Weed Control

Joseph C. Neal
Section Editor and Moderator

Postemergence Oxalis Control in Container-grown Nursery Crops

**Carey V. Simpson, Charles H. Gilliam,
James E. Altland, Glenn R. Wehtje and Jeff L. Sibley
Auburn University, Dept. of Horticulture, Auburn, AL 36849**

Index Words: Oxalis, *Oxalis stricta,* Diuron, Direx, Postemergence Weed Control.

Nature of Work: The markets for nursery crops demand weed free container grown plants. Using labor for weeding of containers is expensive. With increasing costs and declining profit margins, growers have been forced to search for nontraditional methods to reduce costs. Consequently, a paradigm shift has occurred for growers, in that they are willing to accept limited crop injury from herbicides to control weeds, particularly if the resultant injury is early in the crop cycle and the crop completely recovers in a short time period. In the past, growers demanded that herbicides have broad-spectrum control and crop safety. However, some growers are now interested in herbicides that have tolerance in a few crops or that control a major weed problem, i.e. bittercress, spurge, or oxalis (1,2). A 1990 survey of nurserymen reported that oxalis (*Oxalis* spp.) was one of four weeds that were considered very difficult to control in containers (4). While preemergence herbicide applications provide adequate control of oxalis, no method is 100 percent effective. Commonly, container-grown plants may have serious infestations of oxalis when emerging from over-wintering and require hand weeding (3). Therefore, a new method providing postemergence oxalis control would greatly benefit growers. A similar study conducted by Altland et al, recommended Gallery (isoxaben) for postemergence control of bittercress (*Cardimine hirsute* L.)(1). Research conducted by Looman and Vankuik found diuron to provide long lasting preemergence control of several weeds when applied as a granular formulation with tolerance in several crops (6). In addition, Georgia camellia grower suggested Direx for postemergence control of oxalis based on his preliminary test results, which showed potential for postemergence oxalis control with tolerance to camellia. The objective of this study was to evaluate Direx for postemergent oxalis control and tolerance of two landscape crops.

Liriope (*Liriope muscari* L. 'Big Blue') and camellia (*Camellia japonica* L.) liners were potted into 3.875 L (1.0 gal.) containers using a pine bark and sand substrate (7:1 plus amendments), and allowed to become naturally infested with oxalis (*Oxalis stricta* L.). Liriope were grown in full sun; camellias were grown in 53% shade. On April 13, 2001, the day of treatment, liriope and camellia were selected based on size-uniformity of oxalis in the pots. Oxalis size ranged from 10 to 16 cm tall within both crop species. Spray applications were applied with a CO_2 backpack sprayer at (20 psi) 40 gal/A using an 8004 flat fan nozzle. Treatments included 4 rates of Direx 4L (diuron) at 0.28, 0.56, 1.12 and 2.24 kg ai/ha (0.25, 0.5, 1.0, and 2.0 lb ai/A), each applied with a 0.25% (v/v) nonionic surfactant, and a non-treated control. Each treatment consisted of 8 single-plant replications in a completely randomized design. After treatment irrigation was withheld until the following day. Data collected included visual oxalis control ratings (0%= no injury and 100%= death) and crop injury ratings (1=no injury and 10= death) at 7, 14, and 21 days after treatment (DAT). Oxalis shoot fresh weights (SFW) and shoot dry weights (SDW) were collected at 21 DAT. Crops were also evaluated for visual injury and growth monthly for 7 months after treatment. All data was subjected to regression analysis and Duncan's multiple range test.

Results and Discussion: No injury was observed on liriope or camellia and there was no significant difference in liriope and camellia growth 7 months after treatment with any rate (data not shown). However, by 21 DAT Direx provided excellent oxalis control at 0.56 kg ai/ha and higher (Table 1). Oxalis control increased quadraticaly with increasing Direx rates in liriope and increased linearly with increasing Direx rates in camellia. In both crop species, Direx rates of 0.56 kg ai/ha (0.5 lb ai/A) and higher provided good to excellent oxalis control (83 to 100%). Reductions in oxalis SFW and SDW confirmed oxalis injury ratings. This research contradicts data from Kumar and Singh in that they achieved much lower control using diuron on *Oxalis latifolila,* a closely related species (5).

Significance to Industry: These data indicate that Direx (diuron), an herbicide typically used for preemergence weed control in cotton and orchards, can provide good to excellent control of oxalis at rates of 0.56 to 1.12 kg ai/A (0.5 to 1.0 lb ai/A) with tolerance on liriope and camellia. Direx is not currently registered for use on landscape crops. However, the manufacturer is seeking registration through the IR-4 program. More research is needed to determine tolerance of other landscape crops to Direx.

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Table 1. Effect of Direx rate on oxalis control in liriope and camellia.

		Oxalis control in liriope			Oxalis control in camellia		
Herbicide	Rate kg ai/ha	Control 21 DAT[z]	SFW (g)	SDW (g)	21 DAT	SFW (g)	SDW (g)
Direx	0.28	50[y] b[x]	9.2 b	0.7 b	64 b	5.5 b	0.8 b
Direx	0.56	95 a	1.7 c	0.0 b	83 a	1.5 b	0.2 b
Direx	1.12	98 a	1.7 c	0.0 b	98 a	0.7 b	0.0 b
Direx	2.24	100 a	0.0 c	0.0 b	99 a	0.0 b	0.0 b
Significance[w]		Q***	Q***	NS	L*	NS	NS
Control	-	0 c	23.2 a	2.39 a	0 c	28.7 a	4.3 a

[z] DAT = days after treatment; SFW = shoot fresh weight; and SDW = shoot dry weight.
[y]where 0%=no injury and 100%= death.
[x]Means within a column followed by the same letter are not significantly different at the 5% level using a Duncan's means separation procedure.
[w]NS, L, and Q represent not significant, linear and quadratic responses respectively.
(*,**,*** significant where $P< 0.05, 0.01, 0.001$, respectively).

Evaluation of Herbicides for Preemergence Weed Control in Container-Grown Hydrangea

Tabor B. Conwell, Doug Findley, Ken Tilt, Harry Ponder
Auburn University, Dept. of Horticulture
Auburn University, AL 36849

Index Words: *Hydrangea macrophylla*, Bittercress, Preemergence, Herbicide, Phytotoxicity

Nature of Work: Bittercress (*Cardamine hirsuta* L.) is a high seed-producing weed that germinates all year under nursery conditions (Bachman 1995). Up to Five thousand seeds can be produced and dispersed as far as 42 inches from each bittercress plant (Smith 1997). Preemergence weed control of bittercress is needed to reduce the labor involved in production of big leaf hydrangea, using a product that will not cause phytotoxic effects after leaf emergence. Currently only four pre-emergent herbicides (Pendulum 2G, Barricade, OH2, and Pennant Magnum) are labeled for use on *Hydrangea macrophylla* but only OH2 controls bittercress (Turf and Ornamental Reference for Plant Protection Products, 2000).

Hydrangea macrophylla 'Amy Pasquirer', 'Charm Red', 'All Summer Beauty', and 'Nikko Blue' cultivars were obtained from Pride of Mobile nursery in Semmes, AL. Liners were transplanted into full gallon pots using a pine bark and sand (7:1 v:v) amended medium on April 20, 2001. The herbicide treatments were applied on June 18, 2001 and consisted of granular Rout (2.0% oxyfluorfen + 1.0% oryzalin), Snapshot TG (2.0% trifluralin + 0.5% isoxaben), Regal O-O (2.0% oxyfluorfen + 1.0% oxadiazon), OH 2 (2.0% oxyfluorfen + 1.0%pendimethalin), Corral (2.68% Pendimethalin), and Pendulum 2G (2.0% Pendimethalin) each applied at _ x and 1x rates, plus an untreated control (Table 1). Treated containers were overseeded with 25 bittercress seeds each. Data collection consisted of visual ratings for phytotoxic damage on a scale between 1 and 10 with a rating of 1 being a salable plant, while a rating of 10 represented a dead plant. Data was collected at 7,14, 28, 56, and 90 days after treatment (DAT). At the end of 90 days, percent weed control was taken by using visual ratings between 0 and 100, with 0 representing no weed control and 100 representing total weed control. Ending growth indices were calculated as follows: (height + widest width + width perpendicular to widest width) divided by three. Due to limited visual injury a second experiment was initiated on August 31, 2001 using the same herbicides on the same plants but applied at 2xand 3x rates with no additional bittercress being overseeded.

Results and Discussion: Results from the first experiment revealed no significant differences in injury or growth indicies (data not shown). All treatments had greater than 94% weed control. Herbicides OH-2H x and 1x, Rout H x and 1x, and Regal O-O H x had significantly greater weed control (99%) than the control and Corral H x at a significance level of p= 0.0346. A previous study revealed similar results, and even suggested plants grown in full sun had better weed control (Keel, 1995).

In the second experiment, injury was evident 2 DAT and consisted of dark spotting and necrosis of the apical leaves and buds (data not shown). Overall injury symptoms were similar for all cultivars and no treatment x cultivar interaction was observed. The greatest amount of injury occurred with Regal 0-0 and OH2 at 2xand 3x rates. The least amount of injury occurred with Corral 3x and Pendulum 2G 2x. At 7 DAT all treatments except Corral 3x and Pendulum 2G 2x had significantly more injury than the control. Regal O-O 3x, OH2 2x, and OH2 3x had significantly more injury than all other treatments. At 14 DAT injury ratings were reduced for all treatments. At 14 DAT, hydrangeas were injured by Rout 2x, Rout 3x, Snapshot 2x, Regal 0-0 2x, Regal O-O 3x, OH2 2x, and OH2 3x. OH2 2x and OH2 3x had significantly more injury than all the other treatments except for Regal 0-0 2x, Regal O-O 3x. No significant differences in visible injury were observed after 14 DAT indicating the plants outgrew the injury and would be considered marketable. No treatments reduced hydrangea growth compared to the control (data not shown).

