maculata*), annual bluegrass (*Poa annua*), and common chickweed (*Stellaria media*) seeds were sprinkled over the top of each pot, just after application of herbicide-treated mulches and other treatments in both years. In 2001, seed was obtained from The Scotts Co., Western Region (Gervais, OR). In 2002, the seed was purchased from a company specializing in weed science research seed, Herbiseed (Twyford, England).

Experimental design was an 8 × 5 (mulch × herbicide) unbalanced factorial treatment structure in a completely randomized design with four replications per treatment in 2001 and 2002. In 2001, all pots were fertilized immediately after planting with 20N–8.8P–16.6K (20–10–20) water-injected fertilizer (Peters Professional, The Scott's Co.) at 200 mg/liter (200 ppm), and they were then immediately top-dressed with Osmocote 15N–4P–10K (15–9–12) with micronutrients slow release fertilizer (The Scott's Co.) at 15 grams (0.5 oz) per pot. Top dressing of water-injected fertilizer was done to ensure nutrition was available to the medium right after potting. In 2002, the same Osmocote fertilizer was pre-plant incorporated into the medium at 5.9 kg/m^3 (10 lb/yd^3); liquid fertilizer was not applied. Electrical conductivity and pH of the media were measured in both years using Cardy Twin portable meters (Spectrum Technologies, Inc., Plainfield, IL) and the Virginia Tech Extraction Method every 2 weeks to ensure fertility levels were maintained within the correct parameters for container ornamentals: pH of 5.2–6.2 and Ec of 0.20–1.00 dS/m (25). Water was applied daily at 08:00 am throughout the test period by overhead sprinklers at 0.26 cm/

ha (0.25 in/A) per day, regardless of rainfall. Total precipitation during the trial in 2001 was 22.1 cm (8.7 in) and 34.5 cm (13.6 in) in 2002. Visual ratings were conducted at 45 DAT (days after treatment) and 115 DAT both years. Weed shoot dry weights were taken at 115 DAT in 2001 and 45 DAT and 115 DAT in 2002. In 2001, one set of four replications per treatment were evaluated; in 2002, two sets, one set at 45 DAT, and one set at 115 DAT were evaluated. Therefore, no dry weights are presented at 45 DAT in 2001. Visual ratings were based on a 0–10 scale, where 0 = no control, 10 = 100% control and ≥ 7 = commercially acceptable. Ratings were made comparing the percentage and size of weed growth to the controls. Efficacy evaluations were conducted in containers with no crop species present. In 2002, the spurge was cut back to prevent formation of seeds between the 45 DAT and 115 DAT evaluations. Clippings were dried and the weights were added to the dry weights determined at 115 DAT. Regeneration of weed growth occurred after pruning.

Phytotoxicity. The phytotoxicity evaluations of three woody landscape nursery species were conducted with the same treatments and similar methods to the efficacy trial. Golden vicary privet (*Ligustrum xvicaryi*), creeping juniper (*Juniperus horizontalis* 'P.C. Youngstown'), and wintergreen boxwood (*Buxus microphylla* 'Wintergreen') were transplanted on June 10, 2001, and May 30, 2002, into #1 containers filled with the same medium used in the efficacy study. Height of transplants was 15–20 cm (6–8 in) in 2001 and 20–25 cm (8–10 in) in 2002. In 2001 and 2002, golden vicary privet and juniper were transplanted from 10.5 cm (4 in) pots and boxwoods were transplanted from 6.4 cm (2.5 in) pots. Phytotoxicity was assessed by visual ratings and shoot dry weights at 45 and 115 DAT in 2001 and 2002. Treatment design was an 8 × 5 × 3 (mulch × herbicide × species) unbalanced factorial with two sets of four replications for each treatment, one set for the evaluation at 45 DAT and one set for the evaluation at 115 DAT. Visual ratings were based on a 1–10 scale, where 1 = no phytotoxicity, 10 = complete death and ≤ 3 = commercially acceptable. Phytotoxicity containers were hand-weeded weekly to reduce plant-weed competition.

