Weed Science

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Section Editor and Moderator

Early Post-emergent control of *Euphorbia maculata* (Spurge)

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Index Words: BroadStar™, FreeHand™, Tower™, Pendulum™, spurge, weed control

Significance to Industry: This preliminary research indicates that the preemergence applied herbicides Tower™ (dimethenamid) and Pendulum™ (pendimethalin) can provide successful postemergence spurge control at the cotyledon to 1 leaf and 2 to 4 leaf stages of growth.

Nature of Work: Growth of containerized nursery crops can be significantly reduced by weeds (1). Spotted spurge (*Euphorbia maculata*) is a major weed in container production (2). Spurge can be difficult to control once established due to prolific seed production; therefore the primary method of managing spotted spurge is preemergence applied herbicides. However, for preemergence applied herbicides to be effective, containers must be weed free prior to application (3). The color and low-growing habit make small spurge difficult to see in containers, making it difficult for those handweeding the containers. As a result, small plants are often left behind which are not controlled by the preemergence herbicide application (3). These plants are prolific seeders with no dormancy requirement and germinate quickly which results in spurge being the most common summer annual broadleaf weed in most container nurseries (4). These small spurge plants must be removed either by hand or by chemical means for effective spurge control. It is important to find a preemergence applied herbicide which also has some degree of postemergence activity to successfully and consistently control immature spurge in container production.

Postemergence spurge control was tested at two different stages of growth, cotyledon to 1 leaf, 2 to 4 leaf, and also for preemergence control. On July 31, 2008, 3.5 inch pots were filled with pinebark:sand (6:1) (v:v) amended with 14 lbs of 17-6-12 Polyon (8-9 month control release fertilizer) 5.0 lbs of dolomitic lime, and 1.5 lbs Micromax on a per cubic yard basis, overseeded with spurge seed, placed in full sun, and over-head irrigated. Spurge grew for 14 days until treatment date and reached the 2 to 4 leaf stage. On August 7, 2008, 3.5 inch pots were filled with same substrate, overseeded with spurge seed and grew for 7 days, reaching the cotyledon stage prior to treatment. On August 14, 2008, 3.5 inch pots were filled with same substrate and all pots (cotyledon to 1 leaf, 2-4 leaf, and pots newly filled) were treated with herbicide. Pots filled on the day of treatment were then over-seeded with spurge seed (10 seeds per container) immediately after herbicide treatment to evaluate preemergence control. All pots were placed in full sun and received over-head irrigation. Treatments included Broadstar™ 1604 0.25G (flumioxazin) at 150 and 300 lbs per acre, FreeHand™ 1.75G (dimethenamid + pendimethalin) at 200 and 400 lbs per acre, Tower™ 6.0 EC (dimethenamid) at 1.5 and 3.0 lbs aia (active ingredient per acre), Pendulum™ 3.3 EC (pendimethalin) at 2 and 4 lbs aia and a non-treated control. Broadstar™ and FreeHand™ treatments were applied with a hand-shaker. Spray treatments (Tower™ and Pendulum™) were applied at 20 gallons per acre with a CO_2 backpack sprayer (80-04 nozzle) at 25 psi. Each of the 3 growth stages contained 9 treatments with 6 single pot replicates per treatment. Pots were arranged by growth stage (preemergence, cotyledon, and 2 to 4 leaf) in a completely randomized design. Subjective injury ratings on a scale of 1 to 10 (1 = no injury, 10 = dead) were taken at 10, 20, and 30 days after treatment (DAT) on cotyledon and 2 to 4 leaf stage fresh weights were taken on all pots at 30 DAT. Data was analyzed using Duncan's Multiple Range test at *P* = 0.05 for means separation.

Results and Discussion

Preemergence

All herbicide treated pots were weed free at 10 and 20 DAT, and at 30 DAT pots treated with Broadstar™ (150 and 300 lbs/A), Tower™ (1.5 and 3.0 lbs/aia), and FreeHand™ at 400 lbs/A also remained weed free (data not shown). There was no statistical difference in fresh weights of any herbicide treated pot at 30 DAT (Table 2).

Cotyledon to One Leaf

At 10 DAT, Broadstar™ at the 150 lbs/A rate had little effect on the spurge (rating of 2.1), while the 300 lbs/A rate had excellent activity (9.0) (Table 1). This trend continued at 20 DAT, however by 30 DAT, spurge began to recover. Spurge treated with FreeHand™ at 200 lbs/A were injured at 10 and 20 DAT, but began to recover at 30 DAT. However, when FreeHand™ was applied at 400 lbs/A, by 30 DAT, all pots were given an injury rating of 9 or higher. Tower™ at 1.5 lbs/aia had excellent activity throughout the study, and at 3 lbs/aia had an injury rating of 10.0 on all dates. Pendulum™ provided similar results at both rates. Fresh weights show no statistical differences in treatments receiving Broadstar™ at 150 lbs/A and the non-treated control (Table 2). Fresh weights also indicate Broadstar™ at 300 lbs/A was similar to FreeHand™ at 200 lbs/A, while FreeHand™ at 400 lbs/A, Tower™ at both rates, and Pendulum™ at both rates, provided the best control.

Two to Four Leaf

Broadstar™ had little effect on spurge in the 2 to 4 leaf stage at either rate and was statistically similar to the non-treated control on all dates in injury ratings, however fresh weights show Broadstar™ provided some degree of control in comparison with the control (Tables 1, 2). FreeHand™ at 200 and 400 lbs/A had activity at 10 DAT, and were similar to Tower™ and Pendulum™ at the 1.5 and 2.0 lbs/aia rates, respectively. Tower™ at 3.0 lbs/aia (injury rating of 8.8) and Pendulum™ at 4 lbs/aia (injury rating of 7.2) provided the best control postemergence of spurge at 10 DAT. At 20 DAT, the best control was achieved with FreeHand™ at 400 lbs/A, Tower™ at 3.0 lbs/aia, and

Pendulum™ at both rates. By 30 DAT, spurge treated Tower™ at 3.0 lbs/aia and both rates of Pendulum™ had significantly more injury than all other treatments. Fresh weights taken at 30 DAT show Broadstar™ had the least effect of any herbicide (Table 2). FreeHand™ at 200 and 400 lbs/A had similar control to Tower™ at 1.5 lbs/aia and Pendulum™ at 2.0 lbs/aia. Tower™ at 3.0 lbs/aia and Pendulum™ at 4.0 lbs/aia had similar fresh weights to FreeHand™ at 400 lbs/A.

This study indicated that while all of these products at all rates tested provided effective preemergence activity, Broadstar™ provided little postemergence control at either rate tested. FreeHand™ failed to have lasting weed control at the label rate, however at 400 lbs/A, FreeHand™ provided early postemergence activity against spurge in the cotyledon stage and some activity in the 2 to 4 leaf stage. Tower™ and Pendulum™ herbicides provided effective early post emergence activity at either rate tested in the cotyledon stage and also demonstrated excellent activity on spurge in the 2 to 4 leaf stage when the higher rate was applied. Application of these herbicides to control spurge after weed emergence could reduce labor costs from hand weeding, limit postemergence herbicide applications, while still providing preemergence activity. Grower testing is necessary due to potential injury from application of EC herbicides on some plants during hot summer months.

Literature Cited

1. Berchielli-Robertson, D.L., C.H. Gilliam, and D.C. Fare. 1990. Competitive effects of weeds on the growth of container-grown plants. HortScience 25:77-79.
2. Gilliam, C.H., W.J. Foster, J.L. Adrain, and R.L. Shumack. 1990. A survey of weed control costs and strategies in container production nurseries. J. Environ. Hort. 8:133-135.
3. Judge, C.A., J. C. Neal. 2006. Preemergence and early postemergence control of selected container nursery weeds with Broadstar, OH2, and Snapshot TG. J. Environ. Hort. 24:105-108.
4. Neal, J.C. and J.F. Derr. Weeds of container nurseries of the United States. 2005. North Carolina Association of Nurserymen, Inc. Raleigh, North Carolina.

