Research Reports

Auxinic Herbicide Phytotoxicity to Container-Grown *Muhlenbergia capillaris* and *Miscanthus sinensis*[1]

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Abstract

Phytotoxicity of postemergence applications of auxinic herbicides was evaluated on container-grown *Miscanthus sinensis* 'Gracillimus' and *Muhlenbergia capillaris.* Treatments included Triamine II (MCPA, mecoprop-p and dichlorprop-p), Tri-Power (MCPA, mecoprop-p and dicamba), and Triplet Low Odor (2,4-D, mecoprop-p and dicamba), each applied at the labeled dose, twice the labeled dose, or four times the labeled dose. Liners established in 32-cell trays were transplanted to 3-L containers. About two weeks after transplanting, treatments were applied to actively growing plants and re-applied about six weeks later. The experiment was conducted in 2010 and repeated in 2011. *Miscanthus* was uninjured following a single application at the labeled dose, but following a second application all treatments were injurious in one of two years. Foliage fresh weight was generally not reduced by auxin herbicides, but the number and weight of inflorescence stalks were reduced by all herbicides and doses. *Muhlenbergia* was injured by twice and four times the labeled doses of all herbicides in both years and by the labeled doses in one year. All herbicide treatments reduced *Muhlenbergia* inflorescence counts and above-ground fresh weights.

Index words: postemergence, ornamental grasses, phenoxy herbicides, inflorescence, seedhead suppression.

Species used in this study: pink muhly grass (*Muhlenbergia capillaris (*Lam.) Trin.), eulalie grass or maiden grass (*Miscanthus sinensis* Andersson var. *gracillimus* Hitchc.).

Chemicals used in this study: Triamine II (MCPA + mecoprop-p + dichlorprop-p) ((4-chloro-2-methylphenoxy)acetic acid + (*R*)-2-(4-Chloro-2-methylphenoxy)propanoic acid + (*R*)-2-(2,4-dichlorophenoxy)propanoic acid); Tri-Power (MCPA + mecoprop-p + dicamba) ((4-chloro-2-methylphenoxy)acetic acid + (*R*)-2-(4-Chloro-2-methylphenoxy)propanoic acid + 3,6-dichloro-2-methoxybenzoic acid); Triplet Low Odor (2,4-D + mecoprop-p + dicamba) ((2,4-dichlorophenoxy)acetic acid + (*R*)-2-(4-chloro-2-methylphenoxy)propanoic acid + 3,6-dichloro-2-methoxybenzoic acid).

Significance to the Horticulture Industry

The popularity of ornamental grasses for landscaping continues to grow. Growers of ornamental grasses need safe, effective and economical weed management options. While nurseries specializing in ornamental grass production desire selective postemergence broadleaf weed control, auxinic herbicide mixtures commonly used for weed control in turf may cause significant injury to ornamental grasses in production, including reduction in number of flower stalks and reduced growth. This underscores the need to utilize only those herbicides labeled for a particular crop and production site.

Introduction

The popularity of ornamental grasses in landscaping continues to increase. Between 2003 and 2009, sales of ornamental grasses nearly doubled from about $61 million to over $124 million (Meyer 2012). In response to this growing market, the production of ornamental grasses is becoming increasingly common and the diversity of plants available in the trade continues to increase. In order to maximize grower profits as demand continues to rise, cost-effective weed control options must be explored. Even marginally effective herbicide programs have been demonstrated to be cost effective when compared to hand weeding alone (Darden and Neal 1999). Yet few herbicides are labeled for use in ornamental grass production, and limited research is available on herbicide tolerance for ornamental grasses.

Most studies involving herbicide use in container-grown ornamental grasses have focused on options for preemergence weed control. It has been shown that some preemergence herbicides that are labeled for turfgrasses, such as pendimethalin, prodiamine, isoxaben, trifluralin, and oxadiazon, might also be safe on ornamental grasses (Fain et al. 2003, Neal and Senesac 1991). However, other research has demonstrated injury from these and other common nursery herbicides (Green et al. 1997). Studies have shown that preemergence herbicide programs on their own are rarely capable of providing long-term, broad-spectrum weed control due to the inherent unpredictability of weed populations in a given area (Case et al. 2005). Even with effective preemergence herbicide programs, supplemental hand weeding is still required in container nursery crops. Thus, postemergence weed control options are desired.

