HRI's Mission:

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.

The use of any trade name in this article does not imply an endorsement of the equipment, product or process named, nor any criticism of any similar products that are not mentioned.

Yellow Nutsedge Control and Nursery Crop Tolerance with Manage as Affected by Adjuvant Choice[1]

Gary L. McDaniel[2], Donna C. Fare[3], Willard T. Witte[2], and Phillip C. Flanagan[2]
Department of Ornamental Horticulture and Landscape Design
University of Tennessee, Knoxville, TN 37996-4500

Abstract

Adjuvants combined with one-half rate (18 g ai/ha, 0.26 oz ai/A) of Manage (MON 12051, halosulfuron) were evaluated for phytotoxicity on five species of landscape plants grown in containers and for effectiveness of yellow nutsedge (*Cyperus esculentus* L.) control. Adjuvants tested at 0.25 and 0.5% (v/v) were: X-77 (non-ionic), Scoil (methylated soybean seed oil), Sun-It II (methylated sunflower seed oil), Agri-Dex (paraffin crop oil concentrate), and Action "99" (non-ionic organosilicone). Manage combined with each adjuvant injured Japanese holly (*I. crenata* Thunb. 'Bennett's Compacta'), forsythia (*Forsythia* x *intermedia* Zab. 'Lynwood Gold'), green liriope (*Liriope muscari* Bailey 'Big Blue'), and weigela (*Weigela florida* Bunge 'Pink Lady'), but not 'Blue Girl' holly (*Ilex* x *meserveae* S.Y. Hu 'Blue Girl'). Manage with Scoil produced moderate phytotoxicity on forsythia and weigela and reduced growth of all landscape plants. Manage plus Action "99" caused severe phytotoxicity to weigela and reduced growth on all plants tested. Manage plus Agri-Dex treatment resulted in moderate to severe growth reduction to all plants, with severe marginal necrosis of foliage on forsythia and weigela. Manage with Sun-It II resulted in less growth reduction and fewer phytotoxic symptoms of the test species, compared to other adjuvant plus Manage combinations. Initially, foliar chlorosis was observed on all species except 'Blue Girl' holly with the Manage plus Sun-It II treatment, but most plants had recovered by 8 weeks after treatment (WAT). Yellow nutsedge control at 4WAT was greater when Manage (18 g ai/ha, 0.26 oz/A) was combined with Scoil, Sun-It II, Agri-Dex, or Action "99" adjuvants. By 8WAT, Manage combined with Sun-It II resulted in 98–100% control of nutsedge. Manage plus the adjuvants Scoil or Sun-It II resulted in superior yellow nutsedge control compared to X-77, Action "99", or Agri-Dex and had little effect on growth of these landscape plants.

Index words: halosulfuron, surfactant, sulfonylurea herbicide, herbicide tolerance.

Species used in this study: *Forsythia* x *intermedia* Zab. 'Lynwood Gold' (Forsythia); *Liriope muscari* Bailey 'Big Blue' (Green Liriope); *Weigela florida* Bunge 'Pink Lady' (Weigela); *Ilex* x *meserveae* S.Y. Hu 'Blue Girl' ('Blue Girl' Holly); *I. crenata* Thunb. 'Bennett's Compacta' (Japanese Holly); and *Cyperus esculentus* L. (Yellow Nutsedge.).

Chemicals used in this study: Manage (MON 12051, halosulfuron), methyl 5-{[(4,6-dimethoxy-2-pyrimidinyl) amino] carbonylaminosulfonyl}-3-chloro-1-methyl-1H-pyrozole-4-carboxylate; Scoil and Sun-It II (100% proprietary blends of methylated seed oil); Action "99" (99% proprietary blend of polyalkyleneoxide modified heptamethyl trisiloxane and non-ionic surfactants); X-77 (alkylarylpolyoxyethylene, alkylpolyoxyethelene, fatty acids, glycols, dimethylpolysiloxane, and isopropanol); Agri-Dex (83% proprietary blend of paraffin-based petroleum oil, with 17% polyoxyethylate polyol fatty acid ester and polyol fatty ester as non-ionic surfactants).

Significance to the Nursery Industry

Efficient yellow nutsedge control can be accomplished with Manage at one-half the standard rate when combined with the correct surfactant. Manage combined with Sun-It II provided the most effective nutsedge control without reducing growth and caused minimal phytotoxicity to the nursery plants tested. X-77 (a non-ionic surfactant, which is the type recommended for use with Manage) added to Manage provided only moderate nutsedge control. Some temporary phytotoxicity symptoms can be expected and a slight overall growth reduction is possible, depending on the surfactant selected. Phytotoxicity and growth reduction resulting from the reduced-rate Manage and individual surfactant interactions was species dependent. Further testing of surfactants and Manage combinations for nutsedge control and phytotoxicity on additional container nursery crop species is warranted.