The herbicides Rout (2.0% oxyfluorfen + 1.0% oryzalin), Regal O-O (2.0% oxyfluorfen + 1.0% oxadiazon), and OH2 (2.0% oxyfluorfen + 1.0%pendimethalin) all contain 2% oxyfluorfen. Previous research showed that foliar sprays of oxyflurofen at rates of 1.96 lb/A and 4 lb/A injured 'Gloria' Azalea foliage (Moore 1989). But, phytotoxicity was reduced when applications were made to the media, avoiding contact with the foliage, regardless of time of application, rate, or potting medium (Moore 1989).

Significance to Industry: Preemergence weed control of bittercress is needed to reduce the labor involved in the production of big leaf hydrangea while not causing phytotoxic effects after leaf emergence. Of the herbicides tested, Pendulum 2G, Corral, and Snapshot TG show promise for this purpose because they provided the best weed control and least phytotoxic damage. Herbicides containing oxyfluorfen caused greater injury at higher rates and care should be taken closely follow labeled rates.

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Table 1: Herbicides and rates used to evaluate phytotoxicity on containerized *Hydrangea macrophylla*.

Experiment 1			**Experiment 2**		
Herbicide	**lbs. ai/A**	**Rate**	**Herbicide**	**lbs. ai/A**	**Rate**
Control			Control		
Rout	1.5	H x	Rout	6.0	2x
Rout	3.0	1x	Rout	9.0	3x
Snapshot	1.87	H x	Snapshot	7.5	2x
Snapshot	3.75	1x	Snapshot	11.3	3x
Regal 0-0	1.5	H x	Regal 0-0	6.0	2x
Regal 0-0	3.0	1x	Regal 0-0	9.0	3x
OH2	1.5	H x	OH2	6.0	2x
OH2	3.0	1x	OH2	9.0	3x
Corral	1.0	H x	Corral	3.96	2x
Corral	2.0	1x	Corral	5.96	3x
Pendulum 2G	1.0	H x	Pendulum 2G	4.0	2x
Pendulum 2G	2.0	1x	Pendulum 2G	6.0	3x

Table 2: Effects of selected herbicides on *Hydrangea macrophylla* at 7 and 14 DAT in Experiment 2.

Herbicide	7 DAT	14 DAT
Control	1.0 E	1.0 F
Rout	2.9 AB	2.3 BCD
Rout	2.8 AB	2.4 BCD
Snapshot	2.4 CB	2.1 CDE
Snapshot	2.0 CD	1.9 DEF
Regal 0-0	3.0 AB	2.7 ABC
Regal 0-0	3.1A	2.9 AB
OH2	3.1A	3.1 A
OH2	3.4 A	3.2 A
Corral	2.1 CD	1.8 DEF
Corral	1.8 DE	1.5 EF
Pendulum 2G	1.8 DE	1.5 EF
Pendulum 2G	2.0 CD	1.9 DEF

Rating Scale: 1 = marketable and 10 = dead
Means separation by Duncan's Multiple Range Test.

Effect of Prodiamine Formulation on Injury to Ornamentals

Jeanne Briggs and Ted Whitwell
Department of Horticulture
Clemson University, Clemson, SC 29634

Index Words: Barricade, Container Nursery Crop, Dinitroaniline Herbicide, Preemergence Herbicide, RegalKade.

Nature of Work: In the summer of 2001, a study comparing effects of prodiamine formulation on plant injury was conducted at the Ornamental Research Area on the campus of Clemson University. Liners of ten taxa of woody ornamental plants (Table 1) obtained from Gilbert's Nursery, Chesnee, SC, were planted in 3 L containers containing aged pine bark:sand (85:15 v/v) that had been amended to pH 5.5 with pelletized dolomitic limestone. Four days after planting, herbicide treatments were applied. Three formulations of prodiamine, a granular (RegalKade), wettable granule (Barricade 65WG) and suspension concentrate (Barricade 4SC) were applied at labeled (1.5 lb ai/A) and 2X labeled (3 lb ai/A) rates to containers. Granular prodiamine was applied with a handheld shaker can. Sprayable treatments were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 20 gpa (187 L/ha) at 30 psi. There were six replications of the seven treatments in a randomized complete block design within a plant species. Injury was visually evaluated on 7, 13, 17 and 21 weeks after treatment (WAT) on a scale of 0 to 100, with 0 = no injury and 100 = plant death. At 21 WAT, shoot height and width at widest point were measured, summed, and divided by two to derive growth index (GI) of the plant taxa that displayed visible signs of herbicide injury. Injured species were then harvested. Roots were separated from shoots, roots were washed to remove substrate, and fresh weights of shoots and roots were recorded. Plant parts were then dried for 7 to 10 d and dry weights were recorded.

Results and Discussion: Only four of the ten plant taxa displayed visible injury symptoms at 21 WAT (Table 2). Injured taxa were blue rug juniper, Florida leucothoe, pink cascade azalea, and needlepoint holly. Injury symptoms were reduced growth and chlorosis. At 21 WAT, injury to juniper was most severe in the granular formulation treatment applied at the low rate. Needlepoint holly was injured by all formulations with greatest injury noted in the granular formulation treatments. Florida leucothoe was injured by all formulations at all rates with injury being most severe from high rates of the granular and WG formulations (>50%). Pink cascade azalea was also injured severely (>50%) from high rates of the granular and WG formulations, and moderately (38%)

from the low rate of the granular formulation. Visible injury was slow to manifest on blue rug juniper and needlepoint holly and was not observable at 7 WAT. However, injury was observed sooner on pink cascade azalea and Florida leucothoe. At 7 WAT, the granular formulation applied at the high rate injured Florida leucothoe as compared to the untreated, and all herbicide formulations and rates, except the SC at high rate, injured azalea.

Growth index of Florida leucothoe was reduced by all formulations at all rates, with the exception of the SC at low rate, as compared to the untreated controls at 21 WAT (Table 2). Needlepoint holly growth was only reduced by the high rate of the granular formulation, and pink cascade azalea growth was reduced by both rates of the granular treatment and the high rate of the WG formulation. Juniper growth in prodiamine-treated plants was as great or greater than in the control possibly due to reduction in weed populations. Only growth of Florida leucothoe was reduced by the SC formulation.

Fresh weight treatment differences were similar to dry weights and therefore only the dry weight data are presented (Table 3). No treatment differences were found in shoot weight for blue rug juniper, and root weights were similar to or higher in prodiamine treatments than in the untreated control. Needlepoint holly root weights were not different from the untreated or between treatments, but shoot weight was lower from the high rate of the granular formulation. Shoot and root weights of Florida leucothoe and pink cascade azalea were reduced for all prodiamine treatments as compared to untreated. Greatest inhibition in Florida leucothoe root and shoot weights occurred from application of the high rates of the granular and WG formulations, and in azalea from the high granular rate.

Results of this study indicate that prodiamine formulation affects injury in sensitive plant taxa. Sprayable formulation applications will cause less injury to sensitive plant taxa than granular formulations. Similar reports of injury from granular formulations of prodiamine are found in the literature. Shoot weight of Potomac crape myrtle and waxleaf ligustrum were lower from a granular formulation of prodiamine than from the sprayable WDG formulation (1). Root injury in two azalea varieties increased with increasing rates of granular prodiamine (2).

Significance to Industry: In this study, prodiamine injured and reduced growth of Florida leucothoe, pink cascade azalea, and needlepoint holly. Blue rug juniper was slightly injured but no growth effects were found. Prodiamine formulation affected injury in sensitive plant taxa. Sprayable formulation applications caused less injury to sensitive plant taxa than granular formulations. Granular prodiamine formulations should not be used on Florida leucothoe, pink cascade azalea, and needlepoint holly.

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Table 1. List of landscape plant taxa in the study. All plants were newly potted up liners.

Botanical name	Common name
Abelia x *'Little Richard'*	*Little Richard abelia*
Agarista populifolia (Lam.) Judd	Florida leucothoe
Berberis Thunbergii D.C. var. *atropurpurea* 'Rose Glow'	Rose glow Japanese barberry
Buddleja Davidii Franch. 'Nanho Purple'	Butterfly bush
Cotoneaster salicifolius 'Scarlet Leader'	Willowleaf cotoneaster
Euonymus fortunei forma *gracilis* (Regel) Rend.	Wintercreeper euonymus
Ilex cornuta Lindl. and Praxt. 'Needle Point'	Needle point holly
Juniperus horizontalis Moench 'Wiltonii'	Blue rug juniper
Nandina domestica Thunb. 'Fire power'	Dwarf nandina
Rhododendron 'Pink Cascade' Harris	Pink cascade azalea

Table 2. Injury (%) and growth index (cm) of landscape plant taxa treated with prodiamine formulations, at 7 and 21 weeks after application (WAT).

