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Grass Control in Container-grown Ornamentals with Pre- and Postemergence Herbicide Combinations

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Abstract. **Control of large crabgrass [*Digitaria sanguinalis* (L.) Scop.] and goosegrass [*Eleusine indica* (L.) Gaertn.] was evaluated with the preemergence herbicides oryzalin (Surflan), oxyfluorfen (Goal), and metolachlor (Dual) and the postemergence herbicides quizalofop (Assure), fenoxaprop-ethyl (Whip), haloxyfop (Verdict), poppenate-methyl (Trophy), fluazifop-P (Fusilade 2000), and sethoxydim (Poast) when applied alone or in combination. Oryzalin combinations provided maximum preemergence control compared to oxyfluorfen or metolachlor combinations. Greatest preemergence and postemergence control was obtained with oryzalin or metolachlor applied with poppenate-methyl. Antagonism of preemergence or postemergence control occurred with several combinations of preemergence and postemergence herbicides. In some instances, control was enhanced by using other herbicide combinations. Chemical names used: 4-(dipropylamino)-3,5-dinitrobenzenesulfonamide (oryzalin); 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene (oxyfluorfen); 2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl) acetamide (metolachlor); ½(±)-2-[4-[(6-chloro-2-quinoxyalinyl)oxy]phenoxy]propanoic acid¼ (quizalofop); (±)-ethyl 2-[4-[(6-chloro-2-benzoxazolyl)oxy]phenoxy]propanoate (fenoxaprop-ethyl); 2-[4-[[3-chloro-5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid (haloxyfop); methyl 3-hydroxy-4-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]-pentanoate (poppenate-methyl); (*R*)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid (fluazifop-P); and 2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one (sethoxydim).**

Weeds compete with ornamentals for nutrients, water, space, and light, resulting in slower growth and poor-quality plants, which causes 47% to 75% loss depending on weed species and densities (Fretz, 1973). This reduction in crop growth may result in a 1-year delay to produce a marketable plant (Davison, 1970). Weeds also reduce aesthetic quality. Mechanical weed control is impractical, and manual weeding is expensive and laborious (Fretz, 1972); thus resulting in lower profit potential for the grower (Singh et al., 1984). Lamont et al. (1985) estimated that labor costs for manual weeding in Australia can exceed $10,000 (Australian)/ha, depending on severity of the weed infestation. As in many horticultural situations where high moisture and nutrition levels are maintained, a herbicide treatment giving incomplete weed control in containers may permit rapid and vigorous growth of surviving weed species. Soil-active herbicides often have a shorter residual effect in container substrates than in field conditions. This is due to the high adsorptive capacity of the substrate media and the larger amounts of water required by contained plants (Robinson, 1983). Because of the high value of container-grown plants, the importance of obtaining good weed control, and the necessity of avoiding plant injury, control methods that are too expensive or not practical with many other crops may be feasible with container-grown ornamentals.

Weed control provided by initial preemergence herbicide application generally begins to decrease during the early summer, resulting in some weed seed germination. The ideal herbicide under these conditions would selectively kill existing vegetation rapidly while providing long-term residual control. Unfortunately, such a herbicide is not available. This necessitates using herbicide combinations to achieve immediate control from postemergence herbicides and residual control from preemergence herbicides.

Herbicides developed recently are characterized by excellent postemergence activity on grass species, with no activity on broadleaf species. This selectivity offers potential for use in nursery plantings. Fluazifop-P and sethoxydim are two such herbicides currently labeled for postemergence grass control in ornamentals. Fluazifop-P also has limited preemergence activity on annual grasses. Recent research (Gilliam et al., 1984) demonstrated that postemergence applications of fluazifop-P and sethoxydim controlled bermudagrass, with little or no injury to field-grown ornamentals. These herbicides are not recommended as a tank-mix with other herbicides because of potential antagonism. Also, quizalofop, fenoxyaprop-ethyl, haloxyfop, and poppenate-methyl are being developed for postemergence control of grasses.

Oxyfluorfen, a preemergence herbicide, is effective against many broadleaf weeds and grasses, with limited postemergence activity. Oryzalin and metolachlor, preemergence herbicides, are active primarily against annual grasses and small-seeded broadleaf species.

Table 1. Preemergence control of annual grasses with herbicide combinations used on container-grown azaleas and evaluated 60 and 120 days after treatment (DAT); Expt. I.