Introduction

Yellow nutsedge is among the most common weeds found in nursery crops (10), is considered one of the most difficult weeds to control in container-grown plant materials (12), and containers infested with yellow nutsedge may provide a source for contaminating new landscape plantings. Under warm temperatures and high irrigation levels in nurseries, nutsedge may compete severely with container-grown crops and removal is accomplished only by costly manual labor. Hand-removal of nutsedge requires that tubers formed deep within the container are completely eliminated. While preemergent herbicides provide control of seedling nutsedge without causing excessive phytotoxicity to most nursery stock (3, 7, 8, 9), most offer little control of nutsedge after it has produced tubers. The postemergence sulfonylurea herbicide Manage (MON 12051, halosulfuron) was developed for nutsedge control in turfgrass and agronomic crops and shows promise for nutsedge control in nursery crops (14, 24). It is labeled for use as a postemergence control of sedges in established lawns, ornamental turfgrass, and as a directed-spray application to established woody ornamentals.

Control of yellow nutsedge in warm and cool season turfgrasses was greater than 85% at Manage rates of up to 0.071 kg ai/ha (0.063 lb ai/A) with no growth reduction or phytotoxicity to the turf species (20). Hurt and Vencill (15) reported that over the top Manage applications caused no damage to green liriope (*Liriope muscari*) 28 days after treatment (DAT) with rates up to 0.018 kg ai/ha (0.016 lb ai/A). They did, however, report injury to new growth of 'Macrantha Orange' azalea (*Rhododendron* x *hybrida*) at 0.009 and 0.018 kg ai/ha (0.008 and 0.016 lb ai/A) at 28 DAT. Nutsedge con-

[1]Received for publication March 1, 1999; in revised form May 23, 1999.

[2]Professor, Associate Professor, and Research Associate, resp.

[3]USDA-ARS, TSU-Nursery Crops Research Station, McMinnville, TN 37110.

trol at these low Manage rates was not reported. Manage at 0.071–0.28 kg ai/ha (0.063–0.25 lb ai/A) caused a growth reduction of cotoneaster (*Cotoneaster dammeri* C.K. Schneid. 'Coral Beauty') and Hetz Blue Chinese Juniper (*Juniperus chinensis* L. 'Hetzi Glauca'), although no foliar symptoms were observed on juniper (2). Reduced plant growth without visual injury on some landscape plants treated with Basagran (bentazon) has been reported earlier (26).

Adjuvant type and concentration used with a postemergence herbicide can influence retention of spray solutions, sites of entry into foliage, and subsequent efficacy to target weed species or toxicity to desirable landscape species. Often, the severe phytotoxic reactions in landscape plants is caused not by the herbicide alone, but by the herbicide and adjuvant combination being used. Phytotoxic effects of surfactants, when combined with herbicides, are well-established (16) and are primarily the result of their disruption of membranes. Surfactants for herbicide mixtures are classified as crop oil, organosilicones, or non-ionic chemicals. Crop oil surfactants are currently formulated from petroleum by-products, animal fat (paraffin or stearates) or more recently from vegetable oils such as sunflower, rapeseed, corn, cottonseed or other agronomic oil crops.

Crop oil type used may affect the degree of effectiveness of some herbicides (13, 17) and may also influence crop plant tolerance to chemicals. Petroleum oils increase cuticular absorption and uptake of pesticides when used as an adjuvant, but also increase potential for phytotoxicity of crop plants (1). Soybean oil was shown to provide the same benefit to Fusilade (fluazifop-butyl) applied to soybean as with petroleum oils used as an adjuvant, while causing less phytotoxic damage to the crop plants (5). Dayan et al. (6) found that surfactants increased foliar absorption of the herbicide sulfentrazone on two soybean cultivars and selected weeds, with greater herbicide absorption when organosilicone adjuvants were used instead of other surfactants or crop oil concentrates. Roundup (glyphosate) at one-third of the rate of herbicide demonstrated 100% kill of certain hard to control weed species when mixed with an organosilicone adjuvant. When used alone, the standard rate gave less than 80% control of these weeds (23). This ability to increase efficiency of herbicides allows herbicide application at greatly reduced rates with a corresponding reduction in potential for phytotoxicity to target landscape plants. The benefits of organosilicones with herbicides are now well established (18, 22), but have been largely restricted to chemicals for fencerow weed control or pasture renovation. Their value with selective herbicides applied over nursery crops requires further investigation. Non-ionic surfactants are considered safest to most landscape crop species (19) because of their hydrophilic detergent properties that act as a wetting agent, rather than as a penetrant, and low toxicity to plants and animals.