Table 1. Spurge (*Euphorbia maculata*) early postemergence injury ratings[Z]

		Growth Stage					
		Cotyledon			2-4 Leaf		
Treatment	Rate	10 DAT[Y]	20 DAT	30 DAT	10 DAT	20 DAT	30 DAT
Broadstar™	150 lbs[X]	2.1 d[V]	2.0 c	1.0 d	1.17 d	1.3 d	1.0 d
Broadstar™	300 lbs	9.0 ab	9.1 a	6.7 b	2.0 d	2.2 d	1.0 d
FreeHand™	200 lbs	6.3 c	7.6 b	3.9 c	3.8 c	5.7 bc	5.0 bc
FreeHand™	400 lbs	8.3 b	9.7 a	9.9 a	5.2 c	6.8 ab	6.0 b
Tower™	1.5 lbs aia[W]	9.3 ab	9.6 a	10.0 a	4.7 c	4.7 c	4.0 c
Tower™	3.0 lbs aia	10.0 a	10.0 a	10.0 a	8.8 a	8.5 a	8.7 a
Pendulum™	2 lbs aia	9.1 ab	9.9 a	10.0 a	4.7 c	7.7 a	8.0 a
Pendulum™	4 lbs aia	9.7 a	10.0 a	10.0 a	7.2 b	8.7 a	8.7 a
Non-treated	****	1.0 e	1.3 c	1.0 d	1.0 d	1.2 d	1.0 d

[Z] Ratings on scale of 1 to 10 (1 = no injury, 10 = dead plant).
[Y] DAT = Days after treatment.
[X] Rate given at pounds per acre.
[W] aia = active ingredient per acre.
[V] Means separated using Duncan's Multiple Range Test at $P = 0.05$.

Table 2. Spurge (*Euphorbia maculata*) preemergence and early postemergence fresh weights[Z].

			Growth Stage	
Treatment	Rate	Pre-emergence	Cotyledon	2-4 Leaf
Broadstar™	150 lbs[Y]	0.0 b[W]	5.6 a	6.4 b
Broadstar™	300 lbs	0.0 b	0.8 bc	6.7 b
FreeHand™	200 lbs	0.0 b	1.8 b	1.7 cd
FreeHand™	400 lbs	0.0 b	0.0 c	1.3 cd
Tower™	1.5 lbs aia[X]	0.0 b	0.0 c	2.5 c
Tower™	3.0 lbs aia	0.0 b	0.0 c	0.1 d
Pendulum™	2 lbs aia	0.0 b	0.0 c	0.6 cd
Pendulum™	4 lbs aia	0.0 b	0.0 c	0.1 d
Non-treated	****	0.8 a	6.6 a	12.0 a

[Z] Fresh weights measured in grams and taken at 30 days after treatment.
[Y] Rate given at pounds per acre.
[X] aia = active ingredient per acre.
[W] Means separated using Duncan's Multiple Range Test.

Evaluation of Four Herbicides to Control Yellow Nutsedge and Assess Seedling Tolerance in Loblolly and Slash Pine Seedlings

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Significance to Industry: Yellow nutsedge has been one of the most difficult weeds to control in bareroot pine nurseries. Herbicides that can be used as over-the-top applications to pine seedlings in the nursery could reduce competition and improve seedling growth. This experiment evaluated four herbicides in order to identify herbicide(s) that control yellow nutsedge and cause minimal injury to pine seedlings**.** Over-the-top applications with halosulfuron yielded the most positive results by controlling yellow nutsedge and not causing pine seedling injury or adversely affecting loblolly pine seedling growth.

Nature of Work: Weed control is one of the most important nursery practices for producing quality bareroot seedlings in forest tree nurseries. Reducing weed competition allows nutrients and water to be more readily available for absorption by seedling roots, leading to better diameter and height growth. Bareroot nurseries rely heavily on soil fumigation with methyl bromide for weed control. However, methyl bromide is considered an ozone-depleting chemical and strict regulations on its use are currently pending and a complete phase-out is possible in the near future. This will make it more difficult to control troublesome perennial weeds such as yellow nutsedge (*Cyperus esculentus*). Yellow nutsedge reproduces from tubers and can be found in a wide range of climates and soil types. Alternative soil fumigants to methyl bromide have been tested in bareroot nurseries over the years, but nutsedge control has been variable (Carey 2000). The lack of viable alternatives intensifies the need to identify herbicides that can effectively control yellow nutsedge while not jeopardizing seedling health. Trials using glyphosate in fallow fields have produced good control of nutsedge (Fraedwich and Dwinell 2003) but injury can occur when it is applied directly to foliage of loblolly pine (*Pinus taeda*) seedlings (Haywood and Melder 1991). The objectives of this study were to (1) test the efficacy of four liquid herbicides in controlling growth of yellow nutsedge and (2) to assess seedling tolerance to herbicide exposure using slash (*Pinus elliottii*) and loblolly pine seedlings.

Nine-month-old bareroot loblolly and slash pine seedlings were acquired from a south Alabama forest tree nursery on December 9, 2007 and placed in cooler storage (4-5ºC) at Auburn University. On February 21, 2008, 140 seedlings of each pine species were transplanted into one-gallon plastic containers filled with pinebark:sand (6:1) (v:v), amended with 14 lbs/yd^3 of 18-6-12 (N-P-K) Polyon (8-9 month control-release fertilizer), 5 lbs/yd^3 of dolomitic lime, and 1.5 lbs/yd^3 of Micromax. An additional 140 containers were filled with the same formulation of amended media on May 19 (for post-emergent treatments) and June 10 (for pre-emergent treatments). Each container was planted with three yellow nutsedge tubers. All pine and nutsedge containers were irrigated after transplanting and sowing to allow settling. On June 10, four herbicide treatments (1 pre- and 3 post-emergent) were applied over the top of nutsedge and pine seedlings using three levels of active ingredient per acre (aia) using a CO_2 backpack sprayer calibrated to deliver a rate of 20 gal/ac. For post-emergence treatments, applications occurred when nutsedge height was 8 in. Herbicides tested included: dimethanamid (Tower™) as a pre-emergent at 1.0, 2.0, and 4.0 lbs aia, mesotrione (Callisto™) at 0.0935, 0.187, and 0.374 lbs aia, imazasulfuron (Valent-V10-142™) at 0.75, 1.5, and 3.0 lbs aia, and halosulfuron (Sedgehammer™) at 0.031, 0.063, and 0.125 lbs aia. Two control treatments (1 pre- and 1 post-emergent) received no herbicide. Each of the 14 herbicide treatments consisted of 10 replications (containers). Yellow nutsedge and pine seedling injury ratings were made using a scale from 1 to 10 (1 = no injury, 10 = dead). Ratings of 2-9 reflected a progressive increase in the amount of either chlorotic or brown foliage. Ratings were made 15, 30, and 60 days and 15, 30, 60, and 90 days after the application of herbicide treatments for yellow nutsedge and pine seedlings, respectively. Nutsedge was clipped back to one inch after 60 days to measure the fresh weight (g) of aboveground tissues. Thirty days after the 60-day clipping, nutsedge was clipped a second time to measure the fresh weight of re-growth. Nutsedge treated with dimethenamid were not given a rating, but control was assessed based on fresh weight data. Slash and loblolly pine seedling diameters (mm) 1 inch above the soil-line and heights (cm) were measured prior to herbicide application and after 90 days to quantify any effects from herbicides on seedling growth. All plants were maintained under daily irrigation in full sun for the duration of the study. Data were analyzed in a generalized linear model (GLM) using analysis of variance (ANOVA) and means separated using Duncan's Multiple Range Test in SAS.

Results and Discussion:

Yellow nutsedge-Post-emergence

Imazasulfuron post-emergence treatments provided excellent control of yellow nutsedge (Table 1). Mesotrione at 0.374 lbs aia and all rates of imazasulfuron and halosulfuron resulted in significantly lower fresh weights after 60 days (Table 1). The same rates and mesotrione at 0.187 lbs aia reduced the viability of nutsedge tubers by controlling re-sprouting.

Yellow nutsedge-Pre-emergence

Dimethenamid applied at 1.0 lb aia before emergence of nutsedge foliage did not prevent nutsedge growth (Table 1). However, dimethenamid applied at 4.0 lbs aia produced less foliage and re-growth after clipping than the control.

Loblolly pine

Before herbicide applications, the mean diameter and height for loblolly seedlings was 8.3 mm and 61 cm, respectively. Loblolly seedlings that received dimethenamid at 4.0 lbs aia had significantly less height growth (Table 2). All other treatments were similar in seedling diameter to non-treated control loblolly seedlings. Imazasulfuron applied at 1.5 and 3.0 lbs aia significantly reduced seedling height growth. Herbicide injury to loblolly pine was considered minimal with only two seedlings affected by imazosulfuron at 3 lbs aia (loblolly pine mean injury rating = 1.4).