	Preemergence control (%)[z]					
	Preemergence herbicide					
	Oryzalin		Oxyfluorfen		No preemergence	
	Days after treatment					
Postemergence herbicides	60	120	60	120	60	120
Quizalofop	90	84	42	0	30	0
Fenoxyprop-ethyl	48	86	30	0	20	0
Haloxyfop	82	82	52	0	24	0
Poppenate-methyl	74	88	42	0	34	0
Fluazifop-P	78	84	48	0	20	0
Sethoxydim	54	80	24	0	24	0
No postemergence	98	98	20	0	0	0
Mean	75	86	38	0	24	0
Significance, LSD 5%[y]			60 DAT	120 DAT		
Preemergence			8	3		
Postemergence			12	9		
Interaction			10	NS		

[z] 100 = 100% control, 0 = no control.

[y] Mean separation by Fisher's protected LSD ($P \leq 0.05$).

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Table 2. Postemergence control of annual grasses rated 14 days after treatment (DAT) and preemergence control as reflected by weed dry weights at 120 DAT in container-grown azaleas treated with herbicide combinations; Expt. I.

	Postemergence control[z]					
	Preemergence herbicides					
	Oryzalin		Oxyfluorfen		No preemergence	
	(%)	(g)	(%)	(g)	(%)	(g)
	Days after treatment					
Postemergence herbicides	14	120	14	120	14	120
Quizalofop	85	0.3	89	11.3	90	14.7
Fenoxyaprop-ethyl	83	5.8	99	10.5	94	27.7
Haloxyfop	86	1.8	96	5.6	86	23.9
Poppenate-methyl	85	1.3	94	10.6	95	17.6
Fluazifop-P	91	1.4	98	11.8	79	19.1
Sethoxydim	90	3.6	98	11.2	74	17.6
No postemergence	0	13.3	83	20.3	0	16.8
Mean	74	3.9	94	11.6	74	19.6
Significance, LSD 5%			14 DAT	120 DAT		
Preemergence			2	3.3		
Postemergence			3	NS		
Interaction			3	4.2		

[z] 100 = 100% control, 0 = no control.

[y] Mean separation by Fisher's protected LSD ($P \leq 0.05$).

Table 3. Preemergence and postemergence herbicide effects on container-grown 'Coral Bell' azalea growth index following use of herbicide combinations and evaluated 120 days after treatment; Expt. I.

	Growth index (GI)[z]		
	Preemergence herbicides		
Postemergence herbicides	Oryzalin	Oxyfluorfen	No preemergence
Quizalofop	22.2	20.1	20.3
Fenoxyaprop-ethyl	23.1	19.0	18.7
Haloxyfop	21.2	20.3	20.3
Poppenate-methyl	22.7	20.9	19.4
Fluazifop-P	21.7	20.9	20.1
Sethoxydim	20.5	20.6	23.0
No postemergence	22.2	21.1	20.0
Mean	21.9	20.4	20.3
Significance LSD 5% for GI[y]			
Preemergence		0.9	
Postemergence		NS	
Interaction		1.2	

[z] GI = Growth index as determined by height + width-1 + width-2, -3. Width-1 is measured at the widest point and width-2 measured perpendicular to width-1.

[y] Mean separation by Fisher's protected LSD ($P \leq 0.05$).

Chemical interactions may occur when herbicides are applied as tank mixtures (Hatzios and Penner, 1985). Grass control was reduced when sethoxydim was tank-mixed with bentazon (Rhodes and Coble, 1984). Hartzler and Foy (1983) found decreased control of large crabgrass with sethoxydim when bentazon and sethoxydim were applied as a tank mixture. However, increased grass control resulted from tank mixtures of sethoxydim or fluazifop-P with acifluorfen (Chen and Penner, 1985; Hartzler and Foy, 1983). To date, limited research has been conducted on tank mixtures of preemergence and postemergence herbicides for annual grass control.

The objectives of this study were to evaluate combinations of preemergence and postemergence herbicides for annual grass control and their possible antagonistic or synergistic effects on weed control in container-grown ornamentals.

Experiments were conducted in 1984 and 1985 to evaluate combinations of preemergence and postemergence herbicides for control of large crabgrass and goosegrass in container-grown azaleas (*Rhododendron obtusum* 'Coral Bells').

For Expt. I, azaleas were grown in 3.8-liter containers in a 5 pine bark : 1 sand medium (v/v) amended with dolomitic limestone (3.6 kg·m^{-3}), gypsum and superphosphate (1.2 kg·m^{-3} each), and Aqua-Gro (0.6 kg·m^{-3}) (Aquatrols Corp. of America, Pennsauken, N.J.). The azaleas were grown under 47% shade.