The objectives of this research were to compare non-ionic, paraffin-based crop oil, soybean oil, sunflower oil, and organosilicone surfactants combined with Manage applied at a reduced rate for: a) evaluation of phytotoxicity to five container-grown landscape species and b) yellow nutsedge control efficiency.

Materials and Methods

Experiment 1—Manage/adjuvant tolerance. Plants were potted in 3.8 liter (#1) containers filled with ground pine bark:Fafard No. 2 peat-based growing mix (4:1 v/v) amended with 4.2 kg/m^3 (7.0 lb/yd^3) of dolomitic lime, 1.2 kg/m^3 (2 lb/yd^3) of triple superphosphate 0N–20.2P–0K (0–46–0), 1.4 kg/m^3 (2.3 lb/yd^3) of gypsum, and 0.9 kg/m^3 (1.5 lb/yd^3) of Micromax on May 1–5, 1998.

Nursery species used and growth indices prior to treatment were: 'Bennett's Compacta' holly, 7.4 cm (2.9 in); 'Blue Girl' holly, 8.8 cm (3.5 in); 'Pink Lady' weigela, 11.7 cm (4.6 in); 'Big Blue' liriope, 9.2 cm (3.6 in); and 'Lynwood Gold' forsythia, 11.4 cm (4.5 in). Plants in Study 1 were grown weed-free by hand-removal to determine the phytotoxic reactions to the Manage/adjuvant interactions. Following potting, all containers were topdressed at 5 g (0.18 oz)/container with Osmocote 14N–6.2P–11.6K (14–14–14). Supplemental fertilization consisted of Peters General Purpose soluble fertilizer 20N–8.8P–16.6K (20–20–20) at 100 mg/liter N (100 ppm) weekly for 3 weeks to establish plants.

Chemical treatments consisted of Manage (Monsanto Co., St. Louis, MO) herbicide (halosulfuron) at 18 g ai/ha (0.26 oz/A), nearly one-half of the lowest rate recommended for nutsedge control of 31–62 g ai/ha (0.5–1 oz/A), combined with the following surfactants at 0.25 or 0.5% (v/v) (hereafter referred to as 1× and 2× rates): X-77 (non-ionic) [Loveland Industries, Inc., Greeley, CO], Scoil (methylated soybean seed oil) [AGSCO, Inc., Grand Forks, ND], Sun-It II (methylated sunflower seed oil) [AGSCO, Inc., Grand Forks, ND], Action "99" (non-ionic organosilicone) [Universal Cooperatives, Inc., Minneapolis, MN], and Agri-Dex (paraffin crop oil concentrate) [Helena Chemical Co., Memphis, TN]. Herbicide control consisted of Manage without additional adjuvant and untreated control plants received water only. Treatments were applied 5 weeks after planting. The herbicide/adjuvant mixtures were applied overtop the plants with a CO_2-pressurized backpack sprayer delivering 230 liter/ha (25 gal/A) using an 8003 flat fan nozzle.

A preliminary study was conducted to test these surfactants with Manage at their manufacturers' recommended rates on the nursery species used in the present study. Results of that investigation (data not shown) indicated that the suggested rates of 1–2% (v/v) for the methylated seed oils, organosilicone, and crop oil concentrate caused severe phytotoxic reactions to the test plants, when combined with Manage at the lowest recommended rate of 31 g ai/ha (0.031 lb ai/A) and at nearly one-half this rate of 18 g ai/ha (0.016 lb/A). The recommended rate for X-77 [0.25–0.5% (v/v)] was found suitable. Because the rates above 0.5% (v/v) for the remaining adjuvants with Manage at nearly one-half the recommended rate caused mild to moderate phytotoxic reactions to several of the nursery species tested, it was determined that lower rates should be evaluated.

A growth index was calculated by measuring the (height + minimum width + maximum width) / 3 prior to treatment and again at 8 weeks after treatment (WAT), with the final index reflecting new growth. Dead plants were recorded as 0. Visual phytotoxicity evaluations were taken 4WAT and 8WAT using a scale of 0–100 (0 = no damage and 100 = dead plants). Data from the 2 rating periods were transformed using the arcsine method prior to statistical analysis (27).

Experiment 2—yellow nutsedge control. Nursery crop species, general culture, and treatments applied were the same as in Study 1. Yellow nutsedge tubers were transplanted (5 tubers/container) to each plant species to determine effects

Table 1. Influence of adjuvants and Manage herbicide on growth of selected woody landscape crops.

Treatment[z]	Surfactant rate (% v/v)	Growth index (cm) at 8WAT				
		'Blue Girl' Holly	Japanese Holly	Forsythia	Liriope	Weigela
Untreated	0	7.2a[y]	6.9a	20.3a	19.4a	20.7a
Herbicide Control	0	6.9a	5.8ab	18.7a	16.2b	18.9a
X-77	0.25	6.8a	5.2b	17.6ab	15.6b	17.6b
X-77	0.50	6.7a	4.4c	16.2b	12.4c	15.6b
Scoil	0.25	6.5ab	5.1b	15.4b	14.8b	15.1b
Scoil	0.50	6.3b	4.2c	13.0c	12.4c	11.6c
Action "99"	0.25	5.9b	5.4b	14.3c	13.9bc	10.9d
Action "99"	0.50	5.1d	4.8bc	11.6cd	11.6c	7.5e
Sun-It II	0.25	6.6a	5.5b	17.3b	14.1bc	15.8b
Sun-It II	0.50	5.8bc	5.3b	16.0b	13.6c	14.5bc
Agri-Dex	0.25	5.2cd	4.4c	11.3c	6.6d	8.5d
Agri-Dex	0.50	4.7d	3.9d	10.7d	5.8d	7.2e

[z]Manage (halosulfuron) herbicide was applied at 18g ai/ha (0.26 oz/A) to all treatments except untreated control.

[y]Means within columns followed by the same letter do not differ at the 0.05 significance level by Duncan's new multiple range test.

of nutsedge control by the herbicide/adjuvant mixtures and to evaluate growth suppression by nutsedge and chemicals. Treatments were applied 5 weeks after planting and when nutsedge was at a height of 10–15 cm (4-6 in). Yellow nutsedge control was compared to untreated plants and evaluated on the basis of weed density and vigor on a scale of 0% (no control) to 100% (complete control) at 4 and 8 WAT. Treatments in each study were arranged in a completely randomized design with 12 single container replications within a crop species. Analysis of variance (ANOVA) was used for data analysis and means were separated using Duncan's New Multiple Range Test at $P = 0.05$.

Results and Discussion

Experiment 1 – Manage/surfactant tolerance. Phytotoxicity resulting from the reduced-rate Manage and individual adjuvant interactions was species dependent. Growth index data for species maintained weed-free are included in Table 1. Data for those species which exhibited statistically significant phytotoxicity are included in Table 2 for comparison.

Manage with X-77 caused the least growth reduction to 'Blue Girl' holly (6%) and forsythia (13%) at the 1× rate, with the greatest reduction for Japanese holly (25%) [Table 1]. At the 2× rate, Manage with X-77 reduced growth of Japanese holly (36%), forsythia (20%), liriope (36%), and weigela (25%). No phytotoxicity was noted for either holly species at 4 and 8 WAT when Manage with X-77 at 1× rate was applied (Table 2). Foliar chlorosis developed on the other species treated with Manage plus X-77 by 4WAT and for all species treated at the 2× rate. Foliage on all plants recovered significantly by 8WAT, except for weigela receiving Manage combined with 2× X-77.

Manage with Scoil at the 1× rate resulted in a reduction in growth for Japanese holly (26%) and liriope (24%), with the greatest reduction occurring with weigela (27%). The higher rate of Scoil resulted in greatly reduced growth of Japanese holly (39%), forsythia (36%), liriope (36%), and weigela

Table 2. Visual evaluation of phytotoxicity by adjuvants and Manage herbicide to selected woody landscape crops.