Slash pine. Slash pine seedlings had a mean diameter of 9.4 mm and height of 49 cm when herbicide was applied. Applications of dimethenamid at 4 lbs aia, imazosulfuron at 3 lbs aia, and all three rates of mesotrione resulted in less diameter growth when compared to the non-treated control slash seedlings (Table 2). Height growth was reduced by dimethenamid at 4 lbs aia, mesotrione at 0.0935 and 0.374 lbs aia, and all three rates of imazosulfuron and halosulfuron. Slash pine injury occurred when treated with the imazasulfuron 3 lbs aia treatment and was more severe than on loblolly (slash pine mean injury rating = 3.5).

Imazasulfuron was the most effective herbicide in controlling yellow nutsedge, but also caused pine seedling injury. Dimethenamid treatments did not prevent tuber germination and most nutsedge plants treated with 1.0 and 2.0 lbs aia continued to grow. Halosulfuron provided adequate control of nutsedge, while not injuring either pine species or stunting loblolly pine seedlings. Further testing in bareroot nurseries is recommended.

Literature Cited

1. Carey, W.A. 2000. Fumigation with chloropicrin, metham sodium, and EPTC as replacements for methyl bromide in southern pine nurseries. Southern Journal of Applied Forestry, 24(3): 135-139.
2. Fraedrich, S.W. and L.D. Dwinell. 2003. Broadcast applications of glyphosate control nutsedge at a south Georgia forest tree nursery. Southern Journal of Applied Forestry, 27(3): 176-179.
3. Haywood, J.D. and T.W. Melder. 1991. Effectiveness of glyphosate mixed with soil-active herbicides. Research Note SO-365, USDA Forest Service, Southern Forest Experiment Station: 5pp.

Table 1. Mean yellow nutsedge injury ratings, fresh weights, and fresh weights of re-growth.

Herbicide	lbs ai/ac	Injury rating [w]	FW 1 [x]	FW 2 [y]
dimethenamid	0.0	N/A	183.6 bc	24.2 a
	1.0	N/A	146.8 cd	17.6 ab
	2.0	N/A	117.4 de	16.0 ab
	4.0	N/A	37.9 f	12.1 bc
mesotrione	0.0935	3.0 e [z]	221.1 b	11.7 bc
	0.187	3.9 e	143.9 cd	3.9 cd
	0.374	5.4 d	68.4 ef	3.6 cd
imazasulfuron	0.75	9.5 ab	12.5 f	0.9 d
	1.5	10 a	8.4 f	0.1 d
	3.0	10 a	8.8 f	0 d
halosulfuron	0.031	7.8 c	28.8 f	0.4 d
	0.063	9.7 ab	9.7 f	0.1 d
	0.125	8.7 bc	18.9 f	4.6 cd
Control-Post	0	1.6 f	359.4 a	20.1 ab

[w]Herbicide injury ratings on 1-10 scale (1= no injury, 10=dead)
[x]FW 1 is fresh weight (grams) 60 days after herbicide application
[y]FW 2 is fresh weight (grams) of re-growth 30 days after the 60-day clipping
[z]Means (within a column) followed by the same letter are not significantly different based on Duncan's Multiple Range Test ($P \leq 0.05$)

Table 2- Mean difference in diameter and height growth before herbicide application and after 90 days for loblolly and slash pine seedlings

Herbicide	lbs ai/ac	Loblolly [v] diameter	Slash [w] diameter	Loblolly [x] height	Slash [y] height
dimethenamid	0.0	9.2 abc [z]	8.3 ab	49 ab	42 ab
	1.0	8.6 bc	8.3 ab	57 a	39 ab
	2.0	8.2 bc	7.6 abc	54 a	38 ab
	4.0	7.8 c	5.5 de	42 bc	31 bcd
mesotrione	0.0935	9.8 ab	6.7 cd	55 a	32 bcd
	0.187	9.1 bc	7.1 bc	54 a	39 ab
	0.374	8.9 bc	5.1 e	45 abc	26 cd
imazasulfuron	0.75	10.7 a	8.6 ab	45 abc	36 bc
	1.5	9.7 ab	8.4 ab	36 cd	24 d
	3.0	8.4 bc	4.8 e	29 d	11 e
halosulfuron	0.031	9.5 ab	8.9 a	48 ab	36 bc
	0.063	9.6 ab	8.3 ab	50 ab	35 bc
	0.125	9.2 abc	8.5 ab	50 ab	36 b
Control-Post	0	9.6 ab	9.0 a	49 ab	47 a

vDifference in loblolly pine diameter growth (mm)
wDifference in slash pine diameter growth (mm)
xDifference in loblolly pine height growth (cm)
yDifference in slash pine height growth (cm)
[z]Means (within a column) followed by the same letter are not significantly different based on Duncan's Multiple Range Test ($P \leq 0.05$)

Ornamental Plant Safety and Herbicidal Efficacy Following use of Select Combinations of HPPD and PSII Inhibitors

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Significance to Industry: Plant pigment inhibiting herbicides (HPPD inhibitors) applied alone were unable to provide commercially acceptable chamberbitter and mugwort control in postemergence (POST) weed control tests. However, 93 to 97% control of mugwort was achieved when the PSII inhibitors bentazon, diuron, and atrazine were combined with mesotrione and with mixtures of tembotrione plus atrazine or diuron. Moreover, POST applications of mesotrione plus bentazon provided 89 to 98% control of all weeds evaluated in these studies except chamberbitter. Phytotoxic responses of ornamental plants to applications of HPPD and PSII inhibiting herbicides were species dependent. Most HPPD inhibitor applications were unsafe for use on perennial snapdragon and 'Knockout' roses as high levels of persistant foliar injury often remained well past 28 DAT. However, the two lowest rates of tembotrione provided minimal pigment inhibition in 'Knockout' roses. In addition, all rates of mesotrione and mixtures of mesotrione plus bentazon provided minimal foliar injury in azalea and burning bush and all HPPD inhibitors treatments were safe for use on Japanese holly.

Nature of Work: Within the southeastern U.S. (SEUS), estimates of weed management costs for container production nurseries have ranged from $500 to $2,000 per acre and typically require about 3 annual herbicide applications per nursery (5, 9, 10). Beyond direct costs, weed species also present variable competition with crop and ornamental plants for nutrient, light, and water resources and are generally better competitors than the crop plants (3, 4, 10).

As labor costs rise, hand weeding POST emerged weeds from pots further reduces profit margins. There is growing demand to find herbicidal options that offer POST weed control without injuring ornamental plant species. Bleaching herbicides (HPPD inhibitors) including mesotrione, tembotrione and topramezone have shown promise for managing several broadleaf weed species, certain grasses, and nutsedge in corn, particularly when paired with PSII-inhibiting herbicides like bentazon, diuron and atrazine (1, 2, 7). However, these herbicides have not been evaluated for phytotoxicity in most ornamental plant species.

Greenhouse and shadehouse studies were conducted and repeated in time in 2008 at the University of Tennessee campus in Knoxville, TN to evaluate POST control of several weed species including redroot pigweed (*Amaranthus retroflexus*), chamberbitter (*Phyllanthus urinaria*), spotted spurge (*Chamaesyce maculata*), yellow nutsedge (*Cyperus esculentus*), and mugwort (*Artemisia vulgaris*) using select HPPD-inhibiting herbicides, either alone or in combination with PSII-inhibiting herbicides. Non-native chamberbitter was included because it has explosively dehiscent seedpods and densely fibrous root systems (8, 11, 12). In recent years it has become problematic throughout southern U.S. container production systems (6, 8, 12).

Treatments included the HPPD inhibitors mesotrione at 105 to 420 g ai/ha(0.094 to 0.375 lb/Ac), tembotrione at 92 to 370 g ai/ha (0.082 to 0.330 lb/Ac), and topramezone 18 to 147 g ai/ha (0.016 to 0.066 lb/Ac)alone and in combinations with the PSII inhibitors bentazon at 560 g ai/ha (0.5 lb/Ac), atrazine at 560 g ai/ha, and diuron at 448 g ai/ha (0.4 lb/Ac). Nursery crops that were evaluated for phytotoxicity included daylily (*Hemerocallis* 'Siloam June Bug'), burning bush (*Euonymus alatus* 'Compactus'), azalea (*Azalea* 'Girard's Rose'), Japanese holly (*Ilex crenata* 'Noble's Upright', flowering dogwood (*Cornus florida*), rose (*Rosa* 'Knockout'), and snapdragon (*Antirrhinum majus* 'First Ladies'). Because phytotoxicity was not readily apparent 7 DAT, only 28 DAT data are discussed.