For postemergence control, pots were overseeded with equal amounts of goosegrass and large crabgrass to produce a uniform grass infestation 1 month before herbicide application. Grass seedlings were 10 to 15 cm high and tillering when treated. Preemergence grass control was evaluated by treating weed-free pots at the same time that treatments were applied for postemergence evaluation. Two weeks later, the weed-free pots were overseeded with a mixture of goosegrass and large crabgrass. All herbicides were applied with a tractor-mounted compressed-air sprayer (operating at 22.5 kg·cm^{-2}) in a volume of water equal to 187 liters·ha^{-1}. The spray boom was equipped with 11002 flat-fan spray tips.

Herbicides were evaluated at the following rates (all in kg·ha^{-1}) for each experiment: oryzalin, 2.24; oxyfluorfen, 0.56; quizalofop, 0.01; fenoxyaprop-ethyl, 0.084; poppenate-methyl, 0.56; fluazifop-P, 0.14; and sethoxydim, 0.28. Herbicides were applied alone or in combination (tank-mixed) with oryzalin or oxyfluorfen in all possible pair combinations (factorial arrangement) at the rates noted. A petroleum-based crop oil concentrate (Agridex, Helena Chemical, Memphis, Tenn.) was added (1%, v/v) to all treatments.

Phytotoxicity and control of existing grasses (postemergence activity) were evaluated 14 and 120 days following herbicide application (DAT). Suppression of grass seed germination (preemergence activity) was evaluated at 60 and 120 days after herbicide application. The above-ground foliage of the grasses was removed, dried for 48 hr at 40C, and dry weights determined.

Treatments were assigned randomly and replicated four times with three pots per replicate. A randomized complete block design was used. Data were subjected to analyses of variance and means were separated by Fisher's protected LSD ($P \leq 0.05$).

Experiment II was identical to Expt. I except that containers did not contain azaleas, metolachlor was applied at 2.24 kg·ha^{-1} instead of oxyfluorfen, and fenoxyaprop-ethyl was excluded.

Postemergence herbicides (Expt. I) with oryzalin, oxyfluorfen, or alone provided an average of 75%, 38%, and 24% grass control, respectively (Table 1). Antagonism of preemergence control, due to the tank-mixing of postemergence herbicides with oryzalin, was evident in several cases. The most severe reduction of preemergence control occurred when oryzalin was applied with fenoxyaprop-ethyl (48% control) or with sethoxydim (54%), compared to preemergence control of oryzalin applied alone (98%). Significant decreases in preemergence control also were evident when oryzalin was applied with all other postemergence herbicides except quizalofop; this combination provided 90% control. Preemergence control from oxyfluorfen at 60 DAT was generally enhanced with the addition of most postemergence herbicides, but did not equal that of the oryzalin-containing systems. Oxyfluorfen alone provided 20% preemergence control; preemergence control was at least doubled when oxyfluorfen was applied with haloxyfop, fluazifop-P, and quizalofop or poppenate-methyl. Maximum preemergence control at 60 DAT from a postemergence herbicide (≈30%) was obtained with poppenate-methyl and quizalofop. Previous research indicated that poppenate-methyl

Table 4. Preemergence control of annual grasses using herbicide combinations and evaluated 60 and 90 days after treatment (DAT); Expt. II.

	Preemergence control (%)[z]					
	Preemergence herbicides					
	Oryzalin		Metolachlor		No preemergence	
	Days after treatment					
Postemergence herbicides	60	90	60	90	60	90
Quizalofop	100	94	60	40	40	0
Haloxyfop	100	90	95	90	0	0
Poppenate-methyl	100	94	100	90	30	0
Fluazifop-P	90	88	90	74	0	0
Sethoxydim	95	84	35	34	0	0
No postemergence	100	94	80	50	0	0
Mean	98	91	77	63	12	0
Significance, LSD 5%[y]			60 DAT	90 DAT		
Preemergence			5	7		
Postemergence			7	8		
Interaction			6	9		

[z]100 = 100% control, 0 = no control.

[y]Mean separation by Fisher's protected LSD ($P \leq 0.05$).

Table 5. Postemergence control of annual grasses using herbicide combinations and evaluated 14, 30, and 60 days after treatment (DAT); Expt. II.