Auxinic herbicides, such as 2,4-D, mecoprop, dicamba and others, have been used for postemergence control of broadleaf weeds in both agricultural settings and in turfgrass since their introduction in the 1950s (Jagschitz and Skogley 1966). It has become common for auxinic herbicides to be sold in mixtures of two or more active ingredients in order to expand the range of broadleaf weeds controlled (McElroy et al. 2005). While considered to be generally selective for controlling broadleaf plants but not grasses, research has demonstrated that tolerance to auxinic herbicides among grasses can vary depending on the species and cultivar. In some cases, auxinic herbicides have caused unacceptable

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levels of injury to certain turfgrass species which persisted for more than 40 days after the initial treatment (McCarty and Colvin 1992). In other instances, even species that are generally considered tolerant, such as bermudagrass, have exhibited significant injury depending on the growth stage of the plant during application (McCalla et al. 2004).

Many growers of ornamental grasses have assumed auxinic herbicides to be generally safe on grasses and many have reported to us that they use or have tested such herbicides for broadleaf weed control in ornamental grass production, yet, limited research exists on this subject. Tallarico and Voigt (2004) reported that several ornamental grass species tolerated repeated applications of clopyralid without suffering a significant decrease in foliar quality. Clopyralid controls many broadleaf weeds in the asteraceae and fabaceae families, but does not control many other common broadleaf weeds and is thus better utilized in combination with other auxinic herbicides (Neal 1990, Olson and Hall 1988). A small number of trials have been conducted on the herbicide tolerance of *Miscanthus sinensis*. Everman et al. (2011) observed no significant injury after single applications of dicamba to container-grown *Miscanthus*. A recent literature search revealed no reports on the safety of auxinic herbicides on *Muhlenbergia capillaris*.

The objective of this study was to investigate the safety of postemergence applications of auxinic herbicide combinations on container-grown *Miscanthus sinensis* and *Muhlenbergia capillaris*, two commonly-grown ornamental grasses. Results from the research on these two model species could be used to direct future work and decisions regarding the labeling of these products for nursery or landscape use.

Materials and Methods

The experiment was conducted in 2010 and repeated in 2011 to evaluate auxinic herbicide phytotoxicity to container-grown *Miscanthus sinensis* and *Muhlenbergia capillaris*. To ensure that conditions and crop management were representative of industry practices, the experiment was conducted at Hoffman Nursery in Rougemont, NC, a specialty nursery that focuses on ornamental grass production. Divisions of *Miscanthus sinensis* 'Gracillimus' and seedlings of *Muhlenbergia capillaris* were grown in 5.7-cm (2.25-in) square cell pots, 32 per tray. Once well established, those liners were potted to 3 L (#1) containers using a soilless substrate consisting of composted peanut hull/pine bark + pine bark + coir + perlite 50:25:15:10 (v/v) on July 20, 2010, and June 15, 2011. About two weeks after potting, when plants had rooted into the substrate and initiated new growth, herbicide treatments were applied. Treatments included a non-treated control, Triamine II and Tri-Power each at 3.5, 7, and 14 L·ha^{-1} (3, 6, and 12 pt·A^{-1}), and Triplet Low Odor at 2.9, 5.8, and 11.7 L·ha^{-1} (2.5, 5, and 10 pt·A^{-1}) (each manufactured by NuFarm Americas, Inc., 150 Harvester Dr., Burr Ridge, IL). Formulations, active ingredients and doses of each active ingredient are listed in Table 1. These auxinic herbicide combinations were selected for study because they were currently labeled for turfgrass uses and the manufacturer had indicated a willingness to add this use to the label if the research results supported registration. For each herbicide, the lowest dose corresponded to the lowest dose recommended on the product label for turf and was designated as 1×. The two higher doses were twice or four times the low dose, designated as 2× and 4×, respectively. Initial herbicide applications were made on August 4, 2010, and June 28, 2011; herbicides were re-applied on September 16, 2010 and August 11, 2011. Herbicides were applied using a CO_2-pressurized sprayer equipped with flat fan nozzles and calibrated to deliver 280 L·ha^{-1} (30 GPA) at 276 kPa (40 psi) pressure. Treatments were arranged in a randomized complete block design with four replicates and three plants of each species per experimental unit. All data were subjected to analysis of variance. Main effects and interactions were tested using PROC GLM in SAS (SAS 2011). Treatment means were separated using Fisher's protected least significant differences procedure (LSD) with $P \leq 0.05$.