An analyses of variance (ANOVA) was conducted for phytotoxicity and efficacy data using the SAS© (SAS© Institute Inc., Cary, NC) General Linear Model (GLM) procedure. Fisher's protected least significant difference test was used to compare means. Visual ratings were subjected to an arc sin square root transformation (29) to ensure normal distribution of the means. Data sets were analyzed and the two analyses (transformed and non-transformed) were compared. A combined ANOVA using year by treatment interaction as the error term in ANOVA was then conducted to determine if the two years of data could be pooled.

Results and Discussion

The two years were complete replications in time; however, they produced different results for the measured parameters. The test of hypothesis using the year by treatment interaction as an error term in ANOVA indicated that year, and year by treatment interaction were significant. Therefore, the two years are presented separately throughout the remainder of the paper. No differences were found between the ANOVA of the transformed data and the non-transformed data (data not shown). Therefore, the non-transformed data is presented. In both years, there was an herbicide × mulch interaction for efficacy and phytotoxicity; thus main effects of herbicide and mulch are not discussed.

Efficacy. In 2001, 17 of the 43 treatments provided visual ratings above 7 at 45 DAT (Table 1). Of these 17 treatments, 14 were herbicide-treated mulches. The other three were: over-the-top spray of the 0.5× rate of SureGuard, Rout, and Geodisc™. Six of seven untreated mulches did not provide significantly improved efficacy versus the control (2.2) at 45 DAT in terms of visual ratings, but cypress, Douglas fir, cocoa shells and pine nuggets all reduced weed dry weights compared to the control (Table 1). At 115 DAT in 2001, treatments providing acceptable control were reduced to five, four were herbicide-treated mulches and none were herbicides alone (Table 1). Dry weights also indicate these five treatments provided superior control at 115 DAT. Four untreated mulches provided slightly improved efficacy versus the control in terms of visual ratings, including cypress, Douglas fir, pine nuggets, and hardwood. PennMulch™ alone resulted in an increase of weed shoot dry weight. This may have been due to the 1% nitrogen fertilizer it contained. In other research, PennMulch™ provided good control of most weeds but with some weed species Geodiscs™ provided better control (32).

Efficacy was very much reduced in 2002 compared to 2001. Three treatments provided commercially acceptable control at 45 DAT in 2002, Rout, PennMulch™ + 0.5× Surflan, and PennMulch™ + 0.5× SureGuard (Table 2). Rout (0.0 g) also provided the lowest weed dry weights, but 10 other treatments provided similar dry weights to that of Rout. Among the untreated mulches, only PennMulch™ and pine nuggets provided significantly improved efficacy versus the control visually; however, by dry weight only pine nuggets provided better efficacy versus the control. Results at 115 DAT showed similar results to that of 45 DAT. Rout again provided the highest visual rating and lowest weed dry weight (Table 2). Only 2 out of the 7 untreated mulches in 2002 provided a higher visual rating than the control at 115 DAT, the PennMulch™ and pine nuggets.

Although ratings were based on the control of all three species, differences between the two years are mainly due to two species. There was a substantial difference in control of the annual bluegrass and spurge from 2001 to 2002. We speculate this was due to seed source and seed vigor. The same weed species were purchased but the spotted spurge received from Herbiseed grew and looked much different than the spotted spurge that was obtained from Scotts. From observations of growth characteristics, we concluded that the spurge species tested in 2002 was nodding spurge (*Chamaesyce nutans*) not spotted spurge (Neal, personal communication) a much more vigorous and difficult to control spurge than spotted spurge.

There were also differences between the annual bluegrass seed lots. We observed they were the same species, however, germination was higher and faster for the annual bluegrass in 2002 compared to 2001. Annual bluegrass in 2001 did not tiller as profusely as it did in 2002. Differences in dry weights of the control pots (6.6 g, 2001 and 39.6 g, 2002) indicate the weed growth differences between the two years at 115 DAT. Although the spurge species and seed lot differences of annual bluegrass caused visual ratings to be different, there were trends that were similar between the two years.

