Ornamental Grass Tolerance to Postemergence Grass Herbicides

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Abstract. Twelve ornamental grasses from the genera *Calamagrostis*, *Cortaderia*, *Eragrostis*, *Erianthus*, *Miscanthus*, *Sorghastrum*, *Spartina*, *Panicum*, and *Pennisetum* were evaluated for tolerance to the postemergence herbicides fenoxaprop-ethyl, fluzafop-P, and sethoxydim at 0.4 kg a.i./ha. *Calamagrostis* was uninjured by fenoxaprop-ethyl as measured by visual injury ratings, height, and foliage dry weight. Greenhouse studies evaluated the tolerance of three *Calamagrostis* cultivars to fenoxaprop-ethyl rates of 0.4 to 3.2 kg a.i./ha with no observed visual injury from any treatment. However, the expansion rate of the youngest *Calamagrostis* leaf was reduced linearly with increasing herbicide rates each day after application. The highest rate (3.2 kg a.i./ha) reduced the leaf expansion rate by 1 day and all other rates by 3 days after treatment. Leaf expansion rate differed between *Calamagrostis* cultivars at different times after herbicide treatment. Dry weight of *Calamagrostis arundinacea* 'Karl Foerster' was reduced at 4 weeks after treatment but not at 10 weeks after treatment. Chemical names used: (±)-ethyl 2-[4-[(6-chloro-2-benzoxazolyl)oxy]phenoxy]propanoate (fenoxaprop-ethyl); (R)-2-[4-[[5-trifluoromethyl]-2-pyridinyl]oxy]phenoxy]propanoic acid (fluzafop-P); 2-[1-(ethoxy imino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one (sethoxydim).

Ornamental grasses have increased in popularity because of their great versatility and low maintenance requirements. Annual and perennial grass weeds and encroachment of turfgrass species, such as bermudagrass [*Cynodon dactylon* (L.) Pers.], are major problems in landscape establishment and commercial production of ornamental grasses. Little information is available about ornamental grass tolerance to herbicides and this information relates only to preemergence herbicides (Glaze et al., 1980; Neal and Senesac, 1991).

Cyclohexanedione (sethoxydim) and two aryl-oxy-phenoxy propionic acids (fenoxaprop-ethyl and fluzafop-P) are post-emergence herbicides for control of annual and perennial grasses. Fenoxaprop-ethyl, fluzafop-P, and sethoxydim consistently control the annual weeds crabgrass (*Digitaria* spp.) and goosegrass [*Eleusine indica* (L.) Gaertn.] (Baron and Monaco, 1985; Chernicky et al., 1984; Lewis, 1985). Turfgrass species demonstrate a differential tolerance to fenoxaprop-ethyl and sethoxydim. Tall fescue (*Festuca arundinacea* Schreb.), bentgrass (*Agrostis palustris* Huds.), and bermudagrass are tolerant to fenoxaprop-ethyl (Higgins et al., 1987; McCarty et al., 1989),

and fenoxaprop-ethyl is labeled for grass weed control in bluegrasses (*Poa* spp.), fescues (*Festuca* spp.), perennial ryegrass (*Lolium perenne* L.), and zoysiagrass (*Zoysia* spp.). Sethoxydim is not phytotoxic to centipedegrass [*Eremochloa ophiuroides* (Munro) Hack.] (McCarty et al., 1986) and is labeled for use in established and seedling turfgrass. In St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Kuntze], bahiagrass (*Paspalum notatum* var. *saurae* Parodi), and centipedegrass, reduction in foliar dry weight correlated with susceptibility to sethoxydim and fluzafop-P (Willard et al., 1990). Differential tolerance to these herbicides also may exist for ornamental grass species. Sethoxydim, fenoxaprop-ethyl, and fluzafop-P are labeled for control of weedy grasses in many ornamental trees, shrubs, and herbaceous plants and would, therefore, be useful for grass control in ornamental grass plantings if tolerance could be determined. The objective of this research was to evaluate the tolerance of diverse ornamental grass species to single applications of post-emergence grass herbicides.