Treatment effects were visually evaluated one, two, and six weeks after each application using a percent injury scale where 0 = no effect (visually equivalent to non-treated plants) and 100 = dead plants. On November 18, 2010, and October 14, 2011, the number of inflorescence stalks (flowering culms) on each plant was counted and above-ground fresh weights were measured. *Miscanthus sinensis* inflorescence

Table 1. Herbicides, formulations, and doses applied in the container ornamental grass trials.

Herbicide formulations and active ingredients	Product dose [L·ha^{-1} (pt·A^{-1})] 1×	2×	4×	Active ingredient dose[z] [Kg ae·ha^{-1} (lb ae·A^{-1})] 1×	2×	4×
Triamine II	3.5 (3.0)	7.0 (6.0)	14.0 (12.0)	1.06 (0.95)	2.13 (1.90)	4.26 (3.80)
17.15% MCPA dimethylamine salt				0.53 (0.48)	1.06 (0.95)	2.14 (1.91)
8.47% mecoprop-p dimethylamine salt				0.26 (0.24)	1.06 (0.95)	1.06 (0.95)
8.34% dichlorprop-p dimethylamine salt				0.26 (0.24)	0.53 (0.47)	1.06 (0.95)
Tri-Power	3.5 (3.0)	7.0 (6.0)	14.0 (12.0)	1.68 (1.50)	3.36 (3.00)	6.72 (6.00)
40.42% MCPA dimethylamine salt				1.30 (1.16)	2.61 (2.325)	5.20 (4.65)
7.99% mecoprop-p dimethylamine salt				0.25 (0.23)	0.50 (0.45)	0.10 (0.90)
3.97% dicamba dimethylamine salt				0.12 (0.11)	0.25 (0.225)	0.50 (0.45)
Triplet Low Odor	2.9 (2.5)	5.8 (5.0)	11.7 (10.0)	1.13 (1.01)	2.26 (2.02)	4.52 (4.04)
47.33% 2,4-D isopropanol amine				0.75 (0.74)	1.50 (1.48)	3.00 (2.96)
6.75% mecoprop-p dimethylamine salt				0.22 (0.20)	0.44 (0.40)	0.88 (0.80)
2.3% dicamba acid				0.06 (0.07)	0.12 (0.14)	0.24 (0.28)

[z]Application doses are expressed in acid equivalents for the combined active ingredients and for each component. 1×, 2× and 4× indicate the one, two and four times the manufacturer's recommended dose.

stalks were weighed separately from foliage then combined for total above-ground fresh weight. Because it was not possible to accurately separate *Muhlenbergia capillaris* foliage and inflorescence stalks, total above-ground fresh weight was recorded.

Results and Discussion

Analysis of variance revealed that the main effects of species, year, herbicide and dose, as well as the two-way interactions of year by herbicide and year by species were significant (with $P \leq 0.01$) for most evaluations. Therefore, data were analyzed and presented separately by species and year.