Table 1. **Efficacy visual ratings of weeds in containers with selected herbicides, mulch, herbicide-mulch combinations, Geodisc™, and control at 45 and 115 days after treatment and dry weights at 115 DAT in 2001.**

Treatment[y]	45 DAT[z] Visual rating[x]	115 DAT Visual rating	115 DAT Dry weight[w]
A	3.2hijkl[v]	2.0klmnop	4.4defg
B	6.5bcde	5.5defghi	2.0abcde
C	5.0defghi	2.8jklmno	3.4bcdef
D	7.5abc	4.0fghijkl	3.3bcdef
Cocoa shells	4.0fghijk	1.2mnop	3.7cdef
Cocoa shells+A	8.0ab	5.8cdefg	2.3abcdef
Cocoa shells+B	7.2bcd	2.8jklmno	3.8cdefg
Cocoa shells+C	6.2bcdef	4.0fghijkl	2.8abcdef
Cocoa shells+D	5.2cdefghi	0.8nop	4.6efg
Cypress	3.8ghijkl	2.8jklmno	1.5abc
Cypress+A	8.2ab	6.8bcde	1.1abc
Cypress+B	8.5a	6.0cdefg	1.7abcd
Cypress+C	5.8bcdefg	3.8ghijklm	3.3bcdef
Cypress+D	7.0bcd	4.0fghijkl	1.8abcde
Douglas fir	1.5lm	3.0ijklmn	3.1bcdef
Douglas fir+A	3.5ghijkl	4.2efghijk	3.9cdefg
Douglas fir+B	3.0ijkl	3.8ghijklm	3.0bcdef
Douglas fir+C	1.5lm	3.0ijklmn	2.4abcdef
Douglas fir+D	2.0klm	2.2klmnop	4.4defg
Hardwood	4.0fghijk	3.0ijklmn	3.8cdefg
Hardwood+A	6.2bcdef	5.5defghi	2.0abcde
Hardwood+B	8.5a	5.2efghij	1.5abcd
Hardwood+C	5.8bcdefg	5.5defghi	3.1bcdef
Hardwood+D	10.0a	8.2abc	0.0a
PennMulch	0.0m	0.2op	10.7h
PennMulch+A	9.2a	6.5bcdef	1.0abc
PennMulch+B	8.8a	5.2efghij	1.6abcd
PennMulch+C	5.5cdefgh	3.0ijklmn	4.4defg
PennMulch+D	7.5abc	5.8cdefgh	2.0abcde
Pine nuggets	2.2jkl	3.2hijklmn	2.8abcdef
Pine nuggets+A	9.2a	8.0abcd	0.0a
Pine Nuggets+B	4.5efghij	4.0fghijkl	2.3abcdef
Pine nuggets+C	7.8abc	5.2efghij	0.8ab
Pine nuggets+D	1.8klm	1.5lmnop	2.8abcdef
Rice hulls	3.0ijkl	2.5klmnop	5.1fg
Rice hulls+A	4.0fghijk	3.5ghijklm	3.7bcdef
Rice hulls+B	6.8bcde	9.5a	0.0a
Ricehulls+C	10.0a	3.8ghijklm	2.3abcdef
Ricehulls+D	10.0a	9.5a	0.0a
Geodisc	10.0a	8.8ab	0.0a
Oryzalin+Flumioxazin	6.5bcde	1.8klmnop	4.9fg
Rout	8.5a	5.2efghij	1.9abcde
Control	2.2jkl	0.0p	6.6g

[z]DAT = days after treatment.

[y]Codes for treatments: A = 1× oryzalin, B = 1× flumioxazin, C = 0.5× oryzalin, D = 0.5× flumioxazin.

[x]Visual ratings based on a 0–10 scale with 0 representing no control and 10 total weed control.

[w]Dry weight expressed in grams.

[v]Similar letters in the same column are not significantly different (LSD P ≤ 0.05).