	Postemergence control (%)[z]								
	Preemergence herbicides								
	Oryzalin			Metolachlor			No preemergence		
	Days after treatment								
Postemergence herbicides	14	30	60	14	30	60	14	30	60
Quizalofop	62	62	75	48	50	50	62	50	0
Haloxyfop	92	92	75	92	92	95	98	92	0
Poppenate-methyl	94	98	90	94	94	100	94	90	30
Fluazifop-P	82	98	80	80	82	85	94	94	0
Sethoxydim	94	92	80	92	84	40	92	82	0
No postemergence	0	24	35	32	24	80	0	0	0
Mean	71	78	81	73	71	75	73	68	5
Significance, LSD 5%[y]			14 DAT	30 DAT	60 DAT				
Preemergence			5	6	9				
Postemergence			4	10	12				
Interaction			4	9	11				

[z]100 = 100% control, 0 = no control.

[y]Mean separation by Fisher's protected LSD ($P \leq 0.05$).

provides some preemergence weed control (Gilliam et al., 1986).

Only oryzalin-containing herbicide combinations provided acceptable residual control (86%, averaged across all postemergence herbicides) at 120 DAT (Table 1). However, oryzalin applied alone provided nearly perfect preemergence control. No preemergence control from oxyfluorfen-containing combinations or postemergence herbicides was evident at 120 DAT.

Greatest postemergence control at 14 DAT was provided by all oxyfluorfen-postemergence herbicide combinations (94%, averaged across all postemergence herbicides) (Table 2). Postemergence herbicides applied in combination with oxyfluorfen provided control equal to or better than either the oryzalin combinations or the postemergence herbicides applied singularly; both provided 74% control. The increased control from the oxyfluorfen combinations may be partially due to the postemergence activity of oxyfluorfen (83% control alone). Antagonism of postemergence control was evident when oryzalin was applied with quizalofop (5% less), fenoxaprop-ethyl (11% less), and poppenate-methyl (10% less). About 90% control was obtained when fluazifop-P or sethoxydim was applied in combination with oryzalin, compared to 79% and 74% control, respectively, when applied alone. Control from haloxyfop was not influenced by application with oryzalin.

Weed dry weights at 120 DAT (Table 2) for oryzalin combinations were about one-third those for oxyfluorfen combinations. Dry weights were <1 g per plant for treatments that received oryzalin applied with quizalofop. Oryzalin applied alone did not reduce grass dry weights appreciably. The lack of preemergence activity from oxyfluorfen and postemergence herbicides is reflected by the greater weed dry weights harvested from these treatments than from oryzalin–postemergence herbicide combinations. These data illustrate the value of preemergence and postemergence control obtained with herbicide combinations providing both residual preemergence and postemergence control. A residual preemergence herbicide will not control existing vegetation while a postemergence herbicide lacks residual preemergence activity.

Azalea growth indices at 120 DAT were reduced more by the oxyfluorfen-containing combinations than by oryzalin-containing combinations (Table 3). This may be partially attributed to injury from postemergence applications of oxyfluorfen (Table 3). Oxyfluorfen is labeled for applications only to dormant shrubs or as a post-directed treatment—an application where the herbicide spray is directed towards the base of the plant to reduce or eliminate injury to desirable plants—due to the potential injury with foliar applications. Postemergence herbicides did not affect growth indices; however, the preemergence × postemergence herbicide interaction was significant. It appears that the addition of oryzalin with postemergence herbicides resulted in greater growth indices than applications of the postemergence herbicides alone (21.9 and 20.3, respectively, averaged across all treatments). However, the increased growth indices from oryzalin combinations may be due to increased weed control resulting from the preemergence weed control activity of oryzalin. Weed control from postemergence herbicides applied singularly was negligible at 120 DAT (Table 2); thus, the lower growth indices of these treatments may be due to reduced azalea growth resulting from unchecked weed growth. Growth indices were highest for herbicide treatments consisting of sethoxydim or oryzalin applied alone, or oryzalin applied jointly with fenoxaprop-ethyl, quizalofop, or poppenate-methyl. Azalea dry weight was not affected significantly by herbicide application (data not shown).