Miscanthus sinensis. In 2010, no injury was observed on *Miscanthus sinensis* following the initial application of any herbicide treatment, but following the second application significant injury was observed from each herbicide (Table 2). One week after the second treatment (WAT2), the 4× dose of Triamine II, Tri-Power and Triplet Low Odor caused 25, 33 and 18% injury, respectively. Injury was also observed 2 WAT2 with the 2× dose of each herbicide as well as the 1× dose of Tri-Power. By 6 WAT2, injury was generally less severe, with only the 4× dose of Tri-Power exhibiting injury greater than the non-treated. Symptoms of injury included overall reduced growth, including reduced height and number of tillers, as well as foliar necrosis at the higher doses. Following the first application in 2011, *Miscanthus sinensis* exhibited injury from the 2× and 4× doses of Triamine II and Tri-Power; and by the 4× dose Triplet Low Odor, but no injury was observed from the 1× dose of these herbicides. Following the 2nd application, all herbicides caused significant injury at the 2× and 4× doses. Additionally, at 6 WAT, the 1× dose of each herbicide was injurious and the severity of injury increased with increasing herbicide dose (Table 2).

The number of inflorescence stalks and above-ground fresh weights were reduced by all herbicide treatments (Table 3). In 2010, there were no differences among herbicides or doses in inflorescence number, foliage fresh weight or total fresh weight. Plants treated with the 1× dose of Triamine II, Tri-Power and Triplet Low Odor averaged 2, 1, and 4 inflorescence stalks per plant, respectively, whereas non-treated plants averaged 8 stalks per plant. Slight differences in plant responses to herbicides were observed for inflorescence numbers and inflorescence fresh weights in 2011. In 2011, inflorescence stalk numbers and inflorescence fresh weights declined with increasing herbicide doses (Table 3). However, foliage fresh weight was not reduced by auxinic herbicide treatments. These data suggest that auxinic herbicides have

Table 2. Percent injury to container-grown *Miscanthus sinensis* from postemergence auxinic herbicides.

		Percent injury[z]					
		1 WAT[x]		2 WAT		6 WAT	
Herbicide	Dose[y]	2010	2011	2010	2011	2010	2011
		After 1st treatment					
Non-treated	n/a	0	0c	0b	0e	0a	0d
Triamine II	1×	0	3bc	0b	0e	0a	3cd
	2×	0	10bc	0b	13bcd	5a	25a
	4×	0	15ab	0b	15bc	15a	23ab
Tri-Power	1×	0	5bc	8a	5de	8a	10cd
	2×	0	13ab	3ab	8cde	13a	25a
	4×	0	23a	3ab	25a	13a	30a
Triplet Low Odor	1×	0	10bc	0b	5de	5a	13bc
	2×	0	10bc	0b	8cde	15a	10cd
	4×	0	13ab	3ab	20ab	15a	23ab
		After 2nd treatment					
Non-treated	n/a	0d	0f	0d	0d	5b	0d
Triamine II	1×	8cd	3ef	8cd	10cd	8ab	13c
	2×	10bcd	18bcd	18bc	25ab	18ab	20bc
	4×	25ab	23abc	18bc	28ab	18ab	33ab
Tri-Power	1×	20abc	10def	18bc	18bc	18ab	23bc
	2×	10bcd	18bcd	20abc	25ab	10ab	33ab
	4×	33a	28ab	33a	28ab	20a	38a
Triplet Low Odor	1×	10bcd	10def	8cd	10cd	10ab	18c
	2×	8cd	13cde	20abc	20bc	13ab	20bc
	4×	18abc	30a	25ab	38a	15ab	38a

[z]Injury was visually evaluated using a percent scale, where 0 = no visible injury (equivalent to non-treated plants) and 100 = dead.

[y]Dose are listed as multiples of the labeled dose. See Table 1 for specific doses of each product and component active ingredients.

[x]WAT = weeks after treatment. Numbers within columns for each rating date followed by the same letter are not significantly different at $P \leq 0.05$ based on a Fisher's protected least significant difference means separation procedure.