Results and Discussion: By 28 DAT, POST applications of all HPPD treatments had provided 71 to 100% control of redroot pigweed; however topramezone was the only HPPD inhibitor that provided at least 97% control of redroot pigweed at every rate evaluated in these studies. Tembotrione and topramezone did not adequately control yellow nutsedge or spotted spurge, however mesotrione at 210 and 420 g ai/ha controlled both weeds between 75 to 88%. No HPPD inhibitor applied alone was able to give commercially acceptable chamberbitter or mugwort control. However, mixtures of the PSII inhibitors bentazon at 560 g ai/ha, diuron at 448 g ai/ha, or atrazine at 560 g ai/ha with mesotrione at 210 g ai/ha provided 93 to 97% control of mugwort. Similar mugwort control was observed with mixtures of tembotrione at 184 g ai/ha plus atrazine at 560 g ai/ha or diuron at 448 g ai/ha. POST applications of mesotrione at 105 g ai/ha plus bentazon at 560 g ai/ha provided 89 to 98% control at 28 DATof all weeds evaluated in these studies except chamberbitter.

All rates of mesotrione and mixtures of mesotrione at 105 g ai/ha plus bentazon at 560 g ai/ha did not visually injure or cause photo-bleaching of foliage on burning bush or azalea to greater than 5% of the canopy. Similar azalea and burning bush response was observed with tembotrione at 92 and 184 g ai/ha and with topramezone at 18 and 37 g ai/ha (Fig. 1). After 28 days, 'Knockout' roses incurred 12 to 43% and 17 to 55% injury, respectively following applications of tembotrione and mesotrione (Table 1). Foliage on treated rose stem tips did not recover chlorophyll content by 56 DAT (*data not shown*). Conversely, rose foliar injury did not exceed 18% with any rate of topramezone. Daylily injury never exceeded 27% with any HPPD inhibitor application, however topramezone (rates up to 74 g ai/ha) was the safest HPPD inhibitor applied to daylilies (injury of 7% or less). Flowering dogwood injury was 8 to 23% with all herbicide treatments. Japanese holly displayed little to no visual response or photo-bleaching with any application of the HPPD inhibitors. In contrast, no HPPD inhibitor treatment was safe for use in snapdragon. Bentazon alone at 560 g ai/ha did not cause greater than 13% injury to any nursery crop evaluated in these studies.

Literature Cited:

1. Armel, G.R., H.P. Wilson, R.J. Richardson, C.M. Whaley, and T.E. Hines. 2008. Mesotrione combinations with atrazine and bentazon for yellow and purple nutsedge (*Cyperus esculentus* and *C. rotundus*) control in corn. Weed Tech. 22: 391-396.
2. Armel, G.R., H.P. Wilson, R.J. Richardson, and T.E. Hines. 2003. Mesotrione combinations for postemergence control of horsenettle (*Solanum carolinense*) in corn (*Zea mays*). Weed Tech. 17: 65-72.
3. Berchielli-Robertson, D.L., C.H. Gilliam, and D.C. Fare. 1990. Competitive effects of weeds on the growth of container-grown plants. HortScience 25: 77-79.
4. Fretz, T.A. 1972. Weed competition in container grown Japanese holly. HortScience 7: 485-486.
5. Gilliam, C.H., W. J. Foster, J. L. Adrain, and R. L. Shumack. 1990. A survey of weed control costs and strategies in container production nurseries. J. Envir. Hort. 8: 133-135.
6. Hall, D.W., W.L. Currey, and J.R. Orsnigo. 1998. Weeds from other places: the Florida beachhead is established. Weed Technol. 12: 720-725.
7. Kaastra, A.C., C.J. Swanton, F.J. Tardif, and P.H. Sikema. 2008. Two-way performance interactions among *p*-hydroxyphenylpyruvate dioxygenase- and acetolactate synthase-inhibiting herbicides. Weed Sci. 56: 841-851.
8. Klingeman, W.E. and G.R. Armel. 2008. 5 weed species deserve a closer look: explosively dehiscent seedpods can challenge both patience and the economic bottom line. NM Pro 24(7): 33-36, 38, 40-41.
9. Latimer, J.G., R.D. Oetting, P.A. Thomas, D.L. Olson, J.R. Allison, S.K. Braman, J.M. Ruter, R.B. Beverly, W. Florkowski, C.D. Robaker, J.T. Walker, M.P. Garber, O.M. Lindstrom, and W.G. Hudson. 1996. Reducing the pollution potential of pesticides and fertilizers in the environmental horticulture industry: I. Greenhouse, nursery and sod production. HortTechnology 6: 115-124.
10. Mathers, H. 1999. Weed control in container nurseries. Digger 43: 36-37.
11. Norcini, J.G., R.H. Stamps, and J.H. Aldrich. 1995. Preemergent control of long-stalked phyllanthus (*Phyllanthus tenellus*) and leafflower (*P. urinaria*). Weed Tech. 9: 783-788.
12. Penny, G.M. and J.C. Neal. 2003. Light, temperature, seed burial, and mulch effects on mulberry weed (*Fatuoa villosa*) seed germination. Weed Technol. 17: 213-218.

Table 1. 'Knockout' roses (4 plants per trial) demonstrated variable phytoxicity by 28 DAT following over-the-top treatment with HPPD-inhibiting herbicides both alone and combined with PSII-inhibiting herbicides for POST emergent control of broadleaved weeds and nutsedge.

Treatment (trade name)	Rate (lb/acre) [in corn]	Foliar phytotoxicity (canopy %) Trial 1	Trial 2
mesotrione (Callisto)	105 g/ha (0.094 lb/Ac) = 1x	17	23
mesotrione	210 g/ha (0.188 lb/Ac) = 2x	42	35
mesotrione	420 g/ha (0.375 lb/Ac) = 4x	43	55
topramezone (Impact)	8.4 g/ha (0.016 lb/Ac) = 1x	7	5
topramezone	37 g/ha (0.033 lb/Ac) = 2x	5	7
topramezone	74 g/ha (0.066 lb/Ac) = 4x	0	17
tembotrione (Laudis)	91.9 g/ha(0.082 lb/Ac) = 1x	8	20
tembotrione	184 g/ha (0.164 lb/Ac) = 2x	17	18
tembotrione	370 g/ha (0.330 lb/Ac) = 4x	43	33
bentazon (Basagran)	560 g/ha (0.5 lb/Ac) = 1x	8	3
mesotrione + bentazon	1x + 1x	28	18
tembotrione + bentazon	1x + 1x	5	12
untreated (control)		0	0
LSD		14.4	9.2
P		***	***