Treatment[z]	Surfactant rate (% v/v)	Visual rating[y]							
		Japanese Holly		Forsythia		Liriope		Weigela	
		4WAT	8WAT	4WAT	8WAT	4WAT	8WAT	4WAT	8WAT
Untreated	0	0a[x]	0a	0a	0a	0a	0a	0a	0a
Herbicide Control	0	0a	0a	14b	3a	8a	2a	0a	0a
X-77	0.25	0a	0a	29c	6b	17b	2a	17b	0a
X-77	0.50	16d	8b	38c	7b	23c	3a	32cd	21c
Scoil	0.25	8b	0a	39cd	9c	18c	1a	51d	21c
Scoil	0.50	10c	0a	45d	12cd	25c	2a	51d	18c
Action "99"	0.25	5b	0a	51de	9c	27cd	12b	55d	24cd
Action "99"	0.50	7b	0a	53e	21d	34d	18c	49d	23c
Sun-It II	0.25	0a	0a	24b	5ab	13b	2a	19b	0a
Sun-It II	0.50	0a	0a	38cd	6b	18c	2a	22b	9ab
Agri-Dex	0.25	12c	3a	58e	38e	39e	15d	53d	25d
Agri-Dex	0.50	16d	13c	64e	42e	44e	19c	58e	26c

[z]Manage (halosulfuron) herbicide was applied at 18g ai/ha (0.26 oz/A) to all treatments except untreated control.

[y]Visual ratings were on a percent scale where 0 = no damage, 25 = economically tolerable damage, 100 = dead plants. Ratings were taken 8 weeks following treatement applications. 'Blue Girl' holly data are not shown.

[x]Means within columns followed by the same letter do not differ at the 0.05 significance level by Duncan's new multiple range test.

Table 3. Influence of adjuvants and Manage herbicide on yellow nutsedge control.

Treatment[y]	Surfactant rate (% v/v)	Yellow nutsedge control (%)[z] 4WAT	8WAT
Untreated	0	0f[x]	0f
Herbicide Control	0	42e	16fe
X-77	0.25	55d	72c
X-77	0.50	62d	84b
Scoil	0.25	71c	92a
Scoil	0.50	82a	96a
Action "99"	0.25	81b	87ab
Action "99"	0.50	88a	91a
Sun-It II	0.25	83a	98a
Sun-It II	0.50	89a	100a
Agri-Dex	0.25	78b	56d
Agri-Dex	0.50	85a	62d

[z]Yellow nutsedge control was compared to untreated plants and evaluated on the basis of weed density and vigor on a scale of 0% (no control) to 100% (complete control) at 4 and 8 WAT.

[y]Manage (halosulfuron) herbicide was applied at 18g ai/ha (0.26 oz/A) to all treatments except untreated control.

[x]Means within columns followed by the same letter do not differ at the 0.05 significance level by Duncan's new multiple range test.

(44%). Manage with Scoil caused chlorosis of young foliage of all species by 4WAT, except 'Blue Girl' holly. These symptoms disappeared by 8WAT on Japanese holly and liriope. New growth on the remaining species progressively became less chlorotic, although some foliage had not completely recovered by 8WAT.

Manage with Action "99" at the 1× rate moderately reduced growth of Japanese holly (22%). Growth was retarded by Manage and 1× Action "99" combination for the remaining species, compared to other adjuvant treatments, and all growth indices were significantly reduced at the high treatment rate. Weigela was least tolerant of this surfactant, with a 47% growth reduction at the 1× rate and 64% reduction at the 2× rate, with the death of 2 plants occurring by 4WAT. Manage with Action "99" treatment resulted in early foliar chlorosis to Japanese holly and liriope, while marginal necrosis of new growth occurred in forsythia and weigela. Japanese holly outgrew chlorosis by 8WAT, but foliage on the remaining species had not fully recovered by the final evaluation date.

Manage with Sun-It II at the 1× rate reduced growth of Japanese holly (20%), forsythia (15%), liriope (27%), and weigela (24%). No foliar toxicity was observed for 'Blue Girl' holly and Japanese holly at both rates of Sun-It II application. Foliar necrosis appeared on upper leaves within the first 4 weeks on all remaining species, but had nearly disappeared on new growth by 8WAT.

Manage with Agri-Dex resulted in moderate growth reduction to all species tested at the 1× rate: 'Blue Girl' holly (28%), Japanese holly (36%), forsythia (44%), liriope (66%), and weigela (59%). At the high rate, all species were stunted severely. Severe foliar necrosis occurred on forsythia and weigela; causing leaf-drop, stem and bud damage, and resulted in the death of some weigela plants by 4WAT. Upper leaves became chlorotic on all species within the first 2 weeks, except 'Blue Girl' holly. Japanese holly displayed little chlorosis by 8WAT, but the remaining species had not fully recovered. Forsythia (1× = 38%, 2× = 42%) and weigela (1× = 25%, 2× = 26%) treated with Manage plus Agri-Dex exceeded a phytotoxicity rating of 25% damage by 8WAT.

