HRI's Mission:

To direct, fund, promote and communicate horticultural research, which increases the quality and value of ornamental plants, improves the productivity and profitability of the nursery and landscape industry, and protects and enhances the environment.

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

Effects of Herbicide and Time of Application on Pampas Grass Grown in Containers[1]

Christine K. Hayes[2], Charles H. Gilliam[3], Gary J. Keever[3], and D. Joseph Eakes[4]
Department of Horticulture, Auburn University, AL 36849

Abstract

Two experiments evaluated the effects of preemergence herbicides on pampas grass [*Cortaderia selloana* (Schult. and Schult. f.) Asch. and Graebn.] growth. Herbicides were applied 1, 15, or 30 days after potting (DAP) from 36-cell packs into 3.8 liter (#1) containers. Ronstar (oxadiazon) applied at the manufacturer's recommended rate caused little or no injury when applied 1 or 15 DAP. Factor 65 WG (prodiamine) applied 1 DAP suppressed root growth compared to control plants; however, when applied 15 or 30 DAP root ratings of Factor treated plants were similar to control plants 60 and 75 DAP. Plant height at 90 DAP was about 10% greater when the herbicide application was delayed 30 DAP, compared to plants treated 1 DAP. In experiment 2, plant height and root ratings were greater when herbicides were applied 30 DAP than when applied 1 DAP. Pendulum 2G (pendimethalin), Pendulum 60 WDG (pendimethalin), and Factor 65 WG (prodiamine) suppressed root growth in the upper 5.1 cm (2 in) and lower 10.2 (4 in) of container medium. Plants treated with Factor 65 WG or Pendulum 60 WDG generally had the highest percent lodging and the most club roots in both experiments; Ronstar was the only herbicide that did not cause lodging or club root formation.

Index words: ornamental grass, weed control, container-grown landscape plants, lodging, oxadiazon, pendimethalin, prodiamine.

Species used in this study: pampas grass [*Cortaderia selloana* (Schult. and Schult. f.) Asch. and Graebn.].

Herbicides used in this study: Factor (prodiamine), 2,4 dinitro-N^3,N^3-dipropyl-6-(trifluoromethyl)-1,3-benzenediamine; Pendulum 2G and Pendulum 60 WDG (pendimethalin), N-(1-ethylpropyl)-3,4 dimethyl-2,6-dinitrobenzenamine; Ronstar (oxadiazon), 3-[2,4-dichloro-5-(1-methylethoxy)phenyl]-5-(1,1-dimethylethyl)-1,3,4-oxadiazol-2-(3*H*)-one.

Significance to the Nursery Industry

In the southern United States, many nursery growers produce pampas grass (*Cortaderia selloana*) as small liners before transplanting into larger containers. Reduced growth and lodging of pampas grass has been observed in nurseries when dinitroaniline herbicides are applied immediately after potting. While some herbicides, including pendimethalin, specifically limit use until plants are well rooted, the time after potting until plants are well rooted is often a time of major weed infestation. Our data indicate Ronstar did not cause lodging or club root formation when applied immediately after potting and caused little to no injury when applied 1 or 15 days after potting. Dinitroaniline herbicides, Pendulum 2G, Pendulum 60 WDG, and Factor 65 WG, applied 1, 15, or 30 days after potting caused lodging and club root formation. Growers should avoid application of these herbicides to newly transplanted pampas grass. While the length of delay is not identified in this study, it appears that pampas grass transplants should be well rooted in the container prior to application of a dinitroaniline herbicide.

Introduction

Pampas grass is an ornamental grass produced widely across the southern United States. Previous studies have reported pampas grass to be tolerant of several preemergence herbicides (5, 7). Herbicides registered for use on pampas grass currently include Corral (formerly Ornamental Weedgrass Control) (pendimethalin) (Scotts Co., Marysville, OH), Ornamental Herbicide II (pendimethalin + oxyfluorfen) (Scotts Co.), Factor 65 WG (prodiamine) (Novartis Crop Protection Inc., Greensboro, NC), Pendulum 60 WDG (pendimethalin) (American Cynamid, Wayne, NJ), and Regal O-O (oxadiazon + oxyfluorfen) (Regal Chemical Co., Marietta, GA). All of these registered herbicides are dinitroaniline (DNA) herbicides or contain a DNA herbicide, except Regal O-O. Two problems that frequently occur with DNA herbicides are root inhibition and lodging (1, 6). The mode of action of DNA herbicides is through root inhibition; however, the relatively low solubilities and high adsorption coefficients of most DNA herbicides reduce movement through the root zone (1). Another problem, lodging, an inelastic displacement of plants from their vertical position, has been observed by pampas grass growers across the southern United States when using DNA herbicides.

In a study by Green et al. (6), preemergent herbicides were applied to pampas grass immediately after transplanting 72 cell pack liners to 3.8 liter (#1) containers. Ornamental Weedgrass Control (pendimethalin), Pendulum 2G (pendimethalin), Pendulum 60 WDG (pendimethalin), Surflan 4AS (oryzalin), Rout (oryzalin + oxyfluorfen), and Factor 65 WG (prodiamine) suppressed root growth in the upper 5.1 cm (2 in) of the container medium. Factor 65 WG and Pendulum 60 WDG caused the highest percent lodging. Derr and Salihu (3) reported Ronstar and Ornamental Herbicide II (oxyfluorfen + pendimethalin) had essentially no adverse effects on shoot or root growth development of Frasier photinia (*Photinia* x *fraseri*), Japanese holly (*Ilex crenata* 'Helleri'), abelia (*Abelia* x *grandiflora* x *A. schumanni* 'Edward Goucher') (*Abelia* x *grandiflora* 'Francis Mason'), or azalea (*Rhododendron obtusum* 'Tradition'). They indicated plant size at treatment may be a factor in the extent of stunting caused by preemergence herbicides Rout (oxyfluorfen + oryzalin), Surflan (oryzalin), Gallery (isoxaben), and Factor (prodiamine), with larger plants being more tolerant. Their data suggested that delaying herbicide application after transplanting, until the plants are larger may reduce the severity

[1]Recieved for publication April 12, 1999; in revised form September 20, 1999.

[2]Graduate Assistant.

[3]Professor.

[4]Associate Professor.

of herbicide injury to sensitive plants. The objective of this study was to determine if the interval between potting and preemergence herbicide application affects subsequent growth of pampas grass.

Materials and Methods

Experiment 1. On June 19, 1996, uniform liners (36-cell packs) of white pampas grass, propagated from seed, were potted in 3.8-liter (#1) containers with a pinebark:sand (6:1 by volume) medium amended per m^3 (yd^3) with 7.4 kg (12.5 lb) 12 month Polyon 24N–1.7P–11.7K (24–4–14) (Pursell Technologies, Sylacauga, AL), 3.0 kg (5 lb) dolomitic lime, and 0.9 kg (1.5 lb) Micromax (Scotts Co.). Herbicides were applied at the following rates in kg ai/ha (lb ai/A): [granular formulations] Ronstar 2G (oxadiazon) (Rhone Poulenc, Research Triangle Park, NC) at 4.5 (4.0), Pendulum 2G (pendimethalin) (American Cyanamid) at 3.4 (3.0), [liquid formulations] Pendulum 60 WDG (pendimethalin) (American Cyanamid) at 3.4 (3.0), and Factor 65 WDG (prodiamine) (Novartis Crop Protection Inc.) at 1.1 (1.0). Granular herbicides were applied using a hand-held shaker, while liquid-applied herbicides were applied using a CO_2 backpack sprayer with a 8004 flat fan nozzle (R&D Sprayers, Opelousas, LA) at 235 kPa (34 psi) in 187 liter/ha (20 gpa). Following potting and prior to herbicide treatment, containers were placed on a container bed in full sun and irrigated about 1.0 cm (0.4 in) of water with overhead impact sprinklers. Thereafter, plants were watered twice daily as needed with about 0.5 cm (0.2 in) applied with each irrigation. Containers were hand-weeded to eliminate weed competition. The experiment was a 4 × 3 factorial consisting of 12 treatments: 4 herbicide treatments and 3 application dates, plus a non-treated control. Herbicides were applied 1, 15, or 30 days after potting (DAP) to separate sets of plants. Treatments were completely randomized and replicated with 8 single plants.

