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Cultivar Differences in Postemergence Graminicide Phytotoxicity to *Juniperus*

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Abstract. **Several juniper species and cultivars were compared for sensitivity to labeled and experimental postemergence graminicides. The junipers treated were: *Juniperus horizontalis* Moench. 'Wiltonii' (blue rug), *J. h.* 'Bar Harbor' (Bar Harbor), *J. h.* 'Youngstown' (Youngstown Andorra), *J. chinensis* L. 'Pfitzeriana' (Pfitzer), *J. c.* 'Parsonii' (Parson's), *J. c.* 'Sargentii' (Sargent's), and *J. conferta* Parl. (shore). The herbicide treatments were fluazifop-p, sethoxydim, haloxyfop, quizalofop, cycloxydim, and fenoxaprop at recommended rates for annual grassy weed control, with recommended spray adjuvants. 'Bar Harbor' juniper was injured, in decreasing order of severity, by haloxyfop, fenoxaprop, quizalofop, and fluazifop. Sethoxydim and cycloxydim produced no reduction in plant fresh weight for the juniper cultivars tested. However, sethoxydim plus adjuvants did reduce 'Bar Harbor' juniper visual quality ratings in 1986. Pfitzer juniper was slightly injured by haloxyfop in 1985 and by fenoxaprop in 1986. The other junipers were unaffected by herbicide treatments. Chemical names used: (*R*)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy] phenoxy] propanoic acid (fluazifop-p), (±)-2-[4-[(6-chloro-2-benzoxazolyl)oxy]phenoxy] propanoic acid (fenoxaprop), 2-[4-[[3-chloro-5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy] propanoic acid (haloxyfop), (±)-2-[4-[(6-chloro-2-quinoxalinyl)oxy]phenoxy] propanic acid (quizalofop), 2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one (sethoxydim), and 2-[1-(ethoxyimino)butyl]-3-hydroxy-5- (2*H*-tetrahydrothiopyran-3-yl)-2-cyclohexen-1-one (cycloxydim).**

The postemergence graminicides—fluazifop, fluazifop-p, and sethoxydim—have been found to be safe for use in most broadleafed crops, including many ornamentals (1, 6, 7). However, numerous researchers have reported injury to certain cultivars of azalea (*Rhododendron* spp.) by fluazifop and fluazifop-p (2, 3, 5). Fluazifop injury has been confirmed on *R. obtusum* Lindl. 'Hinocrimson' (1, 2, 3, 5). Bing and Macksel (2) also observed injury to *R. obtusum* 'Hinodegeri' and 'Hershey Red'. Injury to numerous other azalea cultivars from fluazifop or fluazifop-p have also been reported (3, 7). Derr (3) observed an increase in injury to certain cultivars when nonionic surfactant or nonphytotoxic crop oil concentrate were added to the spray solution, as compared to applications of fluazifop-p with no adjuvant. In those tests, sethoxydim did not injure woody ornamentals.

Fluazifop injury to certain cultivars of *Juniperus horizontalis* has also been reported. 'Bar Harbor' juniper was injured when fluazifop was applied at 2.2 kg a.i./ha (four times the recommended rate) (4, 8). Weller (10) reported injury to blue rug juniper from fluazifop treatments; however, Rice et al. (8) observed no injury on this cultivar. These apparently contradictory reports have led to some confusion as to the safety of postemergence graminicides on *J. horizontalis* cultivars. One objective of this study was to evaluate fluazifop-p and sethoxydim on several species and cultivars of junipers for potential phytotoxicity.

Numerous other postemergence graminicides are labeled for, or are being tested on, other broadleafed crops. These include haloxyfop, quizalofop, cycloxydim, and fenoxaprop. Limited testing with woody ornamentals has indicated good safety with several species including azalea (*R. obtusum* 'Coral Bells') and Andorra Plumosa juniper (*J. horizontalis*. 'Plumosa' (6). However, in light of reported cultivar-specific phytotoxicity with fluazifop, these other postemergent graminicides should be fully tested before labeling. Therefore, a second objective of this experiment was to compare the safety of these postemergence graminicides with sethoxydim and fluazifop-p on junipers.