Experiment 2—yellow nutsedge control. Yellow nutsedge control at 4WAT was generally greater when crop oil (Agri-Dex, Sun-It II, and Scoil) or organosilicone (Action "99") adjuvants were applied with Manage (Table 3). Herbicide control (Manage applied without added adjuvant) provided limited nutsedge control and considerable regrowth occurred following initial foliar chlorosis. Nearly complete control was achieved when Manage was applied with 2× rates of Scoil (82%), Action "99" (88%), Sun-It II (89%), and Agri-Dex (85%) at 4WAT. X-77 provided moderate nutsedge control (62%) with the reduced rate of Manage, with less nutsedge foliar phytotoxicity and mortality present 4WAT. By 8WAT, Manage with 2× Sun-It II provided 100% nutsedge control. The few remaining nutsedge in treatments combining Manage with Scoil, Action "99", and 1× Sun-It II were chlorotic and had stopped growing. Manage with Agri-Dex provided early nutsedge control, but apparently only 'burned-off' the foliage on contact and by 8WAT significant regrowth had occurred.

Table 4. Influence of adjuvants and Manage herbicide on growth of selected woody landscape crops grown in containers inoculated with yellow nutsedge.

Treatment[z]	Surfactant rate (% v/v)	Growth index (cm) at 8WAT 'Blue Girl' Holly	Japanese Holly	Forsythia	Liriope	Weigela
Untreated	0	5.0d[y]	4.1d	15.2b	13.4c	15.5b
Herbicide Control	0	5.8b	5.2b	16.0b	14.0b	16.3b
X-77	0.25	6.0b	4.8b	17.3a	13.9b	15.7b
X-77	0.50	5.7c	4.1d	15.7b	11.8d	14.9c
Scoil	0.25	6.3a	5.5a	14.7c	15.0a	13.7d
Scoil	0.50	6.0b	4.7c	12.5d	12.7c	10.1e
Action "99"	0.25	6.2b	4.8b	14.0c	13.1c	9.7e
Action "99"	0.50	5.9b	4.5c	11.4d	10.9e	6.2g
Sun-It II	0.25	6.7a	5.9a	16.5a	14.8a	17.6a
Sun-It II	0.50	6.5a	5.5a	15.6b	14.4a	16.9a
Agri-Dex	0.25	5.2d	4.3c	10.6e	6.2e	7.3f
Agri-Dex	0.50	4.5e	3.7e	10.1e	5.7e	6.6g

[z]Manage (halosulfuron) herbicide was applied at 18g ai/ha (0.26 oz/A) to all treatments except untreated control.

[y]Means within columns followed by the same letter do not differ at the 0.05 significance level by Duncan's new multiple range test.

Growth of all landscape plants was affected by the combination of nutsedge competition and Manage with adjuvants (Table 4). By 8WAT, nutsedge in untreated control containers had reached >30 cm (12 in) and had spread to conceal 'Blue Girl' holly, Japanese holly, and liriope. Manage with Agri-Dex provided the poorest control of nutsedge and greatly reduced growth on all landscape plants tested, except 'Blue Girl' holly. The combination of severe phytotoxicity and inability to adequately reduce nutsedge populations placed severe stresses on these nursery plants. Manage with 1× Scoil effectively controlled nutsedge (92%) without significantly reducing growth of 'Blue Girl' holly, Japanese holly, and liriope. This treatment severely stunted growth of weigela and forsythia. Manage with Action "99" reduced growth of all species, but forsythia, liriope, and weigela were most affected, especially at the high application rate. While this treatment provided excellent yellow nutsedge control (87%), it also caused foliar chlorosis within 48 hours on these sensitive landscape species. Manage with Sun-It II provided the most effective nutsedge control (98%) without reducing growth of the landscape species. These plants had higher growth indices than other treatments and were essentially nutsedge-free at the end of the study. Manage with X-77 provided moderate nutsedge control (72%) and only a small reduction in growth. It provided superior growth for forsythia, but this nursery species was less affected by nutsedge competition during the study because of its size. Manage with Scoil or Sun-It II generally resulted in better growth for most landscape species than did Manage with X-77, while controlling nutsedge more effectively.

Achieving maximum growth of containerized plants is essential for commercial nurseries. Nursery crops must be maintained free of weeds and post-emergent herbicides are often required to accomplish this. Adequate postemergence herbicide control of nutsedge requires that there is a rapid absorption and translocation of the active ingredient to the tubers and rhizomes in levels sufficient to kill the entire plant (25). The primary advantage of the organosilicone Action "99" is its ability to rapidly deliver the low rate of Manage to the nutsedge (4, 18, 22). While it did provide for early control of the target weed (2× rate = 88% by 4WAT), it also damaged the foliage of the more sensitive landscape plants. The two evergreen holly species were not adversely affected by this treatment, presumably because of their thicker cuticles. Manage with Sun-It II also controlled yellow nutsedge (2× rate = 89% by 4WAT), yet displayed fewer phytotoxic symptoms and provided equal or greater growth than other Manage/surfactant combinations on the plants tested in this study.

We report phytotoxicity to liriope that is contrary to a previous report (15). Results may have been in part a result of the environmental conditions present at the time of the treatments: 5% cloud cover, 32C (89F), and 87% RH, which later rose to clear sky, 33.5C (92F), 90% RH. While most investigators do not report envirnonmental conditions at application, high temperature and humidity can enhance herbicide uptake and translocation (16). Plants in this study, however, did not show injury ratings above 25% for most of the treatments. At 25% injury, crops exhibit pronounced but only temporary discoloration or stunting (11). Injury ratings in excess of 25% greatly reduce crop marketability and are generally considered to be economically unacceptable by industry standards (21).

Data from this research shows that the manufacturer's suggested use of a non-ionic surfactant with manage may not necessarily provide the best control of yellow nutsedge, without greatly reducing growth of some nursery container crops. The adjuvant recommended for use with Manage is a nonionic surfactant at 0.25–0.5% (v/v) and X-77 was included in this research for this purpose. In the hand-weeded study (Study 1), Manage/adjuvant combinations which provided similar growth of the nursery crops tested as with 1× X-77 were Manage with 1× Scoil or 1× Sun-It II; except for liriope, where the Manage plus Scoil-treated plants had slightly more growth. However, when comparing phytotoxicity ratings of these same plants, only Manage with 1× Sun-It II treatments caused foliar damage that was equal to or less than with Manage plus 1× X-77 treatments at both 4WAT and 8WAT.

When comparing plants tested in Study 1 (hand-weeded) and Study 2 (yellow nutsedge inoculated), the competition caused by the presence of nutsedge resulted in dramatic decreases in growth of untreated control plants of all nursery species tested. Although these two studies were not compared statistically, evaluation of these results do show that Manage plus adjuvant combinations which provided at least 75% yellow nutsedge control by 4WAT without subsequent yellow nutsedge regrowth and the least phytotoxicity from the chemical treatment resulted in reduced nutsedge competition and less reduction in growth indices to the nursery crops tested by 8WAT.

Our data has shown that efficient nutsedge control can be accomplished with Manage at nearly one-half the recommended rate in selected nursery crops, providing the correct surfactant is selected. In this study, the crop seed oil Sun-It II provided the most satisfactory yellow nutsedge control, while minimizing landscape plant growth reduction and phytotoxic symptoms. Some temporary phytotoxic symptoms can be expected and a slight reduction in overall growth is possible, but this is commercially acceptable in order to provide a weed-free product at an economical cost.

Literature Cited

1. Banks, V.E., L.R. Oliver, and M. McClellend. 1988. Influence of soybean oil carrier and method of application on weed control in soybean (*Glycine max*). Weed Sci. 36:504–509.

2. Bachman, G., C. Wilson, and T. Whitwell. 1995. Tolerance of containerized landscape plants to the postemergence herbicides Stinger, Manage and Basagran. J. Environ. Hort. 13:129–132.

3. Berchielli, D.L., C.H. Gilliam, G.R. Wehtje, D.C. Fare, and T.V. Hicks. 1986. Herbicides evaluated for yellow nutsedge control and ornamental phytotoxicity. Highlights of Agric. Res., Alabama Agric. Exp. Stn. 33:4–13.

4. Buick, R.D., B. Robson, and R.J. Field. 1992. A mechanistic model to describe organosilicon surfactant promotion of triclopyr uptake. Pestic. Sci. 36:127–133.

5. Cantwell, J.R. and G. Kapustra. 1986. Application of bentazon and sethoxydim in soybean oil with rotary atomizers. Agron. J. 78:478–482.

6. Dayan, F.E., H.M. Green, J.D. Weete, and H.G. Hancock. 1996. Postemergence activity of sulfentrazone: Effects of surfactants and leaf surfaces. Weed Sci. 44:797–803.