		Injury								Growth index			
		Juniper		Fla. leucothoe		Holly		Azalea		Jun.	Leu.	Holly	Azal.
Formulation / treatment	Rate	7 WAT	21 WAT	7 WAT	21 WAT	7 WAT	21 WAT	7 WAT	21 WAT	WAT	21 WAT		
	lb ai/A	%								cm			
Granular	1.5	0	17	0	38	0	27	19	38	8.7	11.5	6.5	6.8
	3.0	0	5	13	50	0	33	23	52	8.9	9.3	5.8	7.2
WG	1.5	0	5	4	32	0	15	12	15	10.2	11.3	7.8	9.3
	3.0	0	0	3	53	0	25	23	53	11.7	9.3	6.6	7.0
SC	1.5	0	10	9	28	0	20	15	15	9.3	12.0	7.0	9.8
	3.0	0	0	5	25	0	15	7	18	11.8	12.8	7.5	9.2
Untreated	—	0	0	0	0	0	0	0	0	9.6	14.8	8.2	10.6
LSD (0.05)		0	17	12	18	0	16	11	17	2.2	2.5	1.9	2.1

Table 3. Root and shoot dry weight (g) of landscape plants 21 weeks after treatment with three formulations of prodiamine.

Formulation		Dry weight							
		Juniper		Fla. leucothoe		Holly		Azalea	
treatment	Rate	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
	lb ai/A	g							
Granular	1.5	14.4	17.6	15.0	1.5	7.6	2.8	14.0	10.0
	3.0	14.5	14.6	9.5	0.4	5.9	2.2	9.5	5.2
WG	1.5	14.3	13.9	14.7	2.7	6.7	2.6	16.1	9.2
	3.0	17.2	17.9	8.5	1.0	6.3	2.2	11.4	6.4
SC	1.5	19.4	23.8	18.7	3.5	7.5	2.2	15.7	13.5
	3.0	18.6	18.7	20.3	3.9	8.8	2.5	19.0	9.1
Untreated	—	15.7	15.3	36.1	5.7	9.2	2.4	28.2	28.7
LSD (0.05)		5.4	8.0	8.8	1.5	3.1	NS	8.3	9.3

Trifluralin Dissipation in a Bark-based Substrate

Caren A. Judge[1], Joseph C. Neal[1], and Ross B. Leidy[2]
North Carolina State University
[1]Department of Horticultural Science, Box 7609
[2]Department of Environmental and Molecular Toxicology
Box 7633; Raleigh, NC 27695.

Index Words: Bioassay, Container Nursery Production, Dinitroaniline, Herbicide Dissipation, Preemergence Herbicides, Large Crabgrass, Perennial Ryegrass, *Digitaria sanguinalis*, *Lolium perenne*.

Nature of Work: In container nursery crop production systems in the southeastern U.S., frequent applications (every 8 to 10 weeks) of preemergence herbicides are relied upon for broad-spectrum weed control. However, herbicides often lose their effectiveness before re-application. Because there are few selective postemergence herbicides available, weeds that germinate between herbicide applications must be removed by hand, an expensive and laborious task. Gilliam et al. (2) reported that depending on nursery size, annual hand-weeding costs ranged from $246 to $567 per acre based on hourly wages from $3.53 to $3.97. More recently, it was reported in North Carolina that, when no herbicides are used, it costs up to $1,367 to hand weed 1000 (3-L) pots over a 4-month period, based on hourly wages of $14.75, an average of labor costs provided by several local nurseries (1).

Snapshot TG is commonly used in container nursery production for broad-spectrum preemergence weed control. It consists of a dinitroaniline, trifluralin, primarily for grass control and isoxaben for expanded broadleaf weed control. Trifluralin half-life values range from 19 to 132 days in various field soils (6), but no data are available on the half-life of trifluralin in soilless nursery substrates. Since frequent re-application is necessary to maintain acceptable weed control, it is likely that the half-life in the surface of soilless substrates is less than those observed in field soils.

An experiment was conducted to analytically determine trifluralin dissipation over time in a soilless substrate and to assay growth of sensitive grass species over the same time period. By quantifying dissipation of one component of a standard nursery herbicide, we hoped to estimate the dissipation of the prepackaged product, Snapshot TG, and better predict when herbicide re-application is necessary.

Plastic containers (3-gal) were filled with a pine bark:sand substrate (7:1 v/v). Treatments included Preen 1.47G at 4.0 lbs ai/A and a non-treated.

The test was initiated on June 12, 2001 in Raleigh, NC and was repeated on June 18, 2001 in Castle Hayne, NC. The experimental design was a split plot; the main plot factor was +/- herbicide and the subplot factor was treatment to seeding or sampling time interval. The experiment was arranged in a randomized complete block with four replications. Preen was applied using a hand-held shaker jar and irrigation (~ 1 in) was applied daily at each location. For laboratory analysis, samples were removed from the top 0.8 in of the substrate surface 1, 3, 7, 14, 28, 42 and 56 days after treatment (DAT). Trifluralin residues were extracted from the substrate and quantified using gas chromatography with a thermionic specific detector. Concentrations are reported as ug trifluralin per g dry weight of potting substrate.

Concurrent with sampling of the potting substrate, containers were also surface seeded with large crabgrass (*Digitaria sanguinalis*) and perennial ryegrass (*Lolium perenne*) for bioassay determination of trifluralin residues. Each grass species was seeded 0, 7, 14, 28, 42, and 56 DAT in one pot per plot on each seeding date. Shoot and root length of ten randomly selected plants of each species were measured two weeks after seeding and data are expressed as percent of the non-treated. Based on regression equations, concentrations at which 20% (GR_{20}) growth occurred were estimated, which can be considered equivalent to 80% inhibition. Data from each run of the experiment are presented separately. Data from both the lab analysis and bioassay analysis were subjected to analysis of variance and fitted to non-linear regression curves based on the Weibull model (5).

Results and Discussion: Dissipation of herbicides in soil is dependent upon the physiochemical properties of the herbicides and environmental conditions. Trifluralin concentrations at day 0 (after irrigation) were 47.7 and 74.6 ug/g in Raleigh and Castle Hayne, respectively. Based on this, half-life values were calculated to be approximately 6.5 and 3.5 days, much lower than those of field soils.

Herbicide concentrations in Castle Hayne were higher at the onset, but by 3 DAT, concentrations quickly dissipated to levels similar to those in Raleigh (Figure 1). In both studies, losses were rapid during the first seven days and slowly thereafter, beginning to level off about 21 DAT. These applications were considered mid-season applications. Dissipation rates, however, were similar to those observed from late March and early May trifluralin applications (3). It is very unlikely that losses were due to leaching because of its low water solubility (4). Trifluralin vapor losses are greater with increased temperature and moisture (6). Therefore, rapid losses of trifluralin from soilless substrates are presumed to be primarily due to volatilization during the hot growing season in the southeastern U.S. Days until 20% growth (GR_{20}) compared to the non-treated, were determined from regression curves (Table 1). Both roots and shoots of large crabgrass and perennial ryegrass had GR_{20} values of 4 to 21 days. This shows that both species were effectively controlled for 21 days or less.

Significance to Industry: In the southeastern U.S., during mid-summer, trifluralin dissipates quickly from the surface of a bark-based substrate (half life of less than 7 d), and 20% growth of sensitive grass species occurs in less than 21 days. If these are representative of dissipation rates of other preemergence herbicides in nurseries, perhaps the current herbicide reapplication interval of 8 to 10 weeks may need to be shortened to improve performance of preemergence herbicides and reduce the need for hand weeding. Another option to improve herbicide performance might be to apply lower rates more frequently. This may maintain adequate concentrations for weed control without the initial rapid loss of trifluralin. For such strategies, herbicide applicators will need to target the maintenance of trifluralin concentrations greater than 33 ug/g, the concentration at which weeds were no longer controlled.

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Table 1. Days to 20% (GR_{20}) large crabgrass and perennial ryegrass growth and corresponding trifluralin concentrations (ug/g) in soilless substrates (as determined by gas chromatography).

Species	Location	Plant Part	GR_{20}	Trifluralin Concentration
			–(days)–	–(μg/g)–
Large crabgrass	Raleigh	Root	21	9.1
	Castle Hayne	Root	8	18.6
	Raleigh	Shoot	17	11.2
	Castle Hayne	Shoot	9	16.7
Perennial ryegrass	Raleigh	Root	5	28.1
	Castle Hayne	Root	7	20.9
	Raleigh	Shoot	4	31.5
	Castle Hayne	Shoot	4	33.4

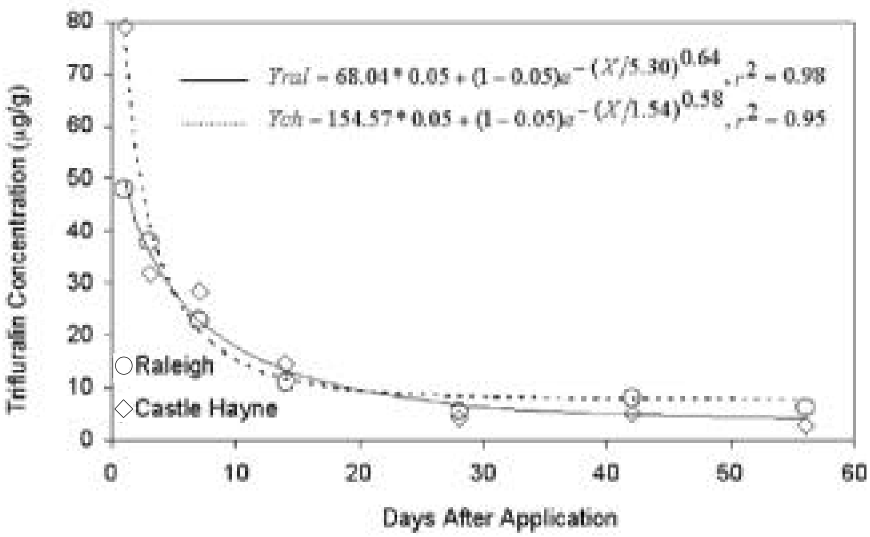

Figure 1. Trifluralin dissipation curves in a soilless substrate. Data were fit to a Weibull model:

$$Y = A + e^{-(X/\sigma)^{C}}$$

where A, C, and σ are estimated parameters and X is days after treatment

Herbicide Treated Mulches for Ornamental Weed Control

Hannah Mathers and Luke Case
Ohio State University, Dept. Horticulture and Crop Science
Columbus, OH 43210

Index Words: Ornamental Production, Nursery, Herbicides, Mulches.