Experiments were conducted in 1985 and 1986 with container-grown junipers at the Long Island Horticultural Research Laboratory, Riverhead, N.Y. The juniper species and cultivars tested were blue rug, Bar Harbor, Youngstown Andorra, Pfitzer, Parson's (1985 only), Sargent's (1986 only), and shore (1985 only). Rooted liners were potted in 3-liter plastic pots using a 1 peat : 1 bark : 1 leaf mold : 1 sand medium (by volume). Pots were arranged in a randomized complete block design with three plants of each species per plot and four replicates. Plants were irrigated daily when rainfall did not occur and fertilized twice during the growing season using one 12-g fertilizer pellet (Agriform 14N-1.7P-5K, Sierra Chemical Co., Milpitas, Calif.) per pot. A maintenance herbicide treatment of oxyfluorfen + pendimethalin (Scotts Ornamental Herbicide 2, O.M. Scott and Sons, Marysville, Ohio) at 2.2 + 1.1 kg a.i./ha was applied over all plants immediately after

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Table 1. Phytotoxicity of postemergent graminicides to 'Bar Harbor' and 'Pfitzer' junipers–1985.

Herbicide	Adjuvant	Rate (kg a.i./ha)	Bar Harbor VR[z] 16 July	Bar Harbor VR[z] 13 Aug.	Bar Harbor Fresh wt[y] (g)	Pfitzer VR 16 July	Pfitzer VR 13 Aug.	Pfitzer Fresh wt (g)
None	None		68	79	105	100	100	206
Fluazifop-p	X-77 (1%, v/v)	0.21	68	90	109	88	92	187
Fluazifop-p	None	0.28	71	88	110	94	94	202
Fluazifop-p	X-77 (1%, v/v)	0.28	66	73	100	98	98	209
Fluazifop-p	COC (1%, v/v)	0.28	59	70	100	85	93	192
Sethoxydim	COC (1%, v/v)	0.28	73	98	104	95	98	208
Sethoxydim	COC (1%, v/v)	0.56	69	84	101	98	100	216
Sethoxydim	X-77 (1%, v/v)	0.56	91	98	136	99	99	185
Cycloxydim	None	0.56	80	84	116	90	90	168
Haloxyfop	X-77 (0.25%, v/v)	0.28	0**	0**	9**	74*	70*	158
Quizalofop	X-77 (0.25%, v/v)	0.28	33*	53*	66	100	100	208
LSD (0.05)			21	22	44	20	19	NS

[z]Visual rating of plant quality (VR) on dates indicated were on a scale of 0 to 100, where 0 = dead and 100 = best growth. Evaluations were "blind"; i.e., treatments were unknown to observer. Therefore, values for untreated checks may indicate the level of variability in plant quality observed.
[y]Above ground fresh weights were determined on 21 May 1986.
NS, *, **Nonsignificant or significantly different from the untreated checks at the 5% or 1% levels, respectively, as determined by Bayes LSD mean comparisons and least-squares individual mean comparison procedures. Data are means of four, three-plant replicates.

Table 2. Phytotoxicity of postemergent graminicides to 'Bar Harbor' and 'Pfitzer' junipers—1986.

Herbicide	Adjuvant	Rate (kg a.i./ha)	Bar Harbor VR[z] 11 July	Bar Harbor VR[z] 26 Aug.	Bar Harbor Fresh wt (g)	Pfitzer VR 11 July	Pfitzer VR 26 Aug.	Pfitzer Fresh wt (g)
None	None		98	93	16.7	100	100	22.4
None	COC (1%, v/v)		90	75	14.3	85	100	25.8
Fluazifop-p	None	0.28	85	43**	6.3*	93	100	25.2
Fluazifop-p	X-77 (1%, v/v)	0.28	85	25**	9.8*	80	95	21.8
Fluazifop-p	COC (1%, v/v)	0.28	85	73	15.7	93	100	24.3
Sethoxydim	None	0.56	93	65	17.4	98	95	24.7
Sethoxydim	X-77 (1%, v/v)	0.56	83	50*	11.8	90	98	22.0
Sethoxydim	COC (1%, v/v)	0.56	73*	83	16.7	100	100	27.0
Haloxyfop	None	0.28	0**	0**	2.2**	95	93	23.4
Haloxyfop	X-77 (0.25%, v/v)	0.28	0**	0**	2.3**	88	98	27.9
Quizalofop	X-77 (0.25%, v/v)	0.28	53*	28*	2.8**	95	98	24.1
Cycloxydim	None	0.56	100	90	20.3	88	100	24.8
Fenoxaprop	None	0.28	28**	5**	2.1**	88	98	23.4
Fenoxaprop	X-77 (1%, v/v)	0.28	35**	0**	2.3**	80	90*	18.9
LSD (0.05)			17	33	6.8	NS	9	9.0