*** Plant response to treatments differed significantly from controls at $P < 0.0001$

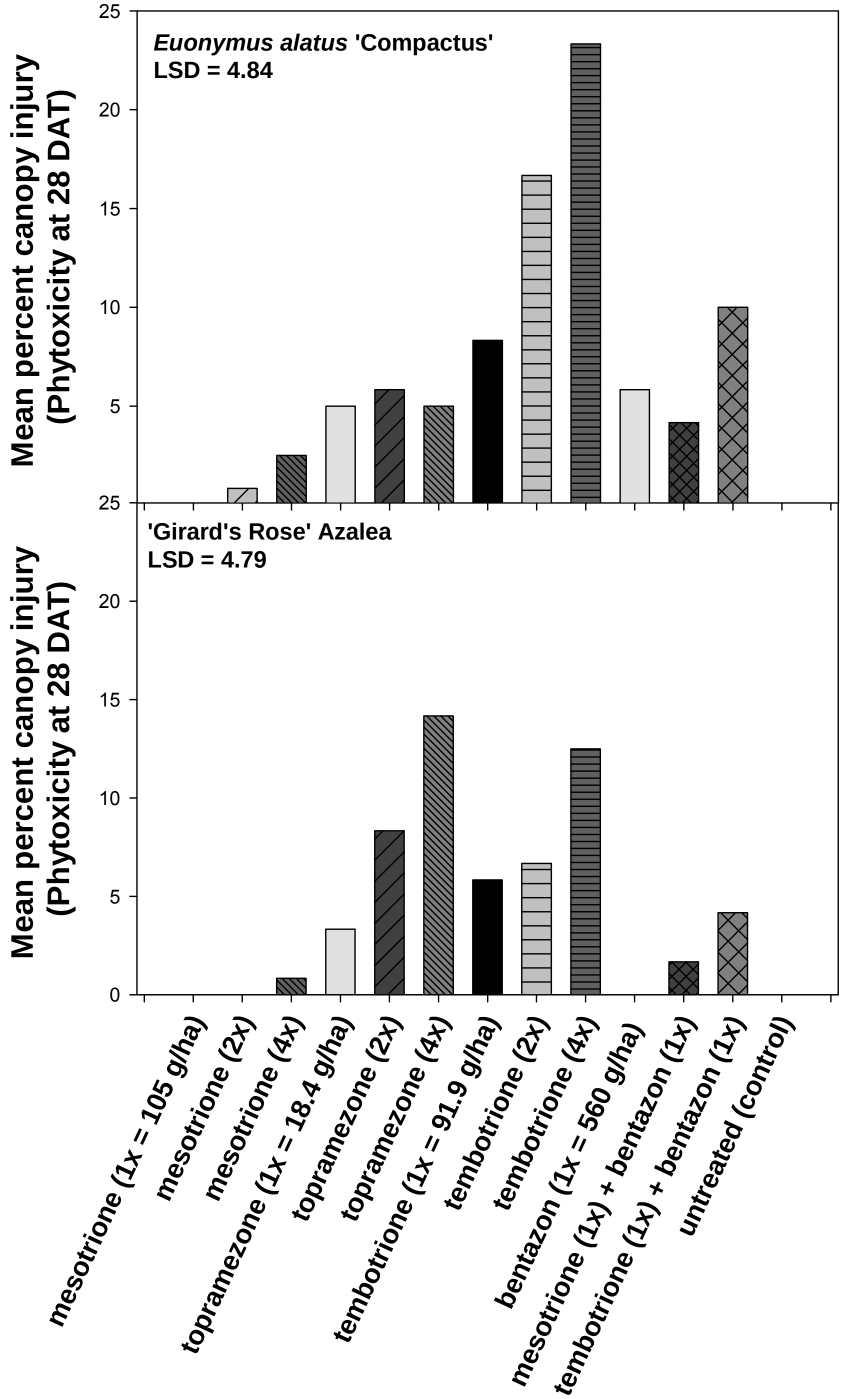

Figure 1. While different HPPD-inhibiting herbicide chemistries yielded variable damage to burning bush euonymus and ‘Girard’s Rose’ azalea foliage when applied at 1x, 2x, and 4x labeled rates for corn (*Zea mays*), both the 1x rates of mesotrione alone and mesotrione plus 1x bentazon had low levels of phytotoxicity with the tank mixture providing good POSTemergent control of tested weeds.

Can Roundup Be Safely Used Over-the-Top of Nursery Crops?

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Index words: Postemergence weed control, ornamental herbicide tolerance

Nature of Work: More and more growers are reporting labor shortages caused by weather events, immigration reform, and lack of capital due to the economic downturn. With reduced labor available, growers may face the prospect of weeds taking over their crops. If labor becomes completely unavailable, total crop loss could occur.

From 1975-1980, Dr. Ray Self and others demonstrated that Roundup® could be applied safely over-the-top on many ornamental species (2,3,6,7,8,9). In 1982 Neal and Skroch (5) conducted experiments on thirteen species of woody ornamentals treated with six rates of glyphosate applied at 6 different times from March 12 to November 11. Their research reported that the time of year of the herbicide application is as important as the amount of herbicide applied. As a general rule, treatments after August 5 showed minimal injury compared to treatments before that time of year. They reported that ratings taken 3.5 weeks after the application generally overestimated the ultimate effect of the treatments, indicating initial injury but no significant long-term effects into the second season. In 2002 Altland et al.(1) demonstrated that Roundup Pro® (Monsanto) could be safely used as a clean-up treatment for postemergence spurge control in *Liriope muscari*. Work in 2006 by Walsworth et al. (10) showed that Roundup could be safely applied as a 1% (by volume) solution over the top of liriope, *Ophiopogon japonicus,* and *Trachelospermum asiaticum*. Work in 2008 by Czarnota (4) showed that minimal injury occurred on three juniper species when Roundup Pro® was applied up to 2.5 lbs ai/a (active ingredient per acre). Our preliminary work shows that many common weeds in container-grown nursery crops are controlled with ≤ 1 lb ai/a.

The objective of this research is to develop a data bank for nursery crop tolerance to over-the-top Roundup applications for growers in the event that significant weed infestations overtake their crops.

Methods and Materials *Juniperus horizontalis* 'Wiltonii' 'Blue Rug', *Juniperus conferta* 'Blue Pacific,' *Ophiopogon japonicus*, *Ophiopogon japonicus* 'Nana,' *Liriope muscari* 'Cleopatra,' *Liriope muscari* 'Variegata,' *Trachelospermum asiaticum*, *Rhodendron* x 'Pink Gumpo', and *Ilex vomitoria* 'Stokes Dwarf' were potted in 3:1 pine bark : peat moss (v/v) amended with 14 lbs. Osmocote 19-6-12, 6 lbs. dolomitic limestone, 2 lbs. gypsum, and 1.5 lbs. Micromax/yd^3 in 1 gallon containers on April 30, 2007. Roundup Pro® was applied at four rates (0.25, 0.50, 1.0, and 2.0 lbs ai/a) in 30 GPA with a CO_2 backpack sprayer. Treatments were applied on June 10, 2007, August 30, 2007, or Feb. 20, 2008 to separate groups of plants not previously treated. One group of plants was treated on all dates and there was one non-treated control group for a total of seventeen treatments. Plant injury ratings were taken throughout the study and final growth indices were taken on June 13, 2008. Three replications from each treatment were rated for marketability on October 11, 2008 to evaluate long-term effects. Plants were grouped by species in a completely randomized block design with 8 single-pot replications. Research was conducted at the Ornamental Research Center in Mobile, Alabama. Data was analyzed in a statistical software package (SAS Institute, Cary, NC) using Waller-Duncan k ratio t tests ($P \leq 0.05$). Data was analyzed separately for each sampling date.

Results and Discussion

Our research indicates varied responses of individual species to applications of Roundup Pro®. Injury ratings showed varying effects of rates and the time of year treatments were applied (data not shown). For example, there was a significant range of tolerance in junipers. 'Blue Pacific' juniper showed injury 15 DAT in February, but recovered quickly. 'Blue Rug' showed no injury from February treatment up to 2 lbs ai/a, but was injured by 1 and 2 lbs ai/a on all other application dates. Dwarf mondo grass, variegated liriope, and liriope 'Cleopatra' were tolerant of single applications up to 2 lbs ai/a. Mondo grass was tolerant up to 2 lbs ai/a applied in June and August. Asiatic jasmine was tolerant up to 2 lbs ai/a and dwarf yaupon was tolerant up to 1 lb ai/a in August.

Growth indices taken after the first spring growth flush following the application appear to be a much better indicator of overall effects than injury ratings (Table 1). Data from June and August, 2007 treatments was collected 12 and 10 months after treatment, thus providing the opportunity to study long-term effects.

Growth indices for dwarf mondo grass, liriope 'Cleopatra,' and 'Blue Pacific' juniper were similar compared to the non-treated control plants regardless of rate or application time. Mondo grass growth indices were similar among all treatments except with 2 lbs ai/a applied on all three dates. Growth suppression on liriope was minimal. Growth of variegated liriope was suppressed by 2.0 lbs ai/a applied either in February or on all three dates. 'Blue Rug' juniper growth indices were smallest with 2 lbs ai/a in June, August, or on all three dates at 1.0 and 2.0 lbs ai/a. The February application did not affect 'Blue Rug' juniper growth. Conversely, Asiatic jasmine was affected most by February application, where rates ≥ 0.5 lb ai/a suppressed plant growth. A similar response occurred when applied on all three dates. There was no effect on growth indices of Asiatic jasmine when applied at any rate in June or August.

'Pink Gumpo' azalea and dwarf yaupon were the two most sensitive species to over-the-top applications of Roundup. 'Pink Gumpo' growth was suppressed with ≥ 1.0 lb ai/a when applied in either June or February. August-only applications resulted in growth indices similar to non-treated controls at all rates. Applications on all three dates resulted in severe growth suppression at 1.0 lb ai/a and plant death at 2.0 lbs ai/a. 'Stokes dwarf' holly growth was reduced by 74% when treated with Roundup at 2.0 lbs ai/a on all dates, by 21% with 1.0 lb ai/a applied in Feb or June, and by 19% with 0.5 lb ai/a in June.