Twelve ornamental grasses (Table 1) were propagated by division and field-planted in May 1989 on an amended Cecil series (clayey, kaolinitic, thermic Typic Hapludults) at the Clemson Botanical Gardens, Clemson, S.C. Each plot consisted of 12 individual plants in a randomized complete block design with three replications. The site was fertilized with 1220 kg-ha⁻¹ 5N-4P-5K before planting and plants were drip-irrigated daily. Herbicide treatments were fenoxaprop-ethyl (F-E), fluzafop-P (F-P), and sethoxydim (SETH) at 0.4 kg a.i./ha and an untreated control

(CONT). F-E and F-P spray mixtures contained 0.5% (v/v) Triton Ag-98 (alkylaryl polyoxyethylene glycols; Rohm and Haas, Philadelphia) and SETH treatments 1.25% (v/v) Dash (BASF Wyandotte Corp., Parsippany, N.J.). Treatments were applied across the top of grasses 5 weeks after planting using a CO₂ backpack sprayer delivering 190 liters-ha⁻¹. At this time, newly expanded leaves were visible and grass height varied between 35 and 95 cm (Table 1). Visual injury ratings (percent) and height measurements were made at weekly intervals, and foliage was harvested 10 weeks after treatment (WAT) and fresh weights recorded. Visual injury was estimated on a percentage scale of 0 to 100% with 0 = no injury and 100% = complete kill. Foliage was dried for 7 days at 65°C and dry weights per plant were recorded. All data were subjected to analysis of variance and means separated using least significant differences at *P* = 0.05.

Calamagrostis arundinacea 'Karl Foerster' was determined to be tolerant to F-E at 0.4 kg a.i./ha in the field study; therefore, a rate study was initiated to determine the response of *Calamagrostis* to increasing rates of F-E. Three ornamental *Calamagrostis* cultivars, *Calamagrostis arundinacea* (L.) Roth 'Karl Foerster', *Calamagrostis arundinacea* ssp. *brachytricha* (Steud.) Tzvel., and *Calamagrostis ×acutiflora* (Schrad.) Reichenb. 'Stricta', were propagated by division and potted in 3.6-liter containers in commercial potting media (Fafard Co., Anderson, S.C.). Plants were fertilized with 473N-206P-392K ppm in the irrigation water for 2 weeks before treatment and irrigated as needed after treatment. Plants were grown in a glasshouse under natural daylength supplying up to 1400 μmol-m⁻²·s⁻¹ photosynthetic photon flux at plant level. F-E rates of 0, 0.4, 0.8, 1.6, and 3.2 kg a.i./ha containing 0.5% Triton Ag-98 (v/v) were applied by use of a CO₂ backpack sprayer that delivered 190 liters-ha⁻¹. A randomized complete block design with four single-plant replications was used and the experiment was repeated. Experiment 1 was initiated in Nov. 1989 and Expt. 2 in Jan. 1990. Length of the youngest expanding leaf at time of herbicide application was measured before treatment and at daily intervals for 5 days. Two leaves per plant were measured and growth rate for the first 5 days after treatment (DAT) calculated. Foliage was harvested 10 weeks (Expt. 1) and 4 weeks (Expt. 2) after treatment, dried for 7 days at 65°C, and dry weights per pot recorded. Visual evaluations of percent injury were made throughout the course of the experiments. All data were subjected to analysis of variance; since differences for the experiments were similar, data were combined. Growth rate response to herbicide rate and DAT was determined using linear regression analysis for overall trends and the least significant difference test for specific mean comparisons.

Most ornamental grasses exhibited maximum injury 4 weeks after herbicide treat-

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Table 1. Taxonomic and common names and height at time of treatment of ornamental grasses in field studies.