Data were collected at 60, 75, and 90 DAP. Plant height was determined by extending and measuring the longest leaf (including lodged plants). Roots in the upper 5.1 cm (2 in) and lower 10.2 cm (4 in) of the container were rated separately on a scale of 1–5 where 1–5 = 0, 25, 50, 75, and 100% root coverage of the substrate-container interface. Lodged plants were recorded as a (+) or (–). At 90 DAP plants were removed from the pot, the roots washed, and club roots [stubby roots enlarged at the distal end and less than 2.5 cm (1 in) long] were counted. Shoot dry weights were also collected at 90 DAP. Factorial analysis was performed using general linear model (P = 0.05); means were separated using least significant difference (P = 0.05) procedure.

Experiment 2. Experiment 2 was conducted similarly to experiment 1 with a few exceptions. Plants were potted June 25, 1998, in a similar medium except 5.9 kg (10 lb) of 12 month Osmocote 17N–3.1P–10K (17–7–12) (Scotts Co.) was used. Two sets of non-treated control plants were added for a total of 3 sets of control plants, one for each application time, making the experiment a complete 5 × 3 factorial.

Results and Discussion

Experiment 1. Factorial analysis of the data yielded mainly significant interactions between herbicide and application time. Upper and lower root ratings at 60 and 75 DAP of plants treated 1 or 15 DAP with Ronstar, Pendulum 2G, and Pendulum 60 WDG were similar to or greater than non-treated plants (Table 1). Plants treated with Ronstar 30 DAP exhibited a slight decrease in upper and lower root ratings 60 DAP, although plants were similar to non-treated plants. Similarly, shoot dry weight of plants treated with Ronstar 30 DAP was lower than plants treated at 1 or 15 DAP and non-treated plants.

Plants treated with Factor 1 DAP had lower root ratings in the upper and lower zones than control plants at 60 DAP and

Table 1. The influence of 4 preemergence herbicides 60 and 75 days after potting (DAP) on root ratings, shoot dry weight, and club root formation of pampas grass, experiment 1.

Herbicide	Rate kg a.i./ha	Application time 1 DAP	15 DAP	30 DAP
		Upper root rating 60 DAP[z]		
Ronstar 2G	4.5	1.6A[y]	1.5AB	1.2B
Pendulum 2G	3.4	1.4A	1.6A	1.6A
Pendulum 60 WDG	3.4	1.4B	1.3B	2.1A*
Factor 65 WG	1.7	1.0B*[x]	1.2AB	1.6A
Control	—	1.6	1.6	1.6
		Lower root rating 60 DAP		
Ronstar 2G	4.5	2.4A	2.5A	1.2B*
Pendulum 2G	3.4	2.2A	3.1A	2.9A
Pendulum 60 WDG	3.4	2.0A	1.8A*	2.5A
Factor 65 WG	1.7	1.5B*	2.0A*	2.1A
Control	—	2.5	2.5	2.5
		Upper root rating 75 DAP		
Ronstar 2G	4.5	1.6A	1.4A	1.6A
Pendulum 2G	3.4	1.4A	1.5A	1.3A
Pendulum 60 WDG	3.4	2.0A*	1.4B	1.4B
Factor 65 WG	1.7	1.1A	1.2A	1.3A
Control	—	1.4	1.4	1.4b
		Lower root rating 75 DAP		
Ronstar 2G	4.5	3.0A	2.9A	2.0A
Pendulum 2G	3.4	3.1A	3.1A	2.5A
Pendulum 60 WDG	3.4	3.2A	2.5A	3.1A
Factor 65 WG	1.7	1.3B*	2.2A	2.6A
Control	—	2.6	2.6	2.6
		Shoot dry weight (g)[w]		
Ronstar 2G	4.5	44.7A	36.3AB	27.5B*
Pendulum 2G	3.4	45.8A	50.2A	43.2A
Pendulum 60 WDG	3.4	45.3A	47.5A	55.6A
Factor 65 WG	1.7	29.2B*	42.1AB	50.3A
Control	—	45.6	45.6	45.6
		Club roots		
Ronstar 2G	4.5	0.0A	0.0A	0.0A
Pendulum 2G	3.4	7.1A	9.4A*	5.8A*
Pendulum 60 WDG	3.4	8.6B	5.9B*	26.3A*
Factor 65 WG	1.7	22.3A*	20.8A*	13.3A*
Control	—	0.0	0.0	0.0

[z]Roots were rated on a scale of 1–5 where 1 = 0, 2 = 25, 3 = 50, 4 = 75, and 5 = 100% coverage of the substrate-container interface.