Marketability ratings showed good recovery for most of the species at all rates and treatments (Table 2). Six of the nine species evaluated had marketability ratings similar to the non-treated controls at the 1.0 lb ai/a rate on all dates of application. Dwarf mondo, liriope 'Cleopatra,' variegated liriope, and 'Blue Pacific' were similar to the controls for all treatments, including those applied three times. Mondo was affected by 2 lbs ai/a in February and June, 'Blue Rug' by 2 lbs ai/a in June, August, and on all three dates. Asiatic jasmine was affected by 1.0 and 2.0 lbs ai/a in February. Dwarf yaupon and 'Pink Gumpo', the two most sensitive species in the test, had marketability ratings that were better than expected. Dwarf yaupon was affected at 2 lbs ai/a in August, 1.0 and 2.0 lbs ai/a in June, and 0.5 lb in ai/a February and on all dates. 'Pink Gumpo' showed effects only from 2.0 lbs ai/a applied in February and 1.0 and 2.0 lbs ai/a applied on all dates.

Individual species should be tested for tolerance before large groups of plants are treated. Our research is intended to provide data for emergency measures for weed control when labor is unavailable or when it would cost more to weed the crop than it is worth. It should not replace a solid program of weed management consisting of monitoring, removal of weeds before seeding, and a good preemergence herbicide program.

Significance to Industry: Information on crop tolerance provides growers a backup alternative should issues such as immigration reform, labor shortage or natural disasters occur and crops are taken over by weeds. At a cost of $100.00 per 2.5 gallons of product, 1 quart per acre of herbicide could be applied at a material cost of $10.00 per acre plus the labor to apply it. These data show that most of the plants tested had some tolerance to an over-the-top application of Roundup Pro®.

Literature cited:

1. Altland, J.E., C.H. Gilliam and J.W. Olive. 2002. Postemergence prostrate spurge (*Chamaesyce prostrata*) control in container-grown liriope. J. Environ. Hort. 20:41-46.
2. Cobb, G.S. and R.L. Self. 1979. Observations of phytoxicity of foliar application of Roundup to nine ornamental species. SNA Res. Conf. 24:250-252.
3. Cobb, G.S. and R.L. Self. 1979 a. Rooting of wintergreen boxwood cuttings following over-the-top applications of glyphosate to stock plants. SNA Res. Conf. 24:221-222.
4. Czarnota, M.A. 2008. Tolerance of three juniper species to glyphosate. Hort Technology 18:239-242.
5. Neal, J.C. and W.A. Skroch. 1985. Effects of timing and rate of glyphosate application on toxicity to selected woody ornamentals. J. Amer. Soc. Hort. Sci. 110:860-864.
6. Self, R.L. 1974. Screening tests with glyphosate on woody ornamentals. SNA Res. Conf. 19:118-119.

7. Self, R.L. 1978. Foliar applications of roundup to 18 container-grown ornamentals. SNA Res. Conf. 23:186-187.
8. Self, R.L. and C.T. Pounders, Jr. 1975. Weed control and phytotoxicity studies on container-grown ornamentals. SNA Res. Conf. 20:117.
9. Self, R.L. and O. Washington. 1977. Over-the-top application of Roundup to rooted cuttings, liners, and pot-grown woody ornamentals. SNA Res. Conf. 22:175-176.
10. Walsworth, C.E., E. Bush, R. Strahan, and A. Gray. 2006. Selective broadleaf weed control in groundcovers. HortScience 40:498. (Abstr.)

Table 1. Growth indices[Z] taken on 6/13/08 for ornamentals treated with Roundup Pro®

Rate Lb aia[Y]	Treatment date	Dwarf Mondo	Mondo	Liriope 'Cleo'	Liriope variegated	Blue Pacific	Blue Rug	Asiatic jasmine	Dwarf yaupon	Pink Gumpo
	nontreated	18.0ab[X]	35.4ab	29.4abc	36.9abc	34.4cde	44.2abc	49.0abc	27.4a	27.2abc
0.25	2/20/2008	17.7ab	35.9ab	33.7ab	37.6ab	44.1abc	39.8bcd	44.3cd	25.5ab	28.6a
0.5		17.2ab	38.0a	33.5ab	38.4a	47.1a	46.3ab	36.2e	24.5a-d	26.0b-e
1		15.0c	36.7ab	29.8bc	38.0ab	45.2ab	47.2ab	25.9f	22.0cde	23.8efg
2		18.5ab	32.7b	26.8c	33.2d	46.6a	45.4ab	26.0f	17.1g	22.0g
0.25	6/10/2007	17.6ab	35.3ab	35.2a	34.0cd	38.3a-d	44.4abc	50.7abc	27.0a	27.9ab
0.5		17.8ab	36.5ab	27.5c	37.5ab	46.2a	45.7ab	54.0a	21.8de	26.3a-d
1		18.6ab	34.9ab	29.0ab	35.5a-d	42.2abc	39.6bcd	46.1bcd	20.6ef	24.5def
2		17.8ab	34.7ab	33.0ab	37.6ab	38.4abc	35.4de	44.2cd	18.9fg	23.4fg
0.25	8/30/2007	19ab	35.0ab	30.6abc	36.4a-d	42.5abc	48.8a	40.6de	27.2a	28.0ab
0.5		19.5a	36.0ab	27.62c	35.3a-d	38.2a-d	44.5abc	45.0cd	24.9abc	27.8ab
1		19.5a	35.6ab	32.7ab	34.0cd	42.7abc	36.2cde	52.4ab	26.3a	26.9abc
2		19.1ab	37.1a	34.0ab	36.1a-d	42.2abc	12.6g	46.5bcd	22.7b-e	24.9c-f
0.25	All dates	18.3ab	34.0ab	31.0abc	35.4a-d	30.5de	46.0ab	45.1cd	27.4a	27.6ab
0.5	shown	18.7ab	36.6ab	26.4abc	35.3a-d	36.0b-d	44abc	35.6e	22.2cde	25.1c-f
1	above	18.0ab	34.9ab	29.3bc	34.5bcd	32.3de	31.0e	28.7f	16.1g	17.2h
2		17.0b	16.6c	23.0c	21.6e	28.4e	22.4f	25.2f	7.2h	0.0i

[Z] Growth indices [(height + width 1 + width 2)/3] presented in centimeters
[Y] aia = active ingredient per acre
[X] Means separated using Duncan's Multiple Range Test at p = 0.05

Table 2. Marketability on 10/11/08 for ornamentals treated with Roundup Pro®

Rate lbs ai/a[Y]	Treatment date	Dwarf Mondo	Mondo	Liriope 'Cleo'	Liriope variegated	Blue Pacific	Blue Rug	Asiatic jasmine	Dwarf yaupon	Pink Gumpo
	nontreated	1[Z]	1	1	1	1	1	1	1	1
0.25	2/20/2008	1	1	1	1	1	1	1	1	1
0.5		1	1	1	1	1	1	1	2	1
1		1	1	1	1	1	1	1.5	3	1
2		1	2	1	1	1	1	2	3	2.5
0.25	6/10/2007	1	1	1	1	1	1	1	1	1
0.5		1	1	1	1	1	1	1	1	1
1		1	1	1	1	1	1	1	2	1
2			1.5	1	1	1	2	1	3	1
0.25	8/30/2007	1	1	1	1	1	1	1	1	1
0.5		1	1	1	1	1	1	1	1	1
1		1	1	1	1	1	1	1	1	1
2		1	1	1	1	1	3	1	2	1
0.25	All dates shown above	1	1	1	1	1	1	1	1	1
0.5		1	1	1	1	1	1	1	1	1
1		1	1	1	1	1	1	1.5	2	2.5
2		1	3	1	1	1	3	2	3	3

[Z] Marketability ratings: 1= no difference from untreated control, 2 = smaller in size, 3 = unmarketable (average rating of three plants from each treatment)

[Y] aia = active ingredient per acre

Phytotoxicity of Granular Formulations of Mesotrione, Pendimethalin + Dimethenamid-P and Sulfentrazone to Six Wildflowers

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Index words: Asclepias, Coreopsis, FreeHand™, Gaillardia, growth, mesotrione, flower, sulfentrazone, Vernonia

Significance to Industry: Although FreeHand™ and sulfentrazone caused acute phytotoxicity, especially to newly planted liners, all six wildflowers treated at the 1× rates fully recovered and grew and flowered as well as the untreated controls. Acute phytotoxicity was also much less after the plants had become established indicating that these two herbicides might be useful for controlling weeds in established landscape and seed-production beds. Mesotrione was very phytotoxic, even at the 1× application rate. The possibility of having two additional products, besides Plateau, for sedge and other weed control in wildflowers—especially since they have two different sites/modes of action—could aid in weed control and resistance management.