Nature of Work: In 1998 and 2000, efficacy and phytotoxicity (data not shown) trials were conducted with herbicide treated mulch applied to 1-gallon (3.8 L) pots. The trial results presented had one objective: 1) determine the efficacy and duration of weed control of herbicide treated mulches compared various treatments including, new and conventional ornamental herbicides, various novel non-chemical alternatives (2000) (data not shown) and herbicide treated fertilizers (1998) and untreated mulches (2000).

Efficacy was evaluated using dry weights and a visual rating on a scale of 0 to 10 where 0 represents no control, 10 represents complete control and 7 or above represents commercially acceptable control. In 1998, large [> 1 inch (2.54 cm)] douglas fir bark nuggets were sprayed with oxyfluorfen 23% (Goal 2XL) 1 (ai) $lb \cdot ac^{-1}$ [1.12 (ai) $kg \cdot ha^{-1}$] oryzalin 40% (Surflan AS) 2 (ai) $lb \cdot ac^{-1}$ [2.24 (ai) $kg \cdot ha^{-1}$] or isoxaben 75% (Gallery 75 DF) 1 (ai) $lb \cdot ac^{-1}$ [1.12 (ai) $kg \cdot ha^{-1}$]. The three herbicides indicated above were also sprayed onto dry Apex 21N-5P-6K (5 month formulation), Osmocote 22N-3P-8K (5-6 month formulation) and Osmocote micro-fertilizer 18-5-9 (5-6 month formulation) spread evenly, one layer thick, on a polyethylene sheet. The three herbicides indicated above were also sprayed onto dry Apex 21-5-6, Osmocote 22-3-8 and Osmocote micro-fertilizer 18-5-9. The fertilizers treated and untreated were applied at 0.36 oz (10 g) per pot. Two pre-formulated preemergent treated fertilizers were also tested in 1998, oxadiazon + pendimethalin on a 28N-0P-0K (Kansel Plus) and oxadiazon + 21N-0P-0K (1.5% Ronstar) both were applied at 0.04 oz (1.2 g) per pot. There were 18 treatments in 1998 study. In 2000 there were additional treatments for a total of 24 (only 15 treatments are reported). The herbicide treated fertilizers were not evaluated in 2000. Two sizes of douglas fir bark nuggets, large > 1 inch and small < 1 inch, were sprayed with oxyfluorfen 23% (Goal 2XL) 0.05 and 1 (ai) $lb \cdot ac^{-1}$ [0.56 and 1.12 (ai) $kg \cdot ha^{-1}$] or oryzalin 40% (Surflan AS) 1 and 2 (ai) $lb \cdot ac^{-1}$ [1.12 and 2.24 (ai) $kg \cdot ha^{-1}$]. The large nuggets were also treated with flumioxazin 51% (Sureguard WDG) 0.34 (ai) $lb \cdot ac^{-1}$ [0.38 (ai) $kg \cdot ha^{-1}$]. The mulches were allowed to dry for 24 to 48 hours before putting them into the pots one layer thick. Two granular preemergent herbicides isoxaben 0.5% + trifluralin 2% (Snapshot 2.5TG) 100 $lb \cdot ac^{-1}$

product and flumioxazin (Broadstar 0.17G) 0.25 (ai) lb·ac^{-1} [0.28 (ai) kg·ha^{-1}] were evaluated for comparison. The studies were evaluated for phytotoxicity and efficacy 70 and 150 d after treatment (DAT) in 1998 and 45 (data not shown) and 130 DAT in 2000.

Results and Discussion: Organic mulches control weeds in two ways, inhibition of germination and suppression of weed growth (2, 4). Skroch et. al. 1992 found that even when bark mulch was applied at a depth 3.5" the mulches only reduced weed counts by 50% over untreated controls (4). Similarly, in our 2000 efficacy study, douglas fir bark mulch applied alone, without pretreatment of herbicide, provided less than acceptable weed control 45 DAT (data not shown) and little weed control 130 DAT (Figure 1). However, the preemergent herbicide treated douglas bark provided excellent weed control in 2000 (Figure 1) compared to the herbicides or mulches applied alone. Preliminary studies by Derr, Neal and Senesac and Hogue have shown excellent control of certain weeds with a layer of pine bark mulch containing preemergents (1). Of the carriers investigated in 1998 the treated bark provided superior efficacy (data not shown). Regardless of which of the three preemergents were applied, the herbicide treated barks provided excellent weed control. However, bark treated with Surflan had significantly greater efficacy than bark treated with Goal or Gallery (Figure 2). The herbicide treated douglas fir bark represented four of the six most efficacious treatments in 2000 at 130 DAT (Figure 1), their corresponding phytotoxicities were below 2.8 (data not shown). Treatment of Surflan onto douglas fir bark in 2000, provided significantly greater efficacy versus treatments with Goal. Little nuggets treated with Surflan AS at 2 (ai) lb·ac^{-1} was the best treatment in 2000.

Significance to Industry: Any method of herbicide application that would increase efficiency, and longevity of preemergent herbicides used in ornamental culture would be of significant interest to nursery managers. In our experiments in 1998 and 2000, the Surflan treated douglas fir bark provided increased efficacy and extended efficacy versus untreated douglas fir bark or Surflan applied alone. We are currently investigating the possibility that the bark can act as a slow release carrier for some herbicides. Recent studies have indicated that the controlled release of herbicides using lignin as the matrix offers a promising alternative technology for weed control (3).

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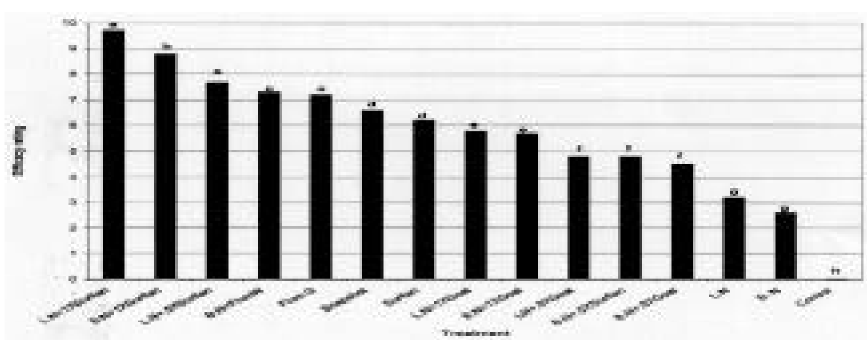

Fig. 1. Efficacies of various weed control treatments (2000) evaluated as rated scores (0-10, where $\geq$7 is commercially acceptable) at 130 DAT. Different letters signify the LSD *P*=0.05. Bars represent the means of five replicates. Abbreviations are, FlumW = flumioxazin WDG, FlumG = flumioxazin G, 1X = 1X label rate, 0.5X = 0.5X label rate, L.N. = little (<1") douglas fir nuggets, B.N. = big (>1") douglas fir nuggets.

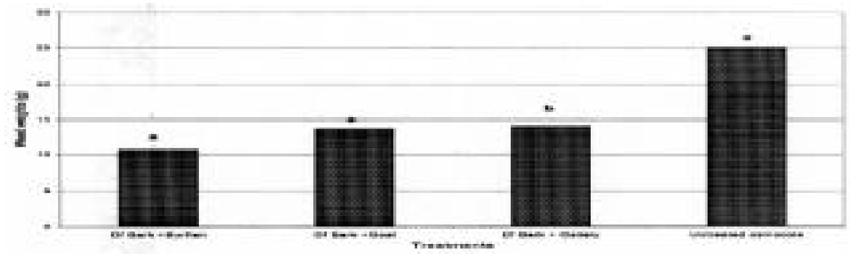

Fig. 2. Efficacy of herbicide treated bark treatments (1998) compared to untreated Osmocote fertilizer expressed as grams of weed weight. Different letters signify the LSD *P*=0.05. Bars represent the means of five replicates evaluated at 150 DAT.

Weed Control During Liner Production of *Hydrangea serrata* Utilizing Self-Felting Wool Pellets

D. Bradley Rowe and R. Thomas Fernandez
Department of Horticulture, Michigan State University
East Lansing, MI 48824

Index words: Weed Control, Wulpak, Wool Pellets, *Hydrangea serrata*, Gallery, Isoxaben, Barricade, Prodiamine, Spin Out® Copper Hydroxide

Nature of Work: The use of herbicides in ornamental nursery crops is challenging due to labeling restrictions, potential crop sensitivities (2), and increasing concerns regarding protection of our water resources (3). However, herbicide use is not likely to decrease without demonstrated effective alternative weed control strategies. Numerous mulches have been studied with varying degrees of success. One of these, Wulpak, self-felting wool pellets (Harroll's, Norway, S.C.), reduced weeds during production of several herbaceous perennials, but was an accompanied by higher crop mortality (4). However, one would suspect that woody plants may be more tolerant to mulch. Even so, the use of wool pellets may prove to be an environmentally friendly method to help control weeds.