[y]Mean separation using LSD (P = 0.05); upper case letters show significance between application times within a herbicide.

[x]Means with asterick are significantly different from the control within an application time, using Dunnett's multiple comparison test (P = 0.05).

[w]Shoot dry weight and club roots per plant were determined at 90 DAP.

Table 2. Height, and upper and lower root rating 90 days after potting (DAP) of pampas grass treated with 4 preemergent herbicides 1, 15, or 30 DAP, experiment 1.

	Rate kg ai/ha	Height (cm)	Root rating[z] Upper 5.1 cm	Root rating[z] Lower 10.2 cm
Application time[y]				
1 DAP		123.5b[x]	1.5a	2.9b
15 DAP		137.3a	1.5a	3.6a
30 DAP		136.0a	1.5a	3.3ab
Herbicide				
Ronstar	4.5	123.5b	1.6a	3.5a
Pendulum 2G	3.4	139.2a	1.5a	3.5a
Pendulum 60 WDG	3.4	131.4ab	1.5a	3.6a
Factor 65 WG	1.7	132.1ab	1.2b	2.5b
Control	—	129.2ab	1.5a	3.3ab

[z]Roots were rated on a scale of 1–5 where 1 = 0, 2 = 25, 3 = 50, 4 = 75, and 5 = 100% coverage of the substrate-container interface.

[y]Herbicide × application time interactions were not significant.

[x]Mean separation using LSD (P = 0.05).

in the lower root zone at 75 DAP. This agrees with work by Green et al. (6) who reported Factor suppressed root development 45, 60, and 75 DAP when applied at potting. Compared to plants treated with Factor 1 DAP, plants treated 30 DAP plants had greater upper and lower root ratings 60 DAP, greater lower root ratings 75 DAP, and higher shoot dry weight (90 DAP).

Only DNA herbicides caused club root formation and they caused club roots regardless of application timing (Table 1). Plants treated with Factor 1 DAP produced greater club roots than non-treated plants, while at 15 and 30 DAP all DNA herbicides caused more club roots than the non-treated plants. Ronstar treated plants had no club roots. These data agree with work by Green et al. (6) and Derr and Salihu (3) who observed stubby aerial roots on Factor or Pendulum treated plants.

At 90 DAP there were no herbicide × application time interactions with height and root ratings therefore, only main effects are presented (Table 2). Plants treated with herbicides 1 DAP were about 10% shorter than plants treated 15 or 30 DAP. Root ratings in the lower 10.2 cm (4 in) of the substrate-container interface of plants treated 1 DAP were lower than plants treated 15 DAP. As observed at 60 and 75 DAP, Factor treated plants had lower root ratings in the upper and lower root sections at 90 DAP than other herbicide treated plants or non-treated plants.

Table 3. Effects of 4 preemergent herbicides applied 1, 15, or 30 days after potting (DAP) on percent of lodged pampas grass plants, experiments 1 and 2.