7. Derr, J.F. and B.L. Appleton. 1989. Phytotoxicity and yellow nutsedge control in azalea and liriope with Basagran (bentazon). J. Environ. Hort. 7:91–94.

8. Derr, J.F. and J.W. Wilcut. 1993. Control of yellow and purple nutsedges (*Cyperus esculentus* and *C. rotundus*) in nursery crops. Weed Technol. 7:112–117.

9. Derr, J.F., R.S. Chandran, and W.D. Ward. 1996. Preemergence and postemergence yellow nutsedge (*Cyperus esculentus*) control with MON 12000 in nursery crops. Weed Technol. 10:95–99.

10. Dowler, C.C. 1994. Weed Survey-Southern States. Proc. Southern Weed Sci. Soc. 47:279–299.

11. Frans, R., R. Talbert, D. Marx, and H. Crowley. 1986. Experimental design and techniques for measuring and analyzing plant responses to weed control practices. p. 29–46. *In*: N.D. Camper (ed.). Research Methods in Weed Science. Southern Weed Sci. Soc. Champaign, IL.

12. Gilliam, C.H., W.J. Foster, J.D. Adrain, and R.L. Shumack. 1990. A survey of weed control costs and strategies in container production nurseries. J. Environ. Hort. 8:133–135.

13. Harrison, K.S., L.M. Wax, and L.E. Bode. 1986. Influence of adjuvants and application variables on postemergence weed control with bentazon and sethoxydim. Weed Sci. 34:462–466.

14. Hurt, R.T. and W.K. Vencill. 1993. Efficacy of single early postemergence treatments of imidazoline on yellow and purple nutsedge (*Cyperus esculentus* L. and *Cyperus rotundus* L.) with ornamental tolerance. Proc. Southern Weed Sci. Soc. 46:363.

15. Hurt, R.T. and W.K. Vencill. 1994. Evaluation of three imidazolinone herbicides for control of yellow and purple nutsedge in woody and herbaceous landscape plants. J. Environ. Hort. 12:131–134.

16. Kirkwood, R.C. 1993. Use and mode of action of adjuvants for herbicides; a review of some current work. Pestic. Sci. 38:93–102.

17. Nalewaga, J.D. and G.A. Skzypczak. 1986. Adsorption and translocation of fluazifop with additives. Weed Sci. 34:572–576.

18. Roggenbuck, F.C., D. Penner, R.F. Burow, and B. Thomas. 1993. Study of the enhancement of herbicide activity and rainfastness by an organosilicone adjuvant using radiolabeled herbicide and adjuvant. Pestic. Sci. 37:121–125.

19. Ross , M.A. and C.A. Lembi. 1985. Applied Weed Science. Burgess Publishing Co., Minneapolis, MN.

20. Sherrick, S.L., A.P. Burkhalter, J.A. Cuarezma and J.F. Mason. 1993. MON 12000—A new herbicide for control of purple nutsedge (*Cyperus rotundus*) and yellow nutsedge (*Cyperus esculentus*) in turfgrass. Proc. Southern Weed Sci. Soc. 46:99.

21. Skroch, W.A., C.J. Catanzaro, and M.H. Yonce. 1990. Response of nine herbaceous flowering perennials to selected herbicides. J. Environ. Hort. 8:26–28.

22. Stevens, P.J.G. 1993. Organosilicone surfactants as adjuvants for agrochemicals. Pestic. Sci. 38:103–122.

23. Stevens, P.J.G., M.O. Kimberley, D.S. Murphy, and G.A. Plicello. 1993. Adhesion of spray droplets to foliage: The role of dynamic surface tension and advantages of organosilicone surfactants. Pestic. Sci. 38:237–245.

24. Vencill, W.K., J.S. Richburg, III, J.W. Wilcut, and L.R. Hawf. 1995. Effect of MON-12037 on purple (*Cyperus rotundus*) and yellow (*Cyperus esculentus*) nutsedge. Weed Technol. 9:148–152.

25. Wills, G.D., R.E. Hoagland, and R.N. Pauil. 1980. Anatomy of yellow nutsedge (*Cyperus esculentus*). Weed Sci. 28:432–437.

26. Wilson, C. and T. Whitwell. 1993. Tolerance of nineteen species of container grown landscape plants to postemergence application of basagran. J. Environ. Hort. 11:86–89.

27. Zar, J.H. 1984. Biostastistical Analysis, 2nd Ed. Prentice-Hall, Inc. p. 239–241.