Other possible benefits of Wulpak may include a potential to bind herbicides to the layer of wool, thus, reducing leaching into the root zone and herbicide contamination of runoff. Furthermore, copper-treated fabric disks have been shown to suppress weed growth in container-grown willow oaks (1), so use of Wulpak in combination with Spin Out® (copper hydroxide) (Griffin LLC, Valdosta, Ga.) may provide weed suppression without the use of herbicides. Therefore, our objective was to determine if Wulpak alone and in conjunction with herbicides or Spin Out® is a viable method of weed control during liner production.

The study was conducted at Spring Meadow Nursery, Grand Haven, MI, and consisted of five treatments applied to rooted liners *Hydrangea serrata* 'Blue Bird' in 18-cell (3.25 in.) flats. Treatments included Wulpak alone, Wulpak treated with Spin Out® (7.1% copper hydroxide), Wulpak treated with the herbicides Gallery 75 DF (isoxaben) or Barricade 65 WG (prodiamine), and a control. The experiment was conducted in a completely random design with five treatments and four replications for a total of 20 flats or 500 liners. To ensure a uniform weed population, flats were exposed to hairy bittercress (*Cardamine hirsuta*) and yellow woodsorrel (*Oxalis stricta*) by placing flats of these weeds every three feet in the growing area.

All Wulpak applications were applied to the surface of the substrate at the recommended rate of 1668 g/m^2 (0.34 lb/ft^2). Spin Out® and Gallery were evenly distributed onto the wool pellets with a sprayer prior to application of pellets to flats. Spin Out® was applied at 13.1 g ai/kg (0.21 oz ai/lb) of Wulpak and Gallery at 0.04 g ai/kg (0.65 oz ai/1000 lb) of Wulpak. These rates resulted in actual treatments of 218.7 kg ai/ha (195.1 lb ai/A) and 0.67 kg ai/ha (0.6 lb ai/A) for Spin Out® and Gallery, respectively. Barricade was sprayed over the plants with a backpack sprayer at 0.99 kg ai/ha (0.88 lb ai/A) following placement of wool pellets.

Initial measurements of plant height were recorded on a sub-sample of five plants per rep when the study commenced 25 May. At this time, plants were evaluated with an overall visual quality rating (ranging from 0 to 5, with a higher number representing higher quality). Additional measurements of plant height, weed density per flat, visual rating, crop survival, and substrate moisture were recorded 23 June and 15 August when plants were harvested. Substrate moisture content was measured with a Theta Probe Soil Moisture Sensor ML2X (Delta-T Devices, Ltd., Cambridge, U.K.). At harvest, shoot and root dry weights were obtained and dry mass accumulation was calculated. Weed dry weights per flat were also determined. Treatment effects were compared by analysis of variance (PROC GLM, SAS Institute, Cary, N.C.) and significant differences among treatments were separated by Tukey's Studentized Range (HSD) test.

Results and Discussion: Wulpak + Spin Out®, Wulpak alone, and Wulpak + Gallery treatments resulted in the lowest weed dry weight per flat when compared to the control (Table 1). The greater weed growth in the Wulpak + Barricade treatment can probably be attributed to the lessened crop competition resulting from a lower crop survival rate and reduced crop quality (Table 1). In general, Wulpak + Spin Out® and Wulpak alone resulted in better plant performance than the control. Increases in shoot dry weight accumulation were significantly greater for the Wulpak + Spin Out® and Wulpak treatments compared to the control (Table 1). Similarly, root dry weight accumulation per plant was greatest for the Wulpak + Spin Out®, Wulpak, and Wulpak + Gallery treatments.

Treating plants with the herbicide Barricade resulted in the poorest performance for all variables measured (Table 1). Visual ratings, which provided a subjective assessment of potential negative effects of Wulpak or herbicide applications, were relatively the same except for plants treated with Barricade (Table 1). Wulpak applications significantly increased volumetric substrate moisture (Table 2). This can be a positive or negative influence on plant growth depending on the watering regime. Contrary to what was found for herbaceous perennials (4), volumetric substrate moisture did not significantly influence visual rating or crop survival (Tables 1 and 2).

Significance to Industry: The application of Wulpak wool pellets suppressed weeds in liners of *Hydrangea serrata* 'Blue Bird'. The use of Wulpak may have potential as an alternative weed control strategy for liner production of other woody species as well. Not only may the practice help suppress weeds, but it could potentially reduce the need for herbicide applications, which in turn may limit potential crop damage, lessen exposure of nursery workers to chemicals, and result in less contamination to the environment. However, there is still the question of whether it is economically feasible to manually apply Wulpak to existing liners.

***Acknowledgment*:** Funding for this study was provided by Spring Meadow Nursery, Grand Haven, MI; Harroll's (formerly Wilbro, Inc.), Norway, S.C.; MSU Project GREEEN, and the Michigan Agric. Exp. Sta.

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Table 1. Effect of Wulpak treatment on liners of *Hydrangea serrata* 'Blue Bird'.

Treatment	Weed dry weight per flat (%)	Crop survival (%)	Visual rating	Shoot dry weight accumulation per plant (g)	Root dry weight accumulation per plant (g)
Wulpak + Spin Out®	3.7 c	90.1 a	4.4 a	11.2 a	5.77 a
Wulpak	7.0 c	94.4 a	4.0 a	10.0 a	4.76 ab
Wulpak + Gallery	7.7 c	86.1 a	4.1 a	7.1 ab	4.72 ab
Control	25.5 b	86.1 a	3.5 ab	4.6 bc	2.38 bc
Wulpak + Barricade	52.2 a	77.8 b	2.7 b	0.9 c	0.09 c

Means separation among treatments by Tukey's Studentized Range (HSD) test, *P* £ 0.05.
Treatments with identical letters are not significantly different.

Table 2. Effect of Wulpak application on substrate moisture.

Treatment	June 23	August 15
Wulpak	0.379	0.446
No Wulpak (Control)	0.347	0.385

Significant differences between means determined by t-test, *P* £ 0.05. Moisture readings taken with Theta Probe soil moisture sensor ML2X which converts output signal into a volumetric moisture fraction. Each value is a mean of 20 measurements.

Granular Preemergent Herbicides Influence Growth of *Gardenia augusta* 'August Beauty'

John M. Ruter
Univ. of Georgia, Dept. Horticulture, Tifton, GA 31794

Index Words: *Gardenia*, Herbicide, Root Growth

Nature of Work: Gardenias are a group of ornamental plants that are suspected to be sensitive to preemergent herbicides in container nurseries. A study was initiated to evaluate several preemergent herbicides and their influence on the growth of *Gardenia augusta* 'August Beauty'. The study was initiated on 15 April 1997 at Wight Nurseries in Cairo, GA. Gardenia plants growing in #1 (2.8 liter) containers were pruned to a uniform height and granular herbicides were applied using pre-weighed aliquots and a hand-held shaker jar (Table 1). One-half to one inch of irrigation water was applied to the plants after application of each herbicide treatment. Plants were grown under standard cultural conditions and received liquid fertilizer (10.0N-1.5P-6.6K) throughout the growing season. Weeds in containers were few and were removed as needed. All treatments were replicated six times in a completely randomized block design.

At 180 days after initiation of the study the plants were measured (height + width1 + width2/3) and growth indices calculated. Plants were removed from the container and the distance from the surface of the substrate to the first visible roots was measured to calculate the percentage of the rootball missing roots at the top of the substrate column due to herbicide damage. Shoots were removed and roots shaken to remove all substrate before dry mass was determined after drying in a forced air oven at 70C (158F) for 72 hours. Data were subjected to analysis of variance using SAS. Mean separation tests were conducted using the Waller-Duncan K ratio t-test.

Results and Discussion: Plant growth data is presented in Table 2. For growth index and shoot and root dry weight, none of the herbicides tested reduced growth compared with the non-treated control plants. Growth indices for plants treated with RegalStar II + fertilizer were greater than plants treated with Regal O-O, the one time application of RegalKade G, and the non-treated control plants. Shoot and root dry weight increased 24% and 46%, respectively for plants treated with RegalStar II + fertilizer compared with the control, indicating that *Gardenia* 'August Beauty' benefitted from the supplemental nitrogen provided by this herbicide-fertilizer combination.

The largest reduction in roots at the top of the substrate column was caused by Snapshot (29%) and RegalKade G at one application of 300 lbs/A (26%). Both of these products contain dinitroanaline herbicides which work by inhibiting root growth. The trifluralin in Snapshot could have leached downward in the substrate column since it is more water soluble than the prodiamine in RegalKade G, whereas the high one-time application rate of RegalKade G could have caused the reductions in root growth noted. Intermediate reductions in roots at the surface of the substrate were caused by both formulations of RegalStar II and RegalKade G at two applications of 150 lbs/A. Reductions in visible roots at the top of the substrate column did not appear to be related to changes in root dry mass. The safest materials for not reducing visible roots in the upper portion of the rootball were OH-2 and Regal O-O. Regal O-O does not contain a dinitroanaline herbicide whereas OH-2 contains pendimethalin, a dinitroanaline herbicide with a water solubility similar to that of trifluralin. No foliar spotting or leaf distortion due to herbicide application was noticed during the experimental period. Significance to Industry: Although various rates and different herbicides reduced visible root growth at the top of the container substrate, none of the herbicide treatments applied reduced final root or shoot growth compared to the non-treated control plants. The increased growth resulting from the use of RegalStar II on a 38-0-0 carrier indicated that fertility levels were below optimum for production of *Gardenia* 'August Beauty' in this study.