Taxonomic name	Common name	Ht (cm $\pm$ SE) ²
<i>Calamagrostis arundinacea</i> (L.) Roth cv. Karl Foerster	Karl Foerster's Feather Reed Grass	50 $\pm$ 3
<i>Cortaderia selloana</i> (Schult.) Asch & Graebn.	Pampas Grass	35 $\pm$ 4
<i>Eragrostis curvula</i> (Schrad.) Nees	Weeping Love Grass	50 $\pm$ 3
<i>Erianthus ravennae</i> (L.) Beauv.	Ravenna Grass	95 $\pm$ 5
<i>Miscanthus sinensis</i> Anderss.		
Gracillimus	Maiden Grass	85 $\pm$ 3
Purpurascens	Purple Leaved Miscanthus	50 $\pm$ 3
Variegatus	Variegated Silver Grass	40 $\pm$ 3
<i>Panicum virgatum</i> L. cv. Haense Herms	Red Switch Grass	70 $\pm$ 2
<i>Pennisetum alopecuroides</i> (L.) Spreng.	Fountain Grass	60 $\pm$ 2
<i>Pennisetum setaceum</i> (Forsk.) Chiov. cv. Rubrum	Crimson Fountain Grass	50 $\pm$ 2
<i>Sorghastrum nutans</i> (L.) Nash	Indian Grass	65 $\pm$ 3
<i>Spartina pectinata</i> Link cv. Aureomarginata	Variegated Cord Grass	80 $\pm$ 3

Table 2. Visible injury (percent) and height (in centimeters) of ornamental grasses 4 weeks after herbicide treatment at 0.4 kg a.i./ha and visible injury and foliage dry weight 10 weeks after treatment.

Grass cultivar	Herbicide ^a									
	F-E	F-P	SETH	CONT	LSD	F-E	F-P	SETH	CONT	LSD
	Injury (%) 4 weeks after treatment ^b					Ht (cm) 4 weeks after treatment				
<i>Calamagrostis arundinacea</i> cv. Karl Foerster	0	35	45	0	13	58	53	57	55	15
<i>Cortaderia selloana</i>	93	37	15	0	25	43	48	50	75	15
<i>Eragrostis curvula</i>	98	80	42	0	34	63	57	53	107	22
<i>Erianthus ravennae</i>	68	77	70	0	12	86	63	78	160	21
<i>Miscanthus sinensis</i>										
Gracillimus	38	55	52	0	7	82	83	77	122	15
Purpurascens	28	45	38	0	9	48	52	50	60	11
Variegatus	38	47	52	0	11	37	38	33	72	30
<i>Panicum virgatum</i>	35	50	43	0	10	77	58	68	137	14
<i>Pennisetum alopecuroides</i>	42	47	35	0	10	65	63	62	98	25
<i>Pennisetum setaceum</i>	92	75	62	0	9	42	47	42	110	14
<i>Sorghastrum nutans</i>	18	17	18	0	7	82	75	75	143	23
<i>Spartina pectinata</i>	20	48	47	0	19	75	78	80	128	21
	Injury (%) 10 weeks after treatment					Foliar dry wt (g) 10 weeks after treatment				
<i>Calamagrostis arundinacea</i> cv. Karl Foerster	0	53	87	0	21	27	13	11	33	16
<i>Cortaderia selloana</i>	88	7	5	0	16	1	8	8	28	9
<i>Eragrostis curvula</i>	98	87	28	0	43	26	48	82	172	56
<i>Erianthus ravennae</i>	73	98	90	0	25	82	52	68	595	290
<i>Miscanthus sinensis</i>										
Gracillimus	12	48	20	0	7	125	40	71	202	64
Purpurascens	20	52	33	0	11	42	24	21	32	33
Variegatus	13	63	25	0	7	29	7	11	61	60
<i>Panicum virgatum</i>	10	58	30	0	17	197	44	83	269	62
<i>Pennisetum alopecuroides</i>	10	57	10	0	11	145	55	98	167	76
<i>Pennisetum setaceum</i>	97	92	15	0	11	18	30	79	385	121
<i>Sorghastrum nutans</i>	7	5	7	0	4	270	231	157	303	208
<i>Spartina pectinata</i>	7	85	43	0	7	96	29	35	121	85

^aF-E = fenoxaprop-ethyl, F-P = fluazifop-P, SETH = sethoxydim, CONT = nontreated control; LSD at $P = 0.05$.