Herbicide	Rate kg ai/ha	Application time (DAP)	Lodging (%)[z] 45 DAP	60 DAP	75 DAP
			experiment 1		
Ronstar 2G	4.5	1	0.0	0.0	0.0
		15	0.0	0.0	0.0
		30	0.0	0.0	0.0
Pendulum 2G	3.4	1	0.0	0.0	12.5
		15	12.5	12.5	25.0
		30	0.0	0.0	0.0
Pendulum 60 WDG	3.4	1	12.5	12.5	25.0
		15	12.5	12.5	12.5
		30	12.5	12.5	25.0
Factor 65 WG	1.7	1	50.0	50.0	50.0
		15	12.5	12.5	12.5
		30	12.5	50.0	50.0
Control			0.0	0.0	0.0
			experiment 2		
Ronstar 2G	4.5	1	0.0	0.0	0.0
		15	0.0	0.0	0.0
		30	0.0	0.0	0.0
Pendulum 2G	3.4	1	25.0	37.5	37.5
		15	25.0	37.5	37.5
		30	0.0	0.0	0.0
Pendulum 60 WDG	3.4	1	12.5	25.0	37.5
		15	12.5	37.5	50.0
		30	0.0	12.5	75.0
Factor 65 WG	1.7	1	25.0	62.5	62.5
		15	25.0	62.5	62.5
		30	25.0	25.0	37.5
Control	—	1	0.0	0.0	0.0
		15	0.0	0.0	0.0
		30	0.0	0.0	0.0

[z]Percent of plants per treatment which exhibited an inelastic displacement from their vertical position.

Table 4. Height, root ratings, club roots per plant, and shoot dry weight of pampas grass treated with 4 preemergent herbicides at 3 application times 60 and 90 days after potting (DAP), experiment 2.

	Rate kg ai/ha	Height		Root rating[z] Upper 5.1 cm		Lower 10.2 cm		Club roots	Shoot dry wt (g)
		60 DAP	90 DAP	60 DAP	90 DAP	60 DAP	90 DAP		
Application time[y]									
1 DAP	—	85.8b	115.4b	1.3b	2.0b	1.8b	3.1b	18.2a	33.6b
15 DAP	—	89.3ab	120.5ab	1.3b	2.0b	1.9b	3.2b	22.6a	35.1b
30 DAP	—	94.6a	125.1a	1.4a	2.8a	2.3a	3.8a	21.3a	41.0a
Herbicide									
Ronstar 2G	4.5	90.3a	131.5a[x]	1.4a	2.8a	2.0b	4.1a	0.4c	38.2a
Pendulum 2G	3.4	91.8a	121.5bc	1.4a	2.2b	2.0b	3.6b	17.3b	37.9a
Pendulum 60 WDG	3.4	89.4a	114.3cd	1.3b	1.9b	1.9b	3.0c	40.5a	36.6ab
Factor 65 WG	1.7	81.1b	107.9d	1.3b	1.3c	1.7c	2.1d	45.1a	30.0b
Control	—	97.2a	127.0ab	1.4a	3.2a	2.3a	4.2a	0.2c	40.3a

[z]Roots were rated on a scale of 1–5 where 1 = 0, 2 = 25, 3 = 50, 4 = 75, and 5 = 100% coverage of the substrate-container interface.

[y]Herbicide × application time interaction not significant, data presented by main effects.

[x]Mean separation using LSD (P = 0.05).

Lodging followed a similar trend as club root formation. The authors observed short stubby aerial support roots on lodged plants. Ronstar, the only non-DNA herbicide in this study, did not cause lodging at any application time (Table 3). All DNA herbicides, except for Pendulum 2G applied 30 DAP, caused some lodging at every application time. With the exception of Pendulum 2G treated plants, delayed application did not decrease lodging. The highest percent lodging (50%) occurred when Factor was applied 1 or 30 DAP. Green et al. (6) also reported the highest percent lodging with Factor and Pendulum 60 WDG while Ronstar did not cause lodging when applied to pampas grass at potting.

Experiment 2. There were no herbicide × application time interactions, therefore only main effects are presented (Table 4). Plants treated with Ronstar or Pendulum 2G, both granular herbicides, had similar heights to control plants 60 and 90 DAP. Pendulum 60 WDG reduced pampas grass height at 90 DAP; while Factor 65 WG reduced grass height at 60 and 90 DAP. These results concur with work by Derr and Salihu (3) who reported Factor decreased shoot growth of azalea by 25% compared to that of untreated plants. Time of herbicide application was significant 60 and 90 DAP with respect to height, root ratings and shoot fresh weights. Plant growth was greatest when herbicide application was delayed until 30 DAP.

All plants to which DNA herbicides were applied had lower root ratings in the upper 5.1 cm (2 in) and lower 10.2 cm (4 in) of the container-medium interface compared to non-treated plants 90 DAP, regardless of when the herbicides were applied. Pendulum 60 WDG and Factor-treated plants also had lower root ratings compared to control plants in the upper and lower root zones at 60 DAP. Our data concur with work by Davies and Duray (2) which demonstrated that pendimethalin and prodiamine reduced root number in hibiscus, and oxyfluorfen + pendimethalin reduced percent rooting in Burford holly (*Ilex cornuta* 'Burfordii'). Plants treated with Ronstar, the only non-DNA herbicide used, had similar root ratings to the non-treated control plants 90 DAP concurring with several studies (2, 4, 5, 6, 9) that reported no negative effects from Ronstar on root development in several woody nursery crops. These data were in contrast with data from experiment 1 in which plants treated with Ronstar 30 DAP had a lower root rating 75 DAP and lower shoot dry weight than control plants; the authors are not sure why this discrepancy occurred. Delay in herbicide application also affected upper and lower root ratings. When herbicides were applied 30 DAP, root ratings in the upper 5.1 cm (2 in) and lower 10.2 cm (4 in) of the container-medium interface, and shoot dry weights were higher 90 DAP than in plants where herbicides were applied 1 or 15 DAP.

Data regarding club root formation and lodging were consistent with the previous experiment. All DNA herbicide treated plants, regardless of when the herbicides were applied, produced club roots. Ronstar was the only herbicide which did not cause club roots (Table 4). Plants treated with Factor or Pendulum 60 WDG, both spray applied herbicides, had more club roots than plants treated with the granular formulation of Pendulum. Factor-treated plants had lower shoot dry weights than plants treated with either granular formulation or non-treated plants. Plants that were treated 30 DAP had more shoot dry weight than plants treated 1 or 15 DAP.

In conclusion, height and root ratings were greater when herbicide application was delayed until 30 DAP. Delayed herbicide application did not decrease lodging or club root formation in DNA herbicide-treated plants. Ronstar applied at potting caused little or no injury in either experiment. Pendulum 2G applied 30 DAP did not cause lodging in either experiment and had similar root ratings and shoot dry weights as control plants in experiment 1. Factor and Pendulum 60 WDG caused lodging and club root formation, regardless of when the herbicides were applied and should not be applied to pampas grass 1, 15, or 30 days after potting up from liners.

Literature Cited

1. Ashton, F.M. and A.S. Crafts. 1981. Dinitroanilines pp. 201–223. *In*: Mode of Action of Herbicides. John Wiley & Sons, Inc., New York.

2. Davies, F.T., Jr. and S.A. Duray. 1992. Effect of preemergent herbicide application on rooting and subsequent liner growth of selected nursery crops. J. Environ. Hort. 10:181–186.

3. Derr, J.F. and S. Salihu. 1996. Preemergence herbicide effects on nursery crop root and shoot growth. J. Environ. Hort. 14:210–213.

4. Gilliam, C.H., D.J. Eakes, and J.W. Olive. 1993. Herbicide use during propagation affects root initiation and development. J. Environ. Hort. 11:157–159.

5. Glaze, N.C., M. Singh, and S.C. Phatak. 1980. Response of pampas grass and two azalea cultivars to alachlor, oxadiazon, and oxyfluorfen. Proc. Weed Sci. Soc. Amer. 229:32.

6. Green, J.C., G.J. Keever, C.H. Gilliam, C.K. Palmer, J.W. Olive, and D.J. Eakes. 1997. Effects of preemergence-applied herbicides on pampas grass grown in containers. J. Environ. Hort. 15:77–80.

7. Neal, J.C. and A.F. Senesac. 1991. Preemergent herbicide safety in container-grown ornamental grasses. HortScience 26:157–159.

8. Stamps, R.H. and C.A. Neal. 1990. Evaluation of dinitroaniline herbicides for weed control in container landscape plant production. J. Environ. Hort. 8:52–57.

9. Thetford, M. and C.H. Gilliam.1991. Herbicide use in propagation: effects on rooting and root growth of stem cuttings. J. Environ. Hort. 9:21–23.