The spurge was controlled both years up to 45 DAT by the SureGuard spray and up to 115 DAT with combinations of SureGuard with rice hulls, hardwood, cypress, and PennMulch™. Spurge was also effectively controlled by Rout to 45 DAT in 2001, and up to 115 DAT in 2002. Spurge is a common problem in container nurseries (15), but SureGuard may provide control in some crops. Ruter and Glaze (24) found that prostrate spurge (*Chamaesyce prostrata*) growth was reduced by 98% compared to the control at 12 weeks after treatment (WAT) only by combination herbicides oxadiazon plus oryzalin or oxadiazon plus prodiamine, and Whitwell and Kalmowitz (31) found that efficacy of prostrate spurge is reduced up to 72% 90 DAT using oxadiazon plus bifenox. The oxyfluorfen in Rout has a similar mode of action to oxadiazon; it also has two chemistries. This could explain why Rout was very effective in this study. SureGuard also has a similar mode of action to oxadiazon and had good efficacy on prostrate spurge; however, it did not provide adequate control of the annual bluegrass. Niekamp et al. (23) also reported reduced flumioxazin efficacy on grasses, possibly explaining the lower visual ratings of the treatments involving SureGuard in 2002. SureGuard has also been reported to have longer residual control versus Surflan + Gallery (isoxaben, Dow AgroSciences, Indianapolis, IN) or OH II (Scott's Co., Marysville, OH). Others (2) working on the longevity of weed control with herbicides for ornamental containers found that treatment intervals for flumioxazin during summer could be extended to at least 12 weeks versus their normal 8 week application interval. Increasing treatment intervals from 8 to 12 weeks resulted in financial savings (2). In our study in 2001 and 2002, the 1× rate of SureGuard provided greater residual at 115 DAT (5.5, 2001 and 4.8, 2002) versus the Surflan (2.0, 2001 and 0.5, 2002).

In this study, Surflan controlled annual bluegrass both years, as a spray alone and in combination with mulch. Surflan did not provide adequate control of spurge when it was used as an over-the-top spray. Derr (7) reported Surflan controlled spurge in container-grown herbaceous perennials, and in a separate study, in pots that were crop-free (13). Surflan, however, is often mixed with other chemicals to provide a broader spectrum of weed control (4, 24, 30). Surflan + pine nuggets was the best Surflan-treated mulch, and it provided some, but not complete control of spotted spurge in 2001, and it provided no control of the spurge in 2002. Integration of two or more methods of weed control may produce a positive interaction (26). The combination of Surflan with another weed control factor such as another herbicide (4, 24, 30) or mulch (22) provides this positive interaction.

Phytotoxicity. Only six of 43 treatments combined over dates, gave a phytotoxicity visual rating of three or higher to golden vicary privet in 2001, two were over-the-top sprays: Surflan + SureGuard, 0.5× SureGuard, pine nuggets + Surflan, pine nuggets + 0.5× Surflan, pine nuggets + SureGuard, and Douglas fir + Surflan (Table 3). Only one treatment, an over-the-top spray, had a phytotoxicity visual rating of three or higher to the boxwood (0.5× SureGuard) and no treatments had a phytotoxicity rating higher than three to the juniper (data not shown).

In 2002, phytotoxicity ratings, in general, were lower than in 2001. When averaged across 45 and 115 DAT only two treatments, both over-the-top sprays, SureGuard and Surflan + SureGuard, were phytotoxic to golden vicary privet (Table 4). SureGuard has been reported to cause phytotoxicity to a number of species, including spirea 'Anthony Waterer' (*Spirea* x *bumalda* 'Anthony Waterer'), dianthus (*Dianthus alpinus*) (5), spirea 'Goldmound' (*Spirea* x*bumalda* 'Goldmound'), and daylily (*Hemerocallis* x'Stella de Oro') (33). With the exception of rice hulls + SureGuard (27.2g) and Douglas fir + SureGuard (26.1) the addition of SureGuard to the majority of mulches produced phytotoxicity results similar to that of the control for golden vicary privet (34.6 g)

Table 2. Efficacy visual ratings and dry weights of weeds in containers with selected herbicides, mulch, herbicide-mulch combinations, Geodisc™, and control at 45 and 115 days after treatment in 2002.