[z]Visual rating of plant quality (VR) on dates indicated were on a scale of 0 to 100, where 0 = dead and 100 = best growth. Evaluations were "blind"; i.e., treatments were unknown to observer. Therefore, values for untreated checks may indicate the level of variability in plant quality observed.
[y]Above ground fresh weights were determined on 21 May 1986.
NS, *, **Nonsignificant or significantly different from the untreated checks at the 5% (*) or 1% (**) levels, respectively, as determined by Bayes LSD mean comparisons and least squares individual mean comparison procedures. Data are means of four, three-plant replicates.

potting. Weed seedlings not controlled by the herbicide treatment were removed by hand for the duration of the experiment.

Postemergence graminicides were applied with a CO_2-pressurized backpack sprayer equipped with flat fan nozzles and calibrated to deliver 280 liters·ha^{-1} at 276 kPa. Plants were treated twice each season, first when ≈20 mm of new growth was present and second at about mid-season. Application dates were 18 June and 31 July 1985; and 3 June and 22 July 1986. Chemical treatments in both years included fluazifop-p, sethoxydim, haloxyfop, quizalofop, and cycloxydim at recommended rates for annual grassy weed control, with recommended adjuvants. In 1986, fenoxaprop was also included in the experiment. Additionally, the influence of spray adjuvants on graminicide phytotoxicity was evaluated. Fluazifop-p and sethoxydim treatments were applied with and without a crop oil concentrate (Crop Oil Concentrate from BASF Wyandotte Corp., Parsippany, N.J.) or a nonionic surfactant (X-77 Surfactant, Chevron Chemical Co., San Francisco). Haloxyfop and fenoxaprop were applied with and without the recommended surfactant. Treatment lists providing specific rates and adjuvants for 1985 and 1986 experiments are in Tables 1 and 2, respectively.

Plant quality was evaluated visually throughout the growing seasons. Data are presented for mid-season, prior to the second treatments, and end of season evaluations. Dates varied between years and are provided in Tables 1 and 2. Above ground fresh weights were measured on 21 May 1986 for the 1985 experiment. Since treatment differences were detectable within a single season, the 1986 experiment was not carried over to 1987, but was harvested on 9 Sept. 1986. Data were subjected to an analysis of variance using the General Linear Models (GLM) procedure of Statistical Analysis Systems (SAS) (9). Treatment effects were analyzed by cultivar. Mean separations were conducted using the LSD–Waller option. Certain treatment means were also compared using least squares analysis for all possible treatment differences, LSMEANS/PDIFF (9). Pooled comparisons of treatments sharing common components were conducted using the polynomial contrasts statement (CONTRAST) in the GLM procedure.

No injury was observed from any treatment on blue rug, 'Youngstown Andorra', shore, 'Parson's', or 'Sargent's' junipers; therefore, data for these species are not presented.

'Bar Harbor' juniper was severely injured by treatments of haloxyfop and quizalofop in 1985 and 1986, and by fenoxaprop in 1986. Fluazifop-p resulted in no injury in 1985, but in significant injury in 1986 when applied alone or with non-ionic surfactant. The in-

Table 3. Pooled comparisons testing for the influence of spray adjuvants on acyloxy phenoxy carboxylate herbicide phytotoxicity and for differences in selectivity between chemical classes for 'Bar Harbor' juniper, 1986 data.