Nature of Work: Interest in wildflowers continues to grow (1) and so has interest in controlling weeds during their production and establishment (2, 5). Weed control is especially important for producers of wildflower seed since weeds can reduce wildflower seed yields. Even more importantly, marketing of wildflower seed lots contaminated with weed seeds can be difficult, and actually prohibited if noxious weed species are present (4). Sedges (*Cyperus* spp.) can be particularly difficult to control since they can even penetrate the polypropylene ground cloth often used to exclude weeds from wildflower seed production beds. Imazapic (Plateau®, BASF, Research Triangle Park, NC), a group 2 herbicide (3) with activity against sedges, has been tested and labeled for use on wildflowers (5). There are a number of other herbicides that suppress or control sedges, as well as other weeds, that might be useful during wildflower seed and plant production. In addition, many have different sites of action than imazapic and each other and could be used in rotations designed to minimize selection for herbicide resistance. FreeHand™ (BASF) is a recently labeled granular herbicide containing 1% pendimethalin + 0.75% dimethenamid-P (group 3 + 15 herbicides). It is one of several products listed for over-the-top phytotoxicity testing in the USDA's IR-4 program. Two other herbicides, mesotrione (Syngenta, Greensboro, N.C.), a group 28 herbicide, and sulfentrazone (FMC, Princeton, N.J.), a group 14 herbicide, are also included in the IR-4 protocol.

Seeds of six wildflower species—*Asclepias curassavica* L., scarlet milkweed; *Coreopsis basalis* (A. Dietr.) S.F. Blake, goldenmane tickseed; *Coreopsis lanceolata* L., lanceleaf tickseed; *Coreopsis leavenworthii* Torr. & A. Gray, Leavenworth's tickseed; *Gaillardia pulchella* Foug., firewheel; and *Vernonia gigantea* (Walter) Trel. ex Branner & Coville, giant ironweed—were germinated in a double-poly covered greenhouse at the University of Florida's Mid-Florida Research and Education Center. On 27 March 2007, the seeds were sown on a pre-moistened peat-based growing media (Metro-Mix® 200, Sun Gro Horticulture Canada, Seba Beach, Alta.) held in 1020 plastic trays. Trays were watered by hand as needed and fertilized once a week with a water soluble fertilizer (Peters Professional® 10-30-20 Blossom Booster, The Scotts Co., Marysville, Ohio). Seedlings were transplanted into cell packs (DP572, Dillen Products, Middlefield, OH), from 20 April 2007 to 07 May 2007, and relocated to a 30% shadehouse for daily overhead watering and weekly fertilization with a water soluble fertilizer. On 11 June 2007, seedlings were transplanted from cell packs into containers (Classic 300S #1, Nursery Supplies, Chambersburg, Pa.) of diameter 6 ½" or 6" at soil line. Pots were filled with a woody ornamental mix of composted pine bark:sedge peat:coarse sand (60:40:10 by vol) (Florida Potting Soils, Orlando, Fla.) amended with 5 lbs/yd^3 of dolomite and 1.5 lbs/yd^3 of a micronutrient supplement (Micromax®, Scotts). The "peat" component was composed of equal parts composted municipal yard waste, composted hardwood bark, and Florida sedge peat. Three containers of each species (18 containers total) were centered in outdoor plots measuring 4' × 3'. Plots had black polypropylene ground cloth secured directly to the ground, and plots were exposed to full sun and received daily irrigation of ½" water by overhead impact sprinklers, along with rainfall. Plants were topdressed with a controlled-release fertilizer (Osmocote® 18-6-12, Scotts).

Initial plant measurements—height, width at widest point (wd1) and perpendicular width (wd2)—were taken on 12 June 2007. Plant top growth indexes (PTGI) were calculated as $PTGI = \pi r^2 h$, where $r = ((wd1 + wd2) \div 2) \div 2$. Each plot was either left untreated (control) or treated over-the-top with one of the following three granular herbicides: FreeHand (1.75%, BASF Crop Science Division); sulfentrazone (0.2%, FMC); or mesotrione (0.116%, Syngenta Crop Protection). Initial treatments were hand broadcast at 1×, 2× and 4× rates (Table 1) using dedicated shakers on 14 June 2007. Herbicides were applied uniformly to plants with dry foliage when wind conditions were calm. After each herbicide application the plots were irrigated with ½" of water. Four weeks after the initial herbicide treatments, measurements were taken for all plants, and mesotrione was reapplied on 13 July 2007 in the same manner as the initial treatments. The four week measurement was final for *C. basalis* due to complete senescence. Eight weeks after the initial herbicide treatments, measurements were taken for all plants, and FreeHand and sulfentrazone were reapplied on 10 August 2007. Final PTGI measurements for all plants were taken on 11 October 2007. Ten treatments (3 herbicides × 3 rates + 1 control) were replicated four times in a randomized complete block design for a total of 40 plots and a total of 720 observational units (pots).

Throughout the experiment, data were collected regarding acute and chronic phytotoxicity. Acute phytotoxicity was estimated visually as a percentage from 0–100%, where 0 = no injury and 100 = plant dead. Chronic phytotoxicity was estimated using differences in plant growth as determined by PTGI. During the growing season, flower blooms were counted at intervals until senescence.

Polynomial regression analysis (PROC GLM, SAS Institute Inc., Cary, N.C.) was performed on 1×, 2×, and 4× herbicide rates. Data were analyzed by analysis of variance and means differing from the untreated controls were determined using Dunnett's procedure at $P \leq 0.05$. Percent values were square root or arcsin-square-root transformed, as needed, prior to analysis.

Results and Discussion:

Acute phytotoxicity from first herbicide application (data not shown). All herbicide treatments caused significant damage to *Asclepias curassavica*. Symptoms (discoloration, distortion and necrosis) appeared first (5 days after initial treatment, DAIT) in sulfentrazone-treated plots (Fig. 1). Damage in the mesotrione-treated plots appeared slightly later (8 DAIT) in the form of foliar bleaching. Damage, expressed mainly as stunting, became apparent in the FreeHand-treated plants by 28 DAIT. By that time the plants treated with sulfentrazone at the 1× rate had recovered from the initial damage. At 56 DAIT, the plants treated with sulfentrazone at all three rates and FreeHand at 1× were fully recovered, and all of the mesotrione-treated *A. curassavica* were dead. The phytotoxicity damage and recovery pattern was similar for *Coreopsis basalis*. At 56 DAIT, plants in the 1× FreeHand and 1 and 2× sulfentrazone treated plots had recovered and all the mesotrione-treated plants were dead. For *C. lanceolata*, plants treated with the 2× rate of FreeHand had also recovered by 56 DAIT and the mesotrione-treated plants, although severely damaged, were still alive. Phytotoxicity to *C. leavenworthii* was very similar to that for *C. basalis* except that only the highest rate of mesotrione was 100% lethal. *Gaillardia pulchella* was very sensitive to all herbicide treatments and only plants in the sulfentrazone plots treated at the low and middle rate fully recovered prior to plant senescence (43 DAIT). Mesotrione caused bleaching and distortion of *G. pulchella* leaves (Fig. 2). *Vernonia gigantea* was also sensitive to all herbicide treatments; however, plants in the FreeHand plots treated at the 1× rate were generally comparable to those in the untreated control plots. Phytotoxicity effects varied from linear to cubic for all herbicides at the various rating dates depending on plant species but, in general, were more often linear for FreeHand, quadratic for sulfentrazone, and cubic for mesotrione. Overall, damage increased with increasing application rate unless all rates were lethal or nearly so (i.e., mesotrione on *A. curassavica*, *C. basalis*, and *G. pulchella*).

Acute phytotoxicity from second herbicide application (data not shown). The results for *A. curassavica* were essentially the same as for the first application, with the same treatments recovering completely by 49 days after the second treatment. *C. basalis* phytotoxicity ratings could not be made due to senescence of this annual Coreopsis. *C. lanceolata* was not significantly damaged by the 1 or 2× rates of FreeHand or the 1× rate of sulfentrazone. *C. leavenworthii* was not significantly damaged by the 1× rate of FreeHand or the 1 or 2× rate of sulfentrazone. The lack of damage to these two Coreopsis species after the second herbicide application was probably due to the plants being larger and more mature than they were when the initial treatments were applied. All second treatments damaged *G. pulchella*, but by 49 days after the second treatment (DAST) the plants treated at the 1 or 2× rate of FreeHand or any rate of sulfentrazone were similar to the untreated controls. The only treatment that did not cause acute damage to *V. gigantea* was the 1× rate of FreeHand. The plants were larger and more established at the time of the second herbicide application and the effects of FreeHand and sulfentrazone were mostly linear while that of mesotrione remained cubic. *Chronic phytotoxicity*. Mesotrione was the most damaging of the three herbicides and caused significant reductions in growth of *A. curassavica*, *C. basalis*, *C. lanceolata* (4× rate), *G. pulchella* and *V. gigantea* (Fig. 3 and 4). Sulfentrazone at the 2 and 4× rates reduced *V. gigantea* growth and FreeHand at the 4× rate stunted *G. pulchella*.