	45 DAT[z]		115 DAT	
Treatment[y]	Visual rating[x]	Dry weight[w]	Visual rating	Dry weight
A	1.5jklmno[v]	20.7hijkl	0.5hi	43.1kl
B	2.2hijklm	7.2cd	4.8bcde	18.1bcde
C	0.8mno	15.6efg	0.5hi	36.5hijkl
D	0.8mno	20.9hijkl	0.0i	42.3kl
Cocoa shells	0.2o	22.1jkl	0.0i	39.1ijkl
Cocoa shells+A	2.8ghijk	23.3kl	0.8hi	35.6ghijkl
Cocoa shells+B	3.8efgh	2.6abc	4.0cde	20.6bcde
Cocoa shells+C	1.0lmno	21.1hijkl	0.0i	38.3hijkl
Cocoa shells+D	2.5hijkl	5.3bc	4.8bcde	26.3 defgh
Cypress	0.2o	18.0ghij	0.8hi	32.9fghijk
Cypress+A	3.0fghij	20.9hijkl	3.2def	41.1jkl
Cypress+B	3.0fghij	4.4abc	6.2b	11.0b
Cypress+C	0.5no	19.7ghijkl	1.5fghi	36.3hijkl
Cypress+D	2.5hijkl	5.6bcd	5.2bc	14.0bc
Douglas fir	1.2klmno	22.5jkl	1.2ghi	37.0hijkl
Douglas fir+A	1.5jklmno	20.9hijkl	2.0fgh	46.5l
Douglas fir+B	2.8ghijk	4.4abc	4.2cde	23.5cdefg
Douglas fir+C	0.8mno	22.7jkl	0.8hi	40.4jkl
Douglas fir+D	0.0o	19.8ghijkl	1.2ghi	33.2fghijk
Hardwood	0.5no	19.6ghijkl	0.5hi	42.7kl
Hardwood+A	2.0ijklmn	19.3ghijkl	1.5fghi	39.8jkl
Hardwood+B	4.5def	2.4abc	4.5bcde	19.4bcde
Hardwood+C	2.0ijklmn	23.4 l	0.5hi	39.4jkl
Hardwood+D	2.2hijklm	6.2bcd	4.5bcde	15.9bcd
PennMulch	5.0cde	12.9ef	4.2cde	28.9efghij
PennMulch+A	6.0bcd	10.6de	4.2cde	37.8hijkl
PennMulch+B	5.2cde	2.7abc	4.5bcde	22.4bcdef
PennMulch+C	7.2b	2.7abc	4.2cde	21.6bcdef
PennMulch+D	7.2b	1.5ab	4.8bcde	16.0bcd
Pine nuggets	6.5bc	6.0 bcd	3.0efg	20.4bcde
Pine nuggets+A	3.2fghi	21.6ijkl	3.2def	40.7jkl
Pine nuggets+B	3.0fghij	5.1abc	4.5bcde	23.6cdefg
Pine nuggets+C	2.8ghijk	18.7hijkl	0.0i	46.8l
Pine nuggets+D	1.0lmno	19.0ghijkl	1.5fghi	40.9jkl
Rice hulls	2.5hijkl	16.2fgh	1.2ghi	33.4fghijk
Rice hulls+A	2.5hijkl	18.2ghijk	0.8hi	38.2hijkl
Rice hulls+B	5.0cde	1.9ab	5.0bcd	15.5bcd
Rice hulls+C	1.2klmno	16.7fghi	0.8hi	40.5jkl
Rice hulls+D	3.8efgh	4.9abc	4.2cde	17.5bcde
Oryzalin+Flumioxazin	2.2hijklm	6.0bcd	4.5bcde	18.7bcde
Geodisc	4.2efg	16.8fghi	4.5bcde	27.2defghi
Rout	10.0a	0.0a	9.2a	0.7a
Control	0.0o	16.9fghi	0.0i	39.6jkl

[z]DAT = days after treatment.

[y]Codes for treatments: A = 1× oryzalin, B = 1× flumioxazin, C = 0.5× oryzalin, D = 0.5× flumioxazin.

[x]Visual ratings based on a 0–10 scale with 0 representing no control and 10 total weed control.

[w]Dry weight expressed in grams.

[v]Similar letters in the same column are not significantly different (LSD P ≤ 0.05).

(Table 4). Only two treatments provided a visual rating of three or higher to boxwood in 2002, again both were over-the-top sprays, SureGuard (4.6), and Surflan + SureGuard (3.2) (data not shown).