Since combination products which include dinitroanaline herbicides are the best products for summer weed control, OH-2 may be a preferred product for summer applications based on safety to roots and spectrum of weeds controlled compared to Regal O-O. The herbicide OH-2 is labelled for gardenia, and though no foliar spotting was noticed in this test, foliar spotting has been noted by other researchers on gardenia when OH-2 was used (Joe Neal, personal communication). Be sure to follow herbicide label instructions as wet foliage during application or young growth may be injured.

Table 1. Herbicides, application dates, and rates in lbs. of granular product applied per acre.

	Date of application		
	4/15/97	6/13/97	8/15/97
	Rate (lb/A)		
Regal Star II + 38-0-0 (oxadiazon 1.0% + prodiamine 0.2%)	200	200	200
RegalStar II (oxadiazon 1.0% + prodiamine 0.2%)	200	200	200
OH-2 (oxyflourfen 2.0% + pendimethalin 1.0%)	100	100	100
Regal 0-0 (oxyfluorfen 2.0% + oxadiazon 1.0%)	200	200	200
Snapshot (isoxaben 0.5% + trifluralin 2.0%)	200	200	200
RegalKade G (prodiamine 0.5%)	150	150	—
RegalKade G (prodiamine 0.5%)	300	—	—
Control	—	—	—

Table 2. Influence of multiple granular herbicide applications on plant growth 180 days after initiation of the study.

		Days after initiation - 180			
Treatment Herbicide (rate x # of applications)		**Growth index (cm)**	**Shoot dry weight (g)**	**Root dry weight (g)**	**Percent of substrate at top of container with no visible roots**
RegalStar II + 38-0-0	(200 x 3)	39.2 a	83 a	102 a	13 c
RegalStar II	(200 x 3)	37.4 abc	77 ab	72 bc	17 b
OH-2	(100 x 3)	37.8 ab	73 ab	64 bc	7 d
Regal 0-0	(200 x 3)	35.3 bc	68 ab	59 c	4 d
Snapshot	(200 x 3)	36.8 abc	66 b	62 bc	29 a
RegalKade G	(150 x 2)	36.8 abc	77 ab	80 b	17 b
RegalKade G	(300 x 1)	35.1 bc	66 b	66 bc	26 a
Control	—	33.7 c	67 b	70 bc	4 d

Mean separation by Waller-Duncan K ratio t-test. Means followed by the same letter are not significantly different at P=0.05.

Preemergence Bittercress Control in Creeping Phlox (*Phlox subulata*)

Ted Whitwell and Jeanne Briggs
Department of Horticulture
Clemson University, Clemson, SC 29634

Index words: Container Production, Herbicide Formulation, Injury, Phytotoxicity, Yellow Woodsorrel.

Nature of Work: At Southeastern nurseries rooted liners of creeping phlox are planted in early fall to produce full containers for sale the following spring. Hairy bittercress is a major weed problem in containerized phlox as production timing coincides with optimal growth conditions for the weed. Though many herbicides are labeled for preemergence bittercress control, none are labeled for use on creeping phlox. Injury to phlox taxa following applications of preemergence herbicides has been reported. Field-grown 'Omega' wild sweet William (*Phlox maculata* L. 'Omega') tolerated Ronstar but was injured by Gallery, Goal, Rout and Surflan (1). Surflan reduced height of perennial phlox (*Phlox paniculata* L.) (3). Ronstar and OH-2 applied bimonthly resulted in slight injury to field-grown creeping phlox at 218 d, but Betasan, Balan, Devrinol, Dacthal and Pennant produced no injury (2).

Three studies were conducted in 2001-02 to determine injury to creeping phlox varieties following single and repeat applications of preemergence herbicides. In the first study, eight commercially available herbicide formulations were applied to creeping phlox varieties 'Crimson Beauty', 'Emerald Blue' and 'Fort Hill' at labeled rates (Table 1). Liners were potted into one gallon containers containing a pinebark: peanut hulls: peat (60:25:15 v/v) substrate, and herbicides were applied one day later. Granular herbicides were applied with a hand-held shaker can and sprayable herbicides were applied with a CO_2 pressurized backpack sprayer calibrated to deliver 20 gal/A at 40 psi. There were five replications of each herbicide treatment and untreated control. Visual injury as compared to the untreated was evaluated at 1, 6, 8, and 13 weeks after herbicide application (WAT), on a scale of 0 (no injury) to 100 (plant death). At 13 WAT, shoots were removed, dried, and weights were recorded.

Herbicides that minimally injured creeping phlox in the initial study were further evaluated for injury and bittercress control in a second study. Gallery, Snapshot TG, Pennant and RegalKade (the granular formulation of Barricade) were applied at low, medium and high recommended rates. (RegalKade was added to the study as prodiamine provides excellent bittercress control and injury may be lower from the granular formulation.) Creeping phlox varieties, herbicide application, experimental design, and growing conditions were as in the first study. Visual injury was rated at 1, 4, 8, and 12 WAT. Herbicides were reapplied 15 WAT, and injury was rated 22 and 27 weeks after initial treatment (7 and 12 weeks after second treatment). At the end of the study, growth index of phlox shoots was determined by measuring two widths (at widest point and 90º to widest point) and height, and calculated as the average width + height divided by two. To evaluate bittercress control, unplanted containers of each herbicide treatment and an untreated control were seeded with bittercress 3 days after herbicide application. Weed control was rated at 8 and 12 WAT on a scale of 0 (no control) to 100 (complete control) in all containers. Natural populations of yellow woodsorrel (*Oxalis stricta*) developed and control was rated as described.

A greenhouse study was conducted to determine if reduced herbicide rates would control bittercress. Gallery 75 DF, RegalKade 0.5 GR, and Snapshot 2.5 TG were applied at three rates to 4 in pots. There were 10 treatments including the untreated control, and 15 replications of each treatment. Treated containers were placed in a greenhouse maintained at 60F night and 75F day and mist irrigation was applied three times per day. Containers of flowering bittercress were placed within the replications to provide a constant source of bittercress seed. Bittercress control was visually evaluated at 4, 8, and 10 WAT on the scale described above.

Results and Discussion: In the first study, Pennant and Snapshot TG did not injure any of the three phlox varieties at 13 WAT and did not reduce shoot growth (Table 1). Barricade, Image, Surflan and Treflan treatments reduced shoot dry weight of all phlox varieties. However, results indicate that tolerance of preemergence herbicides may differ for varieties of creeping phlox. By 13 WAT, Barricade- and Surflan-treated ‘Crimson Beauty’ containers exhibited >82% injury. However, the Pennant, Snapshot TG and Treflan treatments had <8% injury. At 13 WAT, ‘Emerald Blue’ phlox treated with Barricade and Surflan displayed extensive injury (82%), but Gallery, Pennant and Snapshot TG treatments were unaffected. At 13 WAT, ‘Fort Hill’ was in injured >50% by Barricade and Surflan. For all phlox varieties, shoot dry weights from the Snapshot TG treatment were similar to that of untreated plants (Table 1). Pennant reduced dry weight of ‘Crimson Beauty’. Gallery reduced dry weight for ‘Crimson Beauty’ and ‘Fort Hill’ but did not affect growth of ‘Emerald Blue’.

In the second study, at 27 WAT, creeping phlox varieties were not injured by two applications of Pennant or Snapshot TG at low and medium rates, RegalKade at all rates, or Gallery at the low rate (Table 2). On all rating dates, 'Crimson Beauty' was injured by the medium and high rates of Gallery and the high rate of Pennant, but GI at the end of the study (27 WAT) was unaffected by all treatments except for the high rate of Pennant (Table 2). 'Emerald Blue' was also injured by the higher rates of Gallery and the high rate of Pennant at 27 WAT. However, GI at the end of the study was unaffected by all treatments and was similar to or greater than that of untreated plants. 'Fort Hill' was injured by Gallery (medium and high rates) and Snapshot TG (high rate) at 27 WAT, but GI was unaffected by all treatments except for the high rate of Gallery (Table 2). Excellent control of bittercress was obtained with all Gallery and Snapshot TG treatments at 8 and 12 WAT in the second study (Table 3). Yellow woodsorrel was controlled >86% by Snapshot TG (all rates), Gallery (medium and high rates) and RegalKade (high rate) (Table 3). Pennant applied at all rates and RegalKade applied at low and medium rates did not provide adequate hairy bittercress or yellow woodsorrel control. In the greenhouse study, Gallery applied at all rates provided excellent bittercress control through 8 WAT (data not shown). At 4 WAT Gallery applied at 0.12 lb ai/A provided 78% bittercress control, similar to results obtained with higher rates. At 8 WAT, all Gallery treatments adequately controlled bittercress (>87%), though at 10 WAT, a decline in control was found. Snapshot TG provided greater bittercress control when applied at 1.3 to 2.5 lb ai/A than at the 0.65 lb ai/A rate.

Significance to the Industry: These studies indicate that isoxaben provides excellent preemergence control of bittercress and may safely be applied to newly planted creeping phlox. However, optimal rates to avoid injury vary with isoxaben formulation. Snapshot TG (granular formulation) applied at 1.3 to 2.5 lb ai/A (1/4 and 1/2 maximum label rates) did not produce long term injury to the phlox varieties tested, and adequately controlled bittercress under field production conditions. Gallery (sprayable formulation) did not injure phlox varieties when applied at 0.25 lb ai/A (1/4 maximum label rate) and excellent bittercress control was found when Gallery was applied at 0.12 lb ai/A rate. Though no injury to creeping phlox was detected from Pennant and RegalKade at labeled rates, bittercress control was inadequate. Creeping phlox were severely injured by Barricade and Surflan.