Comparison	Visual ratings[z] 11 July	Visual ratings[z] 26 Aug.	Fresh wt[y]
No adjuvant vs. adjuvant added to acyloxy phenoxy carboxylate herbicides	NS	NS	NS
Acyloxy phenoxy carboxylate herbicides vs. sethoxydim and cycloxydim	***	***	***

[z]Visual ratings of plant quality on the dates indicated.
[y]Above-ground fresh weights determined on 9 Sept. 1986.
NS, ***Nonsignificant or significant at the 0.1% level, respectively, as determined by a polynomial contrast procedure on 1986 experimental data.

jury observed was less severe than that caused by haloxyfop, fenoxaprop, or quizalofop. No significant injury was observed when fluazifop-p was applied with crop oil concentrate; however, in 1985, there was a trend (P = 0.14) toward greater injury when crop oil was added as compared to no adjuvant. Conversely, in 1986, fluazifop plus crop oil was significantly superior to fluazifop alone or with surfactant. Although these results are inconclusive, they tend to indicate that fluazifop-p may injure 'Bar Harbor' juniper regardless of whether an adjuvant is used or not, or which type is chosen.

Sethoxydim has been observed to cause a reduction in azalea growth (3). However, neither sethoxydim nor cycloxydim reduced juniper fresh weight in 1985 or 1986 (Tables 1 and 2). Although the results are inconsistent between rating dates, some phytotoxicity was observed from sethoxydim applied with adjuvants in 1986 only (Table 2). No injury from sethoxydim was noted in 1985 (Table 1) or from cycloxydim in either year (Tables 1 and 2).

Single applications of haloxyfop, plus or minus surfactant, killed the plants (Tables 1 and 2). Single treatments of fenoxaprop and quizalofop resulted in severe injury as seen in mid-season ratings (Tables 1 and 2). Second applications of fenoxaprop resulted in increased injury or death. Plants were not killed by quizalofop but injury symptoms persisted through the growing season. Plants appeared to have begun recovery in the next growing season when fresh weights were taken (Table 1).

'Pfitzer' juniper was slightly injured by haloxyfop plus surfactant in 1985 but not in 1986 (Tables 1 and 2). Injury in 1985 was attributed to generally poor vigor of 'Pfitzer' juniper plants obtained for the test. The plants used in 1986 were in excellent condition before treatment and were uninjured by haloxyfop (Table 2). Based on final visual evaluations, fenoxaprop plus surfactant produced a slight reduction in 'Pfitzer' juniper quality (Table 2). This treatment effect was not detected in earlier visual evaluations or in plant fresh weight data. Fenoxaprop applied without additional surfactant did not injure 'Pfitzer' juniper.

No injury was observed on junipers treated with crop oil concentrate alone. In evaluating spray adjuvants for phytotoxicity to azalea, Derr (3) observed no phytotoxicity due to crop oil concentrate or nonionic surfactant applied alone, but did observe increased phytotoxicity of fluazifop-p treatments with the addition of either adjuvant. In the same study, Derr observed no differences between adjuvants in their ability to increase fluazifop-p injury in azaleas. However, the addition of adjuvants generally did not influence graminicide injury to 'Bar Harbor' juniper (Table 3). Some statistical differences between spray adjuvants could be identified, but the trends were not consistent between years. The class of chemical and the plant cultivar were more important in determining selectivity than was the adjuvant (Table 3).

Slight to severe injury to 'Bar Harbor' juniper resulted from treatments with any of the acyloxy phenoxy carboxylate graminicides tested (fluazifop-p, quizalofop, fenoxaprop, and haloxyfop) at recommended rates for grassy weed control with and without additional adjuvants. Sethoxydim caused some injury to 'Bar Harbor' juniper in 1986 only, but the results were inconsistent between rating dates and treatments. Plants recovered from this injury, as evidenced by no significant reduction in fresh weight as compared to untreated plants. 'Pfitzer' junipers were injured by haloxyfop plus surfactant in 1985 and by fenoxaprop plus surfactant in 1986. Cycloxydim caused no injury to the junipers tested. Other juniper species and cultivars tested were uninjured by any of the herbicides tested. Based on these data and previous work with azalea cultivars (3, 5), variation in tolerance by cultivar to the acyloxy phenoxy carboxylate herbicides appears to be more likely than to sethoxydim or cycloxydim, although 'Bar Harbor' juniper can be injured with sethoxydim plus adjuvant. This suggests a cultivar-specific difference in selectivity mechanisms between these two classes of graminicides.

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