There were similarities for the two years that are crucial to the objectives of the research. The herbicide-treated mulch, with the exception of pine nuggets + Surflan in 2001, reduced phytotoxicity visually compared to the respective over-the-top sprays (Tables 3 & 4). However, not all herbicide-treated mulch combinations decrease phytotoxicity and it seems that it is herbicide- (and possibly mulch) dependent. Fretz and Dunham (11) found that petunias (*Petunia hybrida* cv. White Cascade) were more damaged from the dichlobenil-treated peat moss than the over-the-top spray of dichlobenil. Wooten et al. (34) found that pine straw and trifluralin applied together on pansies significantly reduced the number of flowers.

There was slight variation in the amount of damage between 2001 and 2002 to golden vicary privet. This was mainly caused by the size of the transplants. In 2001, some of the privets died because they could not recover from SureGuard injury, but in 2002, the transplants were slightly larger when sprayed and were capable of some recovery. Czarnota et al. (5) found that phytotoxicity was greatest to spirea 'Anthony Waterer' at 1 and 2 weeks after treatment, but declined by 4 weeks after treatment and similar effects were reported by Wooten and Neal (33) on spirea 'Goldmound'.

This study shows that SureGuard and Surflan can be combined with different mulches for weed control to increase

Table 3. **Phytotoxicity visual ratings of Golden Vicary privet (*Ligustrum* x *vicaryi*) averaged across 45 and 115 days after treatment in 2001 from selected herbicides, mulch, herbicide-mulch combinations, Geodisc™, and control.**

Treatment[z]	Visual rating[y]
A	2.4defgh[x]
B	2.8cdefgh
C	1.9efgh
D	5.8b
Cocoa shells	2.1defgh
Cocoa shells+A	1.5efgh
Cocoa shells+B	1.8efgh
Cocoa shells+C	1.5efgh
Cocoa shells+D	2.5defgh
Cypress	1.9efgh
Cypress+A	2.8cdefgh
Cypress+B	2.9cdefg
Cypress+C	1.2fgh
Cypress+D	1.8efgh
Douglas fir	1.0h
Douglas fir+A	3.0cdef
Douglas fir+B	1.6efgh
Douglas fir+C	2.9cdefg
Douglas fir+D	1.4fgh
Hardwood	2.2defgh
Hardwood+A	2.8cdefgh
Hardwood+B	1.4fgh
Hardwood+C	1.5efgh
Hardwood+D	2.2defgh
PennMulch	1.5efgh
PennMulch+A	1.1gh
PennMulch+B	2.0defgh
PennMulch+C	2.2defgh
PennMulch+D	1.5efgh
Pine nuggets	1.5efgh
Pine nuggets+A	4.4bc
Pine nuggets+B	3.2cde
Pine nuggets+C	3.8cd
Pine nuggets+D	2.0defgh
Rice hulls	1.0h
Rice hulls+A	1.1gh
Rice hulls+B	1.1gh
Rice hulls+C	1.6efgh
Rice hulls+D	1.2fgh
Oryzalin+flumioxazin	9.0a
Geodisc	1.5efgh
Rout	1.4fgh
Control	1.5efgh

[z]Codes for treatments: A = 1× oryzalin, B = 1× flumioxazin, C = 0.5× oryzalin, D = 0.5× flumioxazin.

[y]Visual ratings based on a 0–10 scale with 0 being no phytotoxicity and 10 death.

[x]Similar letters in the same column are not significantly different (LSD P ≤ 0.05).

Table 4. **Phytotoxicity visual ratings and dry weights for Golden Vicary privet (*Ligustrum* x *vicaryi*) averaged over 45 and 115 days after treatment in 2002 from selected herbicides, mulch, herbicide-mulch combinations, Geodisc™, and control.**