Table 3. **Effects of auxinic herbicide applications on numbers of inflorescence stalks per plant, and fresh weights of foliage, inflorescence stalks and total above-ground fresh weight of container-grown *Miscanthus sinensis*.**

		Inflorescence stalks (number per plant)		Fresh weight (g)					
				2010			2011		
Herbicide	**Dose**	**2010**	**2011**	**Foliage**	**Inflorescence**	**Total**	**Foliage**	**Inflorescence**	**Total**
Non-treated	n/a	8a[y]	15a	21a	11a	32a	45e	156a	201a
Triamine II	1×	2bc	11b	20a	2bc	22b	65abc	99b	164ab
	2×	3bc	6cd	14ab	4bc	18bc	72a	43cde	115c–f
	4×	1c	3de	13ab	1c	14c	61bc	23e	84ef
Tri-Power	1×	1bc	6c	12b	2bc	14c	68ab	57b–e	125b–e
	2×	3bc	4cde	14ab	4bc	18bc	56cde	33de	88def
	4×	1c	3e	13ab	1c	14c	61bc	20e	80f
Triplet Low Odor	1×	4b	11b	18ab	6b	24b	57bcd	78bc	135bc
	2×	2bc	9b	15ab	3bc	18bc	58bcd	74bcd	132bcd
	4×	2bc	5cde	12b	2bc	14c	48de	38cde	86ef
ANOVA[x]									
Herbicide		NS	<0.01	NS	NS	NS	NS	0.05	NS
Dose		NS	<0.01	NS	NS	<0.01	NS	<0.01	<0.01
Herbicide × Dose		NS	NS	NS	NS	NS	NS	NS	NS

[z]Inflorescence stalks were counted then above-ground fresh weights of foliage and inflorescence stalks were measured 8 to 9 weeks after second application of herbicides. Means are rounded to nearest whole number.

[y]Numbers within columns followed by the same letter are not significantly different at $P \leq 0.05$ based on a least significant difference means separation procedure.

[x]Data for the non-treated plants were omitted from the analysis of variance for main effects and interaction.

a greater impact on *Miscanthus sinensis* inflorescence development than on vegetative growth. These results are similar to those reported by Everman et al. (2011), who observed no injury to *Miscanthus sinensis* foliage following single applications of dicamba at the labeled dose. However, in those experiments, flowering was not measured and dicamba was applied alone. Possible explanations of different results between Everman et al. (2011) and the present study may include that *Miscanthus sinensis* could differ in tolerance to various auxinic herbicides, that combinations of herbicides tested in the present study may be more injurious than dicamba applied alone, or that herbicide applications when plants are not flowering may be less injurious.

Muhlenbergia capillaris. In the 2010 experiment, *Muhlenbergia capillaris* exhibited no injury from 1× doses of Triamine II and Triplet Low Odor, and no injury from the 1× dose of Tri-Power on four of six rating dates (Table 4). Injury symptoms included downward bending of foliage, overall reduction in growth and reduction in the number of flower stalks. In contrast, significant injury was observed from the 1× dose for each herbicide on at least four evaluation dates in 2011. Severity of injury increased with increasing herbicide dose. In 2010 each herbicide caused significant injury at the 2× dose on one to two rating dates, and the 4× doses resulted in significant injury on four to five rating dates. In 2011, significant injury was observed on at least five of six rating dates from both the 2× and 4× doses of each herbicide.

Total plant biomass and number of inflorescence stalks of *Muhlenbergia capillaris* were reduced by all treatments, with the percent reduction increasing with dose (Table 5). There were significant differences among herbicides in both years (Table 5). Yet, the statistical differences among herbicides would be of little practical significance as all products caused significant injury, and severity of injury increased with increasing dose.

Container-grown *Miscanthus sinensis* and *Muhlenbergia capillaris* were not tolerant of postemergence, broadcast applications of the auxinic herbicide combinations tested. Herbicide treatments caused reductions in plant quality, above-ground fresh weights and inflorescence numbers. Both species exhibited greater injury and greater reductions in fresh weight and flower numbers in 2011 than in 2010. One possible reason for the differences could be that the 2011 experiment was initiated earlier in the summer, resulting in greater growth (as measured by above-ground fresh weight) and much greater numbers of flower stalks than in 2010. With greater biomass production, the differences between non-treated plants and plants stunted by auxinic herbicide applications would be more pronounced. Research by Everman (2011) and by Tallarico and Voigt (2004) suggests that other auxinic herbicides, specifically clopyralid and dicamba, and/or treatments at times of the year when plants are not initiating flowers may have greater potential for weed control in ornamental grass production and maintenance than the herbicide combinations and treatments evaluated in these experiments.