<u>Flower production</u>***.*** Flower production is of course important for seed production, marketability of potted wildflowers, and aesthetic effects of landscape plantings. Mesotrione at all tested rates reduced flowering of all the wildflowers except *Coreopsis lanceolata* (Table 1). Sulfentrazone at the 2 and 4× rates reduced flowering of *C. basalis*, *G. pulchella* and *V. gigantea* . Flower production was reduced when FreeHand was applied at the 4× rate to *A. curassavica* and *C. leavenworthii* and at the 2 and 4× rates to *C. basalis* and *G. pulchella*.

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Literature Cited

1. Aldrich, J. 2002. Factors and benefits in the establishment of modest-sized wildflower plantings: a review. Native Plants Journal 3:67-86.
2. Jacobs, J., S. Winslow, and M. Pokorny. 2007. The effect of five pre-emergence herbicides on emergence and establishment of four native wildflowers. Native Plants Journal 8:224-231.
3. Mallory-Smith, C. A. and E. J. Retzinger. 2003. Revised classification of herbicides by site of action for weed resistance management strategies. Weed Tech. 17:605-617.
4. Norcini, J. G. 2005. Seed Production of Blanketflower. Univ. of Fla., IFAS, Fla. Coop. Ext. Serv., Dept. of Environ. Hort. pub. ENH987:10 pages.
5. Norcini, J. G., J. H. Aldrich, and F. G. Martin. 2003. Tolerance of native wildflower seedlings to imazapic. J. Environ. Hort. 21:68-72.

Table 1. Effects of herbicide treatments on flower production of six wildflowers.

Treatment	Application rate (lb a.i. /A)	Total number of flowers counted during growing season[z] (avg/plot)					
		Asclepias curassavica 8/29/07-9/26/07	*Coreopsis basalis* 6/19/07-7/30/07	*Coreopsis lanceolata* 8/16/07-9/26/07	*Coreopsis leavenworthii* 8/16/07-9/27/07	*Gaillardia pulchella* 8/29/07-9/27/07	*Vernonia gigantea* 8/30/07-9/28/07
Untreated control	—	73.5	31.3	4.5	36.9	9.6	40.4
FreeHand 1.75 G (1×)	2.65	74.7	25.8	5.3	38.9	6.3	30.0
FreeHand 1.75 G (2×)	5.3	62.3	11.7 *	4.1	13.8	2.3 *	23.7
FreeHand 1.75 G (4×)	10.6	38.5 *[y]	8.6 *	3.6	4.6 *	0.3 *	32.5
Sulfentrazone 0.2 G (1×)	0.375	73.9	33.1	4.0	45.9	6.5	25.4
Sulfentrazone 0.2 G (2×)	0.75	85.3	19.4 *	3.7	44.1	4.4 *	5.3 *
Sulfentrazone 0.2 G (4×)	1.5	49.5	12.7 *	1.0	34.4	3.0 *	2.6 *
Mesotrione 0.116 G (1×)	0.187	0.0 *	1.8 *	0.1	3.3 *	0.0 *	11.3 *
Mesotrione 0.116 G (2×)	0.25	0.0 *	1.3 *	0.4	1.3 *	0.0 *	2.5 *
Mesotrione 0.116 G (4×)	0.37	0.0 *	1.4 *	0.0	0.6 *	0.0 *	0.8 *

[z] Plants were potted from liners into 6 ½" Classic 300S pots on June 11, 2007 and blooms were counted at intervals until senescence.
[y] * Indicates treatment means different from untreated control mean using Dunnett's procedure at $P \leq 0.05$.

Figure 1. Discoloration of *Asclepias curassavica* leaves caused by sulfentrazone.

Figure 2. Bleaching of *Gaillardia pulchella* foliage due to treatment with mesotrione.

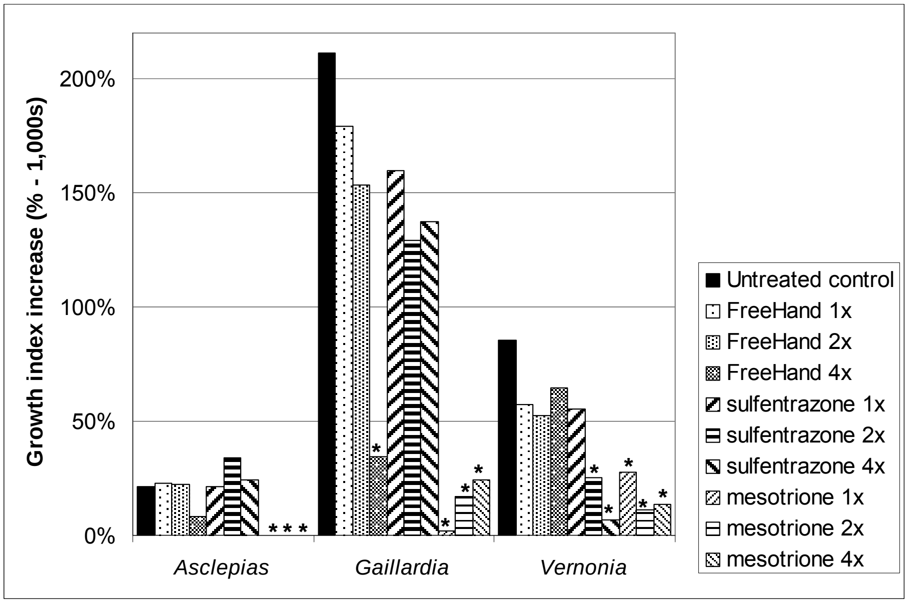

Figure 3. Effects of granular herbicide treatments on growth of three containerized wildflower species. An asterisk (*) above a column indicates significantly reduced growth compared to the untreated control (Dunnett's procedure, $P \leq 0.05$).

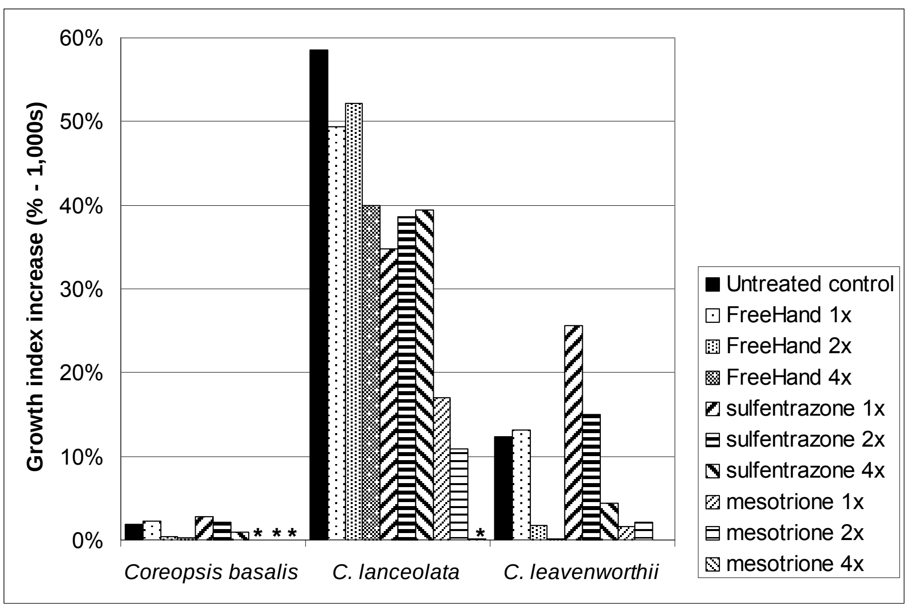

Figure 4. Effects of granular herbicide treatments on growth of three containerized *Coreopsis* species. An asterisk (*) above a column indicates significantly reduced growth compared to the untreated control (Dunnett's' procedure, $P \leq 0.05$).