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Table 1. Injury and shoot dry weight at 13 weeks after treatment (WAT) with preemergence herbicides of creeping phlox varieties 'Crimson Beauty' (CrB), 'Emerald Blue' (EmB), and 'Fort Hill' (FtH) in the first study.

		Injury			Shoot dry weight		
Herbicide	Rate	CrB	EmB	FtH	CrB	EmB	FtH
	lb ai/A	%			g		
Dimension GR	0.75	16	16	15	23.0	6.2	11.9
Barricade WDG65	0.5	82	82	64	2.1	2.0	6.2
Gallery DF	0.5	22	8	20	20.4	8.5	9.6
Image	0.5	20	18	16	13.1	6.9	12.5
Pennant	2.0	6	0	6	25.8	10.6	18.4
Snapshot TG	2.5	0	2	4	41.6	8.0	16.9
Surflan A.S.	2.0	100	82	86	0.1	1.3	1.3
Treflan HSP	2.0	8	18	28	25.4	6.7	10.8
Untreated	—	0	0	0	40.4	9.2	20.6
LSD (0.05)		19	10	19	9.4	1.8	4.5

Table 2. Visual injury (%) to creeping phlox varieties at 27 weeks after treatment with preemergence herbicides, and growth index (GI) (cm) at 27 WAT in the second study. Containers received a second application of herbicide at 15 WAT.

		'Crimson Beauty'		'Emerald Blue'		'Fort Hill'	
Herbicide	Rate lb ai/A	Injury %	GI cm	Injury %	GI cm	Injury %	GI cm
Gallery DF	0.25	0	19.5	3	13.5	8	14.2
	0.50	20	16.5	10	12.2	18	12.3
	1.0	16	16.0	0	12.4	18	11.6
Pennant	1.0	0	20.8	5	13.4	0	14.6
	2.0	3	18.7	13	12.2	0	15.2
	4.0	30	14.0	5	13.1	0	14.5
RegalKade	0.25	3	20.6	0	15.3	0	14.4
	0.50	0	21.1	10	13.6	8	14.3
	1.0	13	17.6	8	12.6	5	13.8
Snapshot TG	1.3	8	19.1	5	12.4	10	13.5
	2.5	3	19.2	0	14.9	5	13.6
	5.0	18	17.1	15	12.1	25	13.0
Untreated	—	0	17.8	0	13.3	0	13.7
LSD (0.05)		15	3.0	14	2.1	12	1.9

Table 3. Hairy bittercress and yellow woodsorrel control at 8 and 12 weeks after treatment (WAT) with preemergence herbicides in the second study.

Herbicide	Rate lb ai/A	Bittercress 8WAT	Bittercress 12WAT	Yellow woodsorrel 8WAT	Yellow woodsorrel 12WAT
		---------------%---------------			
Gallery DF	0.25	97	98	86	79
	0.50	100	99	99	96
	1.0	100	100	98	96
Pennant	1.0	54	65	16	45
	2.0	69	74	42	52
	4.0	79	69	76	71
RegalKade	0.25	63	72	43	57
	0.50	73	79	74	88
	1.0	92	90	97	99
Snapshot TG	1.3	98	98	86	91
	2.5	99	99	97	99
	5.0	100	100	100	100
Untreated	—	0	0	0	0
LSD (0.05)		11	11	16	9

Effects of Mulches and Trifluralin on Pansy Performance

Robert E. Wooten, Joseph C. Neal and Bernadette S. Clark
NC State University, Dept. of Horticultural Science
Raleigh, NC 27695-7609

Index Words: Pinestraw, Yardwaste, Wulpak, Emerge, Pansy, Trifluralin, Preen

Nature of Work: Organic mulches such as pinestraw and various barks (pine, cedar, hardwood) have been shown to effectively reduce weed populations in landscape plantings (2, 4). Traditionally the material used by landscapers to mulch pansy plantings in the southeastern US has been pinestraw. With the advent of conservation and recycling, several other materials that have potential as mulches have come on the market. For example, Wulpak (pelleted wool) and pelleted recycled newspaper (such as PennMulch and Emerge) have been shown to suppress weeds in container trials (1, 3). Studies were conducted during fall/winter 1999 and 2000 to determine the effectiveness of several mulching materials in controlling weeds and to evaluate their effects on the growth, quality and flowering of field planted pansies.

Each year the area was tilled then 5 pansy plants (*Viola x wittrockiana* 'Delta Pure Primrose' 1999 and 'Skyline Orange' 2000) were planted 6" apart into each 2' x 5' plot. The planting dates were November 24, 1999 and October 31, 2000. Next, mulches were applied, then the trifluralin (Preen 1.47G) was applied to the appropriate plots by a shaker jar. Irrigation was applied to settle the plants in the soil and to incorporate the trifluralin. The mulches and herbicide treatments were 3" pinestraw, 3" pinestraw plus 4 lb ai/A Preen, 3" municipal compost (yardwaste), Emerge [pelletized recycled newspaper waste at 1 lb. (1999) and 1.5 lb. (2000) product per square foot] or Wulpak [pelletized sweepings from a sheep shearing room floor at 1 lb. (1999) and 1.5 lb. (2000) product per square foot]. These treatments were compared to an untreated, hand-weeded control. In 2000, a Preen at 4 lb. ai/A alone treatment was added to clarify indications of reduced plant growth we observed in 1999. The 1999 study contained 6 replications, while in 2000 replication was increased to 8. Plant quality was visually evaluated weekly on a scale of 0 to 5 with 0 = dead and 5 = best. Visual ratings were also conducted for weed control and flower numbers were counted. In 2000, above-ground plant fresh weights were measured.

Results and Discussion: In 1999, the best plant quality and flower production were observed in the control, yardwaste and Wulpak treatments (Tables 1 and 2). Flower numbers in the pinestraw alone plots were reduced by half compared to the control plots and addition of Preen lowered the counts by an additional 25% (Table 2). Emerge slightly reduced the number of flowers per plant.

In the 2000-01 study, plant quality, flower production and plant fresh weight were reduced by all treatments except yardwaste, compared to the hand-weeded control. In the April evaluation, pinestraw and Preen each reduced growth and flower counts by about 33%, but combining them reduced the flower counts to only 7 flowers per plant compared to 21 flowers per plant in the hand-weeded plots. In the Wulpak treatment, the fresh weights were marginally greater than in the Emerge treatment, but plant quality and flower counts were similar.

Both studies contained the same predominant weeds, chickweed [*Stellaria media* (L.) Vill.] and henbit (*Lamium amplexicaule* L.), which were controlled well by all the mulches (Data not shown). Pinestraw alone was slightly less effective than the other treatments.

These data demonstrate that all of the mulches effectively suppressed common winter annual weeds. However, pinestraw reduced pansy growth and flowering; Preen reduced pansy growth and flowering; Emerge slightly reduced pansy growth; and flowering and Wulpak reduced pansy growth in 2000, but not in 1999.

Significance to the Industry: Two standard and considered safe mulch/mulch + herbicide treatments were shown to be detrimental to the growth and flower production of field planted pansies. Landscapers should avoid using pinestraw and Preen (or Treflan) on pansy beds.

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Table 1. Mulch and Herbicide Effects on Pansy Plant Quality[1] in 1999 and 2000.

	1999-00 Test			2000-01 Test		
TREATMENT	**12/2/99**	**2/16/00**	**4/11/00**	**12/6/00**	**2/7/01**	**3/28/01**
Check	3.0a	3.4a	4.4a	3.5a	4.0a	3.8a
Pinestraw	3.0a[2]	3.5a	4.0ab	3.0b	3.5a	2.7b
Pinestraw + Preen	3.0a	2.7a	2.7c	2.8bc	2.9b	1.7c
Yardwaste	3.0a	3.3a	4.1ab	3.1b	3.6a	3.6a
Wulpak	3.0a	3.4a	4.2ab	2.5c	2.4b	2.8b
Emerge	3.0a	3.3a	3.4bc	3.1b	2.7b	2.6b
Preen	—-	—-	—-	3.1b	2.7b	2.6b

[1]Plant quality was evaluated on a scale of 1 to 5; where 1 = dead and 5 is best quality.
[2]Means within a column followed by the same letter are not significantly different at the 5% level.

Table 2. Effects of Mulches and Preen on Pansy Flower Numbers.

	1999-00 Test		2000-01 Test	
TREATMENT	**2/28/00**	**3/14/00**	**2/21/01**	**4/12/01**
Check	40ab	45a	17a	21a
Pinestraw	17d	26c	2c	14b
Pinestraw + Preen	5e	13d	1c	7c
Yardwaste	31c	38ab	9b	19a
Wulpak	42a	37ab	7b	13b
Emerge	33bc	28c	10b	15b
Preen	—-	—-	8b	15b

Means within columns followed by the same letter are not significantly different at the 5% level.