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Table 4. Percent injury to container-grown *Muhlenbergia capillaris* from postemergence auxinic herbicides.

		Percent injury[z]					
		1 WAT[x]		2 WAT		6 WAT	
Herbicide	Dose[y]	2010	2011	2010	2011	2010	2011
		After 1[st] treatment					
Non-treated	n/a	0	0c	0c	0f	0d	0f
Triamine II	1×	0	3c	0c	18e	8bcd	15d
	2×	0	10bc	3c	25de	8bcd	28cd
	4×	0	18ab	15a	45b	20a	43bc
Tri-Power	1×	0	8bc	5c	23de	10bc	15d
	2×	0	8bc	3c	40bc	8bcd	35c
	4×	0	20ab	13ab	58a	23a	58b
Triplet Low Odor	1×	0	13abc	0c	30cd	3cd	30cd
	2×	0	18ab	0c	43b	3cd	55b
	4×	0	25a	15a	58a	15ab	78a
		After 2[nd] treatment					
Non-treated	n/a	0d	0e	0f	0g	0d	0g
Triamine II	1×	5cd	18d	0f	18f	3cd	10efg
	2×	13bcd	25d	10b–e	18f	18bc	20cde
	4×	13bcd	43bc	18b	45bcd	28ab	30bc
Tri-Power	1×	20ab	18d	3ef	23ef	15bcd	15def
	2×	18bc	28cd	15bc	38cd	10cd	25cd
	4×	33a	45b	28a	58ab	38a	38b
Triplet Low Odor	1×	5cd	33bcd	5def	33de	10cd	8fg
	2×	20ab	48b	8c–f	48bc	10cd	25cd
	4×	18bc	73a	13bcd	70a	15bcd	63a

[z]Injury was visually evaluated using a percent scale, where 0 = no visible injury (equivalent to non-treated plants) and 100 = dead.

[y]Dose are listed as multiples of the labeled dose. See Table 1 for specific doses of each product and component active ingredients.

[x]WAT = weeks after treatment. Numbers within columns for each rating date followed by the same letter are not significantly different at P ≤ 0.05 based on a least significant differences means separation procedure.

Table 5. Effects of auxinic herbicide applications on number of inflorescence stalks and total above-ground fresh weights of container-grown *Muhlenbergia capillaris*.

		Inflorescence number		Above-ground fresh weight (g per plant)	
Herbicide	Dose (L·ha^{-1})	2010	2011	2010	2011
Non-treated	n/a	32a[y]	66a	58a	261a
Triamine II	3.5	25bc	51bc	47bc	187b
	7	20d	51bc	36de	147cd
	14	13ef	45cd	28fg	115de
Tri-Power	3.5	21d	52bc	36de	152bcd
	7	15e	46cd	31ef	119de
	14	11f	36d	24g	90ef
Triplet Low Odor	2.9	27b	59ab	51ab	172bc
	5.8	22cd	49bc	40cd	123de
	11.7	15e	21e	29efg	53f
ANOVA[x]					
Herbicide		< 0.01	<0.05	<0.01	<0.02
Dose		< 0.01	< 0.01	< 0.01	< 0.01
Herbicide × Dose		NS	<0.01	NS	<0.01

[z]Inflorescence stalks were counted then total above-ground fresh weights were measured 8 or 9 weeks after second herbicide application.

[y]Numbers within columns followed by the same letter are not significantly different at P ≤ 0.05 based on a least significant difference means separation procedure.

[x]Data for the non-treated plants were omitted from the analysis of variance for main effects and interactions.

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