^bVisible injury was rated on a scale of 0 to 100%, with 0 = no injury and 100% = complete kill.

ment (Table 2). Injury symptoms consisted of chlorosis and necrosis of young foliage that spread to older parts of the plant; necrosis of shoot meristems; red pigmentation of foliage in some species, such as *Panicum virgatum*; and cessation of growth. No visual injury was observed for F-E on *Calamagrostis arundinacea* and only minimal injury was noted for SETH on *Cortaderia selloana*. Height reduction 28 DAT was observed for all treated grasses except for F-P and SETH on *Miscanthus sinensis* 'Purpurascens' and all herbicides on *Calamagrostis arundinacea*. Immediately before harvest, 10 weeks after treatment, significant injury was still evident on the majority of grasses, although only minimal injury was observed from SETH on *Eragrostis curvula*, F-E on *P. virgatum* and *Spartina pectinata*, SETH and F-E on *Pennisetum alopecuroides*, and SETH and F-P on *Cortaderia selloana*. Only minimal

injury was observed from all herbicides on *Sorghastrum nutans* and no injury resulted from F-E treatment on *Calamagrostis arundinacea*.

Treated and nontreated *M. sinensis* 'Purpurascens', *M. sinensis* 'Variegates', and *S. nutans* had similar foliage dry weights. Foliage dry weights of *Calamagrostis arundinacea*, *P. alopecuroides*, and *S. pectinata* at 10 weeks were reduced only following F-P and SETH treatments. Herbicide treatments caused reduced dry weights of all other species compared to the controls.

Calamagrostis arundinacea showed no injury symptoms following F-E application and did not differ from nontreated plants in height or dry weight. These data indicate that *Calamagrostis arundinacea* is tolerant to F-E at the rate tested. All other grasses evaluated were either visibly injured or growth was reduced by the herbicides. Researchers

have reported injury, height reduction, and dry weight reduction as a result of post-emergence grass herbicide treatment of other grass species (Willard et al., 1990). Tolerance of several turfgrass species to post-emergence grass herbicides has also been reported, with tall fescue, bentgrass, and bermudagrass being tolerant to F-E (Higgins et al., 1987; McCarty et al., 1989) and centipedegrass being tolerant to SETH (McCarty et al., 1986).

In the greenhouse study, no injury was observed on any of the *Calamagrostis* cultivars at any rate of F-E, indicating that these species are highly tolerant to F-E. The highest herbicide rate represents nearly 10 times the normal use rate of F-E, indicating at least a 10-fold tolerance of *Calamagrostis* cultivars. The growth rate of the youngest leaf was analyzed by regression over days after treatment with no significant linear response

Table 3. Expansion rate of the youngest leaf of *Calamagrostis* (combined data from *Calamagrostis arundinacea* 'Karl Foerster', *C. ×acutiflora* 'Stricta', and *C. arundinacea* spp. *brachytricha*) for the first 5 days after treatment with fenoxaprop-ethyl.

Rate (kg a.i./ha)	Expansion rate (mm·day ⁻¹)				
	Day after treatment ²				
	1	2	3	4	5
0	30.1	25.5	30.9	25.8	27.5
0.4	27.7	23.8	24.1	17.8	22.5
0.8	28.0	23.7	25.4	18.5	22.8
1.6	27.7	23.1	23.8	17.4	19.4
3.2	26.0	22.6	24.9	17.4	19.7
Response ³	L	L	L	L	L
LSD (P = 0.05)	3.4	2.6	3.7	3.6	3.9

²There was not significant response to time after treatment.

³Linear (L) response.

for any species. Analysis of variance for the growth rate of the youngest leaf revealed no treatment x grass interaction, so data for all three cultivars were combined for each treatment (Table 3) and for all herbicide treatments (excluding the nontreated control) for each grass (Table 4). Growth rate of the youngest leaf of *Calamagrostis* was reduced linearly by increasing rates each day after application. The highest rate (3.2 kg a.i./ha) of F-E reduced the growth by 1 and 2 DAT, while all rates restricted the growth rate compared to the nontreated on subsequent days (Table 3).

Analysis of variance for the daily expansion rate of the nontreated grass cultivars showed no significant differences between cultivars (data not shown). Therefore, differences in daily expansion rate can be attributed to differing sensitivity of *Calamagrostis* cultivars to F-E. 'Stricta' had the highest growth rate for each day after herbicide treatment, with the exception of 4 DAT (Table 4), and 'Karl Foerster' had the lowest growth rate each day after treatment. *Brachytricha* had an intermediate growth rate response, except for 4 DAT when it had the highest growth rate.

No reduction in foliage dry weight was observed for 'Stricta' and *brachytricha* at 4 or 10 WAT (data not shown). However, all rates of F-E reduced the dry weight of 'Karl Foerster' at 4 WAT, but the reduction was nonlinear (Table 5). It is possible that 'Karl

Table 4. Expansion rate of the youngest leaf of *Calamagrostis arundinacea* 'Karl Foerster', *C. ×acutiflora* 'Stricta', and *C. arundinacea* spp. *brachytricha* for the first 5 days after treatment with fenoxaprop-ethyl (combined data from application rates of 0.4, 0.8, 1.6, and 3.2 kg a.i./ha).

Species	Expansion rate (mm·day ⁻¹)				
	Day after treatment				
	1	2	3	4	5
<i>C. arundinacea</i>					
cv. Karl Foerster	26.6	22.6	21.1	14.6	18.6
<i>C. ×acutiflora</i>					
cv. Stricta	30.1	25.4	24.7	17.3	23.4
<i>C. arundinacea</i>					
spp. <i>brachytricha</i>	25.3	21.9	27.8	21.5	21.3
LSD (P = 0.05)	2.8	2.3	3.2	3.2	3.3

Foerster' plants were able to recover so that dry weight was not reduced at 10 WAT. Therefore, although all three *Calamagrostis* cultivars appeared visually to be tolerant to F-E, growth of the youngest leaf was inhibited. 'Stricta' appears to be the most tolerant to F-E and 'Karl Foerster' the most sensitive, with *brachytricha* exhibiting intermediate tolerance.

The greenhouse study shows *Calamagrostis* to be tolerant to F-E, at » 10 times the normal use rate. Vegetable plants have been reported to be injured by post-emergence grass herbicides in the greenhouse but not in the field (Boucounis et al., 1988), which may be explained by the positive correlation of absorption of these herbicides with higher relative humidity and temperature in the greenhouse environment (Harrison and Wax, 1986; Kells et al., 1984). Based on the field and greenhouse studies, F-E could be safely used for grass weed control in greenhouse production and outdoor plantings of *Calamagrostis*. Several grasses in the field study recovered from earlier herbicide injury based on dry weight measurements and percent injury evaluations at 10 WAT. Sequential application of post-emergence grass herbicides may be necessary to control grassy weeds that germinate throughout the growing season, thus tolerance of ornamental grasses to sequential herbicide applications needs to be studied.

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Table 5. Foliage dry weights per pot of *Calamagrostis arundinacea* 'Karl Foerster' 4 and 10 weeks after treatment (WAT) with fenoxaprop-ethyl (F-E).

Rates (kg a.i./ha)	Dry wt (g)	
	4 WAT	10 WAT
0	8	12
0.4	5	14
0.8	6	12
1.6	6	13
3.2	6	14
Response ²	NS	NS
LSD (P = 0.05)	1	1

²No linear response (NS).

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