Tolerance of two varieties of *Canna hybrida* for simazine

Sandra L. Knuteson[1], Ted Whitwell[2], and Stephen J. Klaine[1]
Clemson University, Dept. of [1]Environmental Toxicology,
Pendleton, SC 29670
and [2]Horticultural Dept., Clemson, SC 29634

Index Words: Canna, Phytotoxicity, Phytoremediation, Constructed Wetland

Nature of Work: Extensive use of pesticides can lead to significant risk to non-target organisms onsite and in adjacent aquatic and terrestrial ecosystems. One promising method for reducing risk from pesticide use is phytoremediation by ornamental wetland plant species. The result may be low cost, low maintenance, and aesthetically pleasing constructed wetlands. Research in our laboratory investigated the use of several ornamental wetland plant species to remediate pesticide waste in constructed wetlands (1). For improved aesthetics, these wetlands were established with ornamental plant species, including *Canna* X *hybrida, Pontederia cordata, and Acorus gramenius.* The effectiveness of a plant species for phytoremediation may depend in part on its tolerance for the pesticides. Variations in plant metabolism, life cycle, nutrition, and habitat needs may result in differing responses to stress. The toxicity studies performed to evaluate suitable species for these wetlands used *C. hybrida* var. “Yellow king humbert” (1); therefore, in this research, we compared the tolerance of two varieties of the *C. hybrida* for simazine.

Simazine is the active ingredient in pre-emergent herbicides labeled for general use on turfgrasses and ornamentals to control annual broad-leaf weeds and grasses. Due to its moderate water solubility, low volatility and long soil half-life, simazine may contaminate ground and surface waters (2). The two varieties evaluated were *C. hybrida* var. “Yellow king humbert” and *C. hybrida* var. “Bengal tiger.” The Yellow king humbert has green foliage and yellow flowers, while the Bengal tiger has green/ yellow variegation of the leaves and orange flowers. The *C. hybrida* were propagated from tubers in potting soil in a glass greenhouse. Two weeks prior to exposure, plants approximately 10 cm (4 in) tall with 3 to 4 leaves were detached from their tubers. Plants were placed in darkened glass jars containing 300 ml of 10% Hoagland’s liquid nutrient medium (HNM). For the first 2 to 3 days, plants were placed in a humidity chamber to acclimate to hydroponic conditions. Once removed from the humidity chamber, plants were placed in the greenhouse and acclimated to the following exposure conditions: a minimum light intensity of 375 mmol/m^{2}s provided by metal halide lamps, with a maximum depending on sunlight; a 16:8 day/night photoperiod; and 24 $\pm$ 4 °C (75 $\pm$ 7 °F). During acclimation, plants were placed in fresh 10% HNM weekly; medium lost due to transpiration or evaporation was replaced daily.

Technical grade simazine (99.6% purity) was obtained from Novartis Crop Protection (Greensboro, NC, USA). A stock solution was prepared by dissolving simazine overnight in 10% HNM with constant stirring. Exposure solutions were then prepared through dilution to 0.1, 0.5, 1.0, and 2.0 mg/L (ppm) simazine in 10% HNM with a 10% HNM as a negative control. All simazine concentrations were verified using solid phase extraction (Burdick & Jackson, Inc., Muskegon, MI, USA) into two ml of Optima grade acetone (Fisher Scientific, Fair Lawn, NJ, USA) and analysis by a Hewlett-Packard 5890 Series II Gas Chromatograph (Palo Alto, CA, USA). To prevent light from reaching the root zone, exposure vessels consisted of 300 ml exposure solution in aluminum foil-wrapped glass containers using 12 oz. styrofoam cups with a hole in the bottom to hold the plant with its roots submerged. After seven days, roots were rinsed with running tap water; measurements were taken; and plants were placed in simazine-free medium for another seven days post-exposure to assess short-term recovery. Medium lost due to transpiration or evaporation was quantitatively replaced with 10% HNM. Evaporation controls consisted of exposure vessels without plants. Toxicity of simazine was evaluated by examining growth. Measurements of root volume and fresh weight were made prior to exposure, after the exposure period, and after the post-exposure period. Biomass production for each period was calculated from fresh weight data. Water uptake was measured by recording the amount of medium replaced during the 7-d period and correcting for evaporation. Photosynthetic yield was measured on the innermost leaf of the plants on days 0, 1, 3, 5, 7, and 13 using an OPTISCIENCES OS-500 modulated fluorometer (Haverhill, MA, USA). A completely randomized design was used with four replications per treatment. Due to non-normality of variances, biomass production, water use, and fluorescence data were ranked with the Wilcoxon rank-sum test. Differences were determined using ANOVA and Dunnett's test at $P<0.05$. Lowest Observable Effect Concentrations (LOEC) were determined for all endpoints.

Results and Discussion: Biomass production (Figure 1) and photosynthetic yield (Figure 2) LOEC values for both varieties of *C. hybrida* were 2.0 and 0.5 mg/L simazine, respectively. After seven days in simazine-free medium, all plants showed full recovery with respect to photosynthetic yield. Biomass production recovered only slightly; however, because photosynthetic yield fully recovered, biomass may fully recovered given more time. We saw no differences in tolerance of either variety for simazine for any endpoint. The results of the toxicity bioassay show that either variety of *C. hybrida* would perform well in the constructed wetlands designed by this laboratory.

Significance to Industry: Results from this study, along with other studies from this laboratory will be used to develop gravel-based, subsurface-flow constructed wetlands for the remediation of excess pesticide and nutrients from rinse water from sprayer apparatus for nurseries, greenhouses, and golf courses. Such constructed wetlands may also be used by nurseries, greenhouses, and golf courses to remediate runoff water; therefore, various ornamental plant species may be desired. Our laboratory has screened many species for use in these wetlands (Table 1). We have found that *C. hybrida*, both varieties, *P. cordata,* and *T. latifolia* are the more tolerant species tested. Studies have also shown that after pesticide exposure, plants may fully recover from the injury of low concentrations of simazine. This is important because plants in a constructed wetland scenario would be exposed to episodic exposures of up to approximately 1.0 mg/L simazine.

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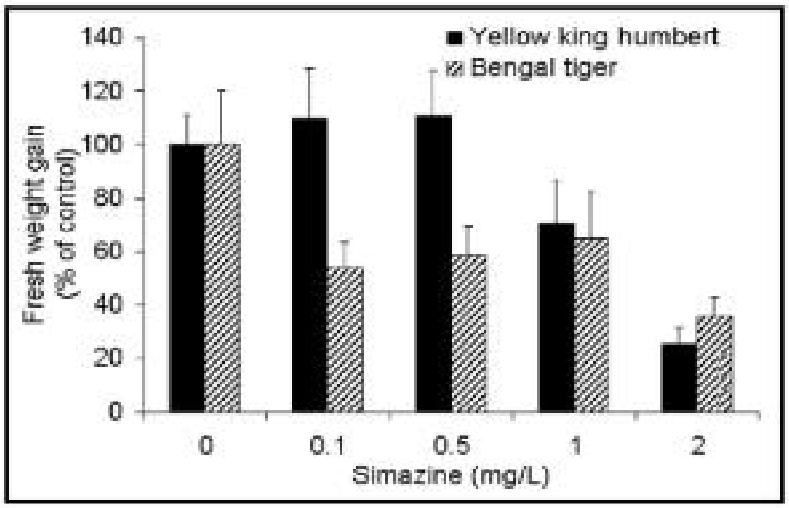

Figure 1. Biomass production of *C. hybrida* during 7-day exposure to simazine. Bars represent standard error. '*' indicates that the treatment is significantly different from control for that variety, *P*<0.05.

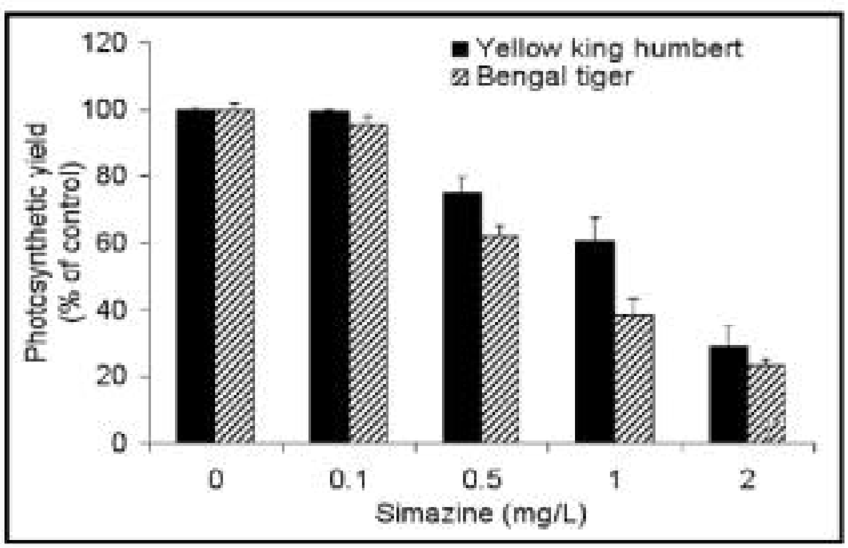

Figure 2. Photosynthetic yield by *C. hybrida* on day 3 of exposure to simazine. Bars represent standard error. '*' indicates that the treatment is significantly different from control for that variety, *P*<0.05.

Table 1. Lowest Observable Effect Concentration (LOEC) (mg/L) of simazine to biomass production in various plant species. ^ (3), * (4).

Species	**LOEC**
Canna X *hybrida* “Bengal tiger”	2.0
C. hybrida “Yellow king humbert”	2.0 / 1.5 * / 1.0 ^
Pontederia cordata	1.0 ^
Typha latifolia	*1.0*^
Myriophyllum aquaticum	*0.3* / 0.1* ^
Acorus gramenius	*0.3* ^
Lemna gibba	0.1 ^