Treatment[z]	Visual rating[y]	Dry weight[x]
A	1.1cd[w]	27.8cdefg
B	5.0a	7.0a
C	1.1cd	26.9cde
D	2.8b	14.7b
Cocoa shells	1.0d	28.8cdefgh
Cocoa shells+A	1.1cd	27.2cdef
Cocoa shells+B	1.0d	28.5cdefg
Cocoa shells+C	1.0d	33.2defghijkl
Cocoa shells+D	1.0d	33.9efghijkl
Cypress	1.0d	33.2defghijkl
Cypress+A	1.1cd	30.5cdefghijk
Cypress+B	1.0d	36.7ijkl
Cypress+C	1.1cd	25.1c
Cypress+D	1.1cd	27.0cde
Douglas fir	1.0d	37.2jkl
Douglas fir+A	1.0d	29.4cdefgh
Douglas fir+B	1.0d	26.1cd
Douglas fir+C	1.0d	34.3fghijkl
Douglas fir+D	1.0d	38.1l
Hardwood	1.0d	35.7hijkl
Hardwood+A	1.0d	34.4ghijkl
Hardwood+B	1.0d	31.3cdefghijkl
Hardwood+C	1.0d	29.2cdefgh
Hardwood+D	1.1cd	32.1cdefghijkl
PennMulch	1.1cd	37.4kl
PennMulch+A	1.0d	34.0efghijkl
PennMulch+B	1.4c	32.2cdefghijkl
PennMulch+C	1.0d	29.6cdefghi
PennMulch+D	1.0d	34.6ghijkl
Pine nuggets	1.0d	29.2cdefgh
Pine nuggets+A	1.0d	33.0defghijkl
Pine nuggets+B	1.0d	30.2cdefghij
Pine nuggets+C	1.0d	34.7ghijkl
Pine nuggets+D	1.0d	36.7ijkl
Rice hulls	1.0d	30.7cdefghijk
Rice hulls+A	1.0d	31.4cdefghijkl
Rice hulls+B	1.1cd	27.2cde
Rice hulls+C	1.0d	29.0cdefgh
Rice hulls+D	1.1cd	31.1cdefghijkl
Oryzalin+flumioxazin	4.8a	5.0a
Geodisc	1.0d	28.1cdefg
Rout	1.0d	33.4efghijkl
Control	1.0d	34.6ghijkl

[z]Codes for treatments: A = 1× oryzalin, B = 1× flumioxazin, C = 0.5× oryzalin, D = 0.5× flumioxazin.

[y]Visual ratings based on a 0–10 scale with 0 being no phytotoxicity and 10 death.

[x]Dry weight expressed in grams.

[w]Similar letters in the same column are not significantly different (LSD P ≤ 0.05).

and extend the efficacy up to 115 DAT and provide low phytoxicity compared to the respective over-the-top sprays. Extending weed control and reducing leachates would be very desirable for nursery managers. Knight et al. (18) reported that pine bark, pine straw, and newspaper mulch significantly reduced leaching of pendimethalin, isoxaben, and metolachlor by 35–74%. Herbicide treated mulches appear to work like granulars; they work as herbicide carriers. For example, BroadStar 0.17G (Valent U.S.A.) has the same active ingredient (flumioxazin) as SureGuard WDG, but is labeled for more crops because it has less foliar activity. Some mulches in our study show superiority as herbicide slow-release carriers versus a traditional clay granular like Rout, especially in 2001. Unless granulars are hand applied, much of an application can be lost (14) making them not as efficient as herbicide-treated mulches. On the other hand, herbicide treated mulch increases herbicide efficiency by spraying only the target mulch. They also ensure that optimum coverage and drop size can be used in the process of spraying, increasing efficiency further (19). After spraying, the mulch can then be placed in the desired environment (containers, landscapes, field nurseries, etc.) without the herbicide touching the desirable plant. For some herbicides like SureGuard which have foliar activity, this significantly reduces phytotoxicity. Since herbicide-treated mulch is placed only in the desired environment, this also alleviates off-site movement of herbicides.

Herbicide-treated mulches are a novel method of weed control (22), combining two different control methods [chemical and physical (mulch)] to produce a positive interaction. There needs to be more university research to get effective weed control with reduced herbicide use to address the issue of ground water contamination. More research on the interactions of mulch × herbicides is required. Since no two herbicides are the same it follows that no herbicide × mulch combination acts the same. Herbicide-treated mulches have the potential in commercial landscapes and nurseries to: 1) help reduce ground water contamination; 2) increase application efficiency because only the target mulch is sprayed; 3) lower chemical rates; 3) enhance and extend efficacy reducing application frequencies and making proper timing of applications easier; and 4) simplify and enhance the safety of applications (compared to sprays).

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