For Expt. II, residual preemergence weed control at 60 DAT (averaged across all treatments) was greater with oryzalin than with metolachlor combinations (Table 4). Sixty days after treatment, all postemergence herbicides applied with oryzalin provided the greatest preemergence control (>95%), except fluazifop (90%). Applications of metolachlor with haloxyfop or poppenate-methyl also provided excellent preemergence control. Among postemergence herbicides applied alone, quizalofop and poppenate-methyl both provided a minimal amount (≤40%) of preemergence control. The preemergence activity of quizalofop and poppenate-methyl also was observed in Expt. I (Table 1). Antagonism of preemergence activity by the addition of postemergence herbicides to oryzalin or metolachlor was evident in several instances. Oryzalin applied with fluazifop-P provided 90% control, compared to 100% control from oryzalin applied alone. Metolachlor provided 80% preemergence control when applied alone, compared to 60% and 35% when applied with quizalofop or sethoxydim, respectively.

Residual preemergence control at 90 DAT

was greater with oryzalin combinations (91% control, averaged across all treatments) than for metolachlor combinations (63%) (Table 4). These herbicides applied alone provided similar control. Good preemergence control (≈90%) also was achieved when oryzalin was applied alone or with quizalofop, haloxyfop, poppenate-methyl, or fluazifop-P. Comparable preemergence control also was obtained from metolachlor applied with either haloxyfop or poppenate-methyl. Antagonism of preemergence activity occurred when sethoxydim was applied with oryzalin (84% control), compared to 94% control from oryzalin applied alone. This result is in agreement with data from Expt. I (Table 1). Preemergence control from metolachlor was antagonized by ≈20% when applied with sethoxydim or quizalofop.

No difference existed between oryzalin- or metolachlor-containing combinations (averaged across postemergence herbicides) on postemergence control at 14 DAT (Table 5). At 14 DAT, postemergence control exceeded 90% with either haloxyfop, poppenate-methyl, or fluazifop-P applied alone. Sethoxydim or poppenate-methyl applied in combination with oryzalin provided similar postemergence control. Simultaneous applications of the postemergence herbicides with any of the preemergence herbicides resulted in equivalent or less postemergence control than from postemergence herbicides applied alone.

Postemergence weed control at 14 DAT (Table 5) provided by poppenate-methyl or sethoxydim was not influenced by the addition of either preemergence herbicide. Both haloxyfop and fluazifop were antagonized by the addition of oryzalin or metolachlor. Postemergence control from quizalofop was reduced by 14% when applied with metalochlor, but unaffected when applied with oryzalin relative to quizalofop (62%) applied alone. Control from all postemergence herbicides at 14 DAT applied alone exceeded 90%, except for quizalofop.

At 30 DAT, nearly 80% postemergence control was obtained with oryzalin combinations, but only ≈70% with metolachlor combinations or with postemergence herbicides applied alone (Table 5). Postemergence control ≥90% was obtained from haloxyfop, poppenate-methyl, or fluazifop-P applied alone. Similar control also was obtained with oryzalin applied with either haloxyfop, poppenate-methyl, fluazifop-P, or sethoxydim, and with metolachlor combined with haloxyfop or poppenate-methyl. Postemergence control from quizalofop and sethoxydim was increased when applied in combination with oryzalin. Antagonism of postemergence control occurred when fluazifop-P was applied with metolachlor.

Perfect to excellent postemergence control at 60 DAT (Table 5) was achieved with poppenate-methyl or haloxyfop applied with metolachlor, or with oryzalin applied with poppenate-methyl. Sixty days after treatment, grass control provided by postemergence herbicides was negligible due to later germinating grass which escaped postemergence applications. Annual grasses frequently germinate throughout the growing season (Gilliam et al., 1986), and this lack of control of later germinating grass seed emphasizes the importance of residual weed control in container-grown ornamentals.

The mechanisms by which two herbicides applied jointly (tank-mixed) may interact are complicated and, for the most part, poorly understood (Hatzios and Penner, 1985). A recent review by these authors discusses the complexity of these interactions. Herbicide mixtures may influence phytotoxicity characteristics by affecting herbicide absorption, translocation, and/or biotransformations in the plant. Hartzler and Foy (1983) reported that the antagonism of sethoxydim activity, when applied with bentazon, resulted from reduced absorption of sethoxydim. The mechanism for the antagonistic and synergistic responses of the herbicide combinations used in this study is unknown. However, this research indicates that care should be observed when applying postemergence and preemergence herbicides simultaneously to container media. Antagonism of both preemergence and postemergence control is possible. However, excellent control or increased control also may be obtained from simultaneous applications of other herbicide combinations. Examining all treatments, maximum preemergence and postemergence control was obtained with joint applications of oryzalin or metolachlor with poppenate-methyl.

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