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Sequential Herbicide Applications for Weed Control in Azaleas

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Abstract. **Sequential applications of granular oxyfluorfen (2 G) at 3.3 kg a.i.·ha^{-1}, oxadiazon (2 G) at 3.3 kg a.i.·ha^{-1}, napropamide (10 G) at 4.5 kg a.i.·ha^{-1}, and chlorpropham (20 G) at 1.1 kg a.i.·ha^{-1} were evaluated for weed control in newly planted *Rhododendron obtusum* (Lindl.) Planch cv. Hinocrimson azaleas in the field. Granular oxyfluorfen, oxadiazon, or napropamide applied twice per season controlled 99%, 77%, or 73% of the weeds, respectively, for 2 years. A combination of napropamide, oxyfluorfen, and oxadiazon applied twice per season controlled >99% of the weeds at the season's end. Single seasonal applications of oxyfluorfen or oxadiazon controlled 63% and 77% of the weeds, respectively. Phytotoxicity to azaleas was not observed with any treatment. Chemical names used: 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyel)benzene (oxyfluorfen); 3-[2,4-dichloro-5-(1-methylethoxy)phenyl]-5-(1,1-dimethylethyl)-1,3,4-oxadiazol-2(3 *H*)-one (oxadiazon); 2-(α-napththoxy)-*N*,*N*-diethylpropionamide (napropamide); and 1-methylethyl 3-chlorophenyl carbamate (chlorpropham).**

Shallow-rooted azaleas often are grown in raised field beds and are extremely susceptible to root or foliage injury caused by handweeding or other mechanical methods (3). Handweeding is also extremely expensive, with costs estimated at \$4800·ha^{-1} in 1980 (2).

Chlorpropham, napropamide, oxadiazon, and oxyfluorfen control weeds in ornamentals under a wide range of growing systems (1, 3, 6, 8, 9). Many weed species are not controlled for the entire growing season because they are either tolerant or emerge before the first application or later in the season from weed seeds that are blown in or from emerging species when the herbicide is not concentrated enough for effective control.

Experiments were conducted to determine effectiveness and phytotoxicity of sequential applications of the 4 herbicides alone or in combination in newly planted azaleas in raised ground beds.

The experiment was conducted near Salisbury, Md., from May 1982 to Mar. 1984. 'Hinocrimson' azaleas propagated from stem cuttings in July 1981 were planted into 4 raised field beds on 27 May 1982. Beds were 1.5 m wide and 140 m long and raised 30 cm in a Matapeake silt loam (typic hapludult, fine-silty mixed mesic), which contained 1.5% organic matter before modification with 390 MT·ha^{-1} (fresh weight) of decomposed pine bark and wood. An additional 2 cm of the same material was applied as a mulch immediately after planting.

Fourteen treatments of granular formulations of oxadiazon (2 G) and oxyfluorfen (2 G) at 3.3 kg a.i.·ha^{-1} and napropamide (10 G) at 4.5 kg a.i.·ha^{-1} were broadcast by hand over the top of the foliage within 2 hr after mulch was applied. After application, foliage was shaken to dislodge granules in leaf whorls. Additional applications were made on 26 Aug. 1982, and 12 Apr. and 15 Sept. 1983. Chlorpropham (20 G) granules were applied on 5 Oct. 1982 and 15 Sept. 1983 in some treatments (Table 1). The plots were sprinkler-irrigated immediately after treatment and as needed during the season. The experimental design was a randomized complete block with 4 replications. Plot size was 2.4 by 1.5 m and contained 20 azaleas. Paraquat was applied at 0.28 kg a.i.·ha^{-1} as a directed spray to all plots following the 15 July 1982 evaluation.

The percentage of weed control was visually estimated by 3 observers 21, 50, 97, 113, and 132 days after the initial treatment in 1982, and before and 36, 64, 77, 92, 128, 159, and 330 days after treatment in 1983. The percentage of weed control was the average of 3 ratings. Weed control ratings are reported for the 3 dates each year when weed cover was the highest. These represent seasonal trends. The percentage of control of each major weed species in the beds also was estimated at each observation.

Thirty-seven species of broadleaf weeds and 10 grass weeds were identified in the plots. Major broadleaf weeds were common chickweed [*Stellaria media* (L.) Cyrillo], mouseear chickweed (*Cerastium vulgatum* L.), henbit (*Lamium amplexicaule* L.), horseweed [*Conyza canadensis* (L.) Cronq.], knawel (*Scleranthus annuus* L.), common purslane (*Portulaca oleracea* L.), Pennsylvania smartweed (*Polygonum pensylvanicum* L.), thymeleaf speedwell (*Veronica serpyllifolia* L.), and common yellow woodsorrel (*Oxalis stricta* L.).

Major grass weeds were annual bluegrass (*Poa annua* L.), slender foxtail (*Alopecurus myosuroides* Huds.), and fall panicum (*Panicum dichotomiflorum* Michx.)

Ten random azaleas in each plot were labeled, and height and width were measured each time the percentage of weed cover was evaluated. Visual estimates of injury to azaleas also were made at the same time, using a rating system of 0–10. Plants with a rating of 0–3 were considered acceptable for sale; 4–9 were considered not marketable. Dead plants were rated as 10. The azaleas in these experiments were harvested in Mar. 1984. Where appropriate, data were subjected to analysis of variance and Duncan's multiple range test at the 5% level. An arcsin transformation was made on the percentage of weed control ratings prior to analysis.

The percentage of weed control. New weed seedlings emerged continuously during the study, permitting a study of how long the herbicides were effective. Weed cover in the untreated plots during 1982 and 1983 averaged 21% and 27%, respectively. On 12 Apr. 1984, the weed cover in the untreated control plots averaged 33%.

The percentage of weed control, derived from the weed cover data, is reported for 1982, 1983, and Mar. 1984 (Table 1). Weed control of less than 80% would be considered unsatisfactory because a reduction of azalea size probably would result. Three weeks after treatment of the azaleas in 1982, all treatments (except napropamide) controlled 86% or more of the weeds. After 7 weeks, all treatments except the single treatment of napropamide controlled 72% or more of the weeds. A single application of oxyfluorfen controlled 91% or more of the weeds. At the end of the first year, all treatments controlled 72% or more of the weeds. Two treatments of oxyfluorfen alone controlled 99% of the weeds.

In 1983, 2 applications per year of oxyfluorfen alone or oxyfluorfen in the spring followed by either chlorpropham or napropamide in September were nearly as effective as the 3-way combination of napropamide, oxyfluorfen, and oxadiazon.

Weed species controlled. Two treatments with oxyfluorfen each season controlled 100% of all of the major weed species except knawel (98%) and slender foxtail (90%) (Table 2). The combination of oxyfluorfen, oxadiazon,

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Table 1. The percentage of weed control in 'Hinocrimson' azaleas[z] by multiple applications of napropamide, oxadiazon, and oxyfluorfen.

Herbicide applications[y]				Weed control[x] (%)						
1982		1983		1982			1983			1984
27 May	26 Aug.	12 Apr.	15 Sept.	16 June	15 July	5 Oct.	12 Apr.	28 June	15 Sept.	8 Mar.
Untreated	---	---	---	0 b[w] (59)[v]	0 c (33)	0 c (26)	0 f (47)	0 cd (7)	0 e (31)	0 e (34)
Oxyfluorfen	None	Oxyfluorfen	None	98 a	91 a	72 b	68 cde	46 abc	54 abc	74 abc
Oxadiazon	None	Oxadiazon	None	90 a	72 ab	88 ab	3 f	0 cd	67 bcd	0 e
Oxyfluorfen	Oxyfluorfen	Oxyfluorfen	Oxyfluorfen	99 a	93 a	99 a	95 a	95 a	99 ab	100 a
Oxadiazon	Oxadiazon	Oxadiazon	Oxadiazon	86 a	78 ab	74 ab	53 de	65 abc	80 abc	65 ab
Oxyfluorfen	Chlorpropham[u]	Oxyfluorfen	Chlorpropham	99 a	88 a	74 ab	80 abc	77 abc	99 ab	93 ab
Oxadiazon	Chlorpropham[u]	Oxadiazon	Chlorpropham	97 a	78 ab	77 ab	69 bcd	74 abc	87 abc	48 bcd
Oxyfluorfen + napropamide	None	Oxyfluorfen + napropamide	None	97 a	94 a	79 ab	90 ab	80 ab	71 abc	88 ab
Oxadiazon + napropamide	None	Oxadiazon + napropamide	None	95 a	84 a	88 ab	60 cde	92 ab	82 abc	81 ab
Oxyfluorfen	Napropamide	Oxyfluorfen	Napropamide	99 a	91 a	72 b	82 abc	86 ab	99 ab	97 a
Oxadiazon	Napropamide	Oxadiazon	Napropamide	87 a	77 ab	72 ab	61 cde	32 bc	58 cde	92 ab
Oxyfluorfen	Oxadiazon	Oxyfluorfen	Oxadiazon	96 a	91 a	85 ab	43 e	63 abc	94 abc	81 ab
Oxyfluorfen	Napropamide	Oxadiazon	Napropamide	98 a	86 a	78 ab	80 abc	56 abc	94 abc	57 abc
Oxyfluorfen + oxadiazon + napropamide	Oxyfluorfen + oxadiazon + napropamide	Oxyfluorfen + oxadiazon + napropamide	Oxyfluorfen + oxadiazon + napropamide	99 a	93 a	99 a	97 a	100 a	100 a	94 ab
Napropamide	Napropamide	Napropamide	Napropamide	29 b	42 bc	79 ab	87 abc	68 abc	68 abc	96 a

[z]Newly planted azalea liners rooted in July 1981, grown in flats in the greenhouse and transplanted inthe field 27 May 1982. Herbicide treatments applied after planting.
[y]Herbicide treatments were oxyfluorfen (3.3 kg ai·ha^{-1}), oxadiazon (3.3 kg ai·ha^{-1}), napropamide (4.5 kg ai·ha^{-1}), and chlorpropham (1.1 kg ai·ha^{-1}).
[x]Reduction in weed count in untreated.
[w]Mean separation within columns by Duncan's multiple range test, 5% level.
[v]The numbers in parenthesis indicate the percentage of weed cover, an average of 3 ratings.
[u]Applied 5 Oct. 1982.

and napropamide applied twice per year was slightly better in control of these 2 species than oxyfluorfen alone. Henbit, Pennsylvania smartweed, thymeleaf speedwell, and fall panicum were controlled over 80% (Table 2).

Oxadiazon was less effective (86%) than oxyfluorfen (100%) for yellow woodsorrel control, but oxadiazon followed by napropamide controlled yellow woodsorrel completely, whereas napropamide alone did not control yellow woodsorrel (56%). Oxadiazon did not control common or mouseear chickweed, but 2 applications of napropamide or oxyfluorfen were more than 97% effective.

Two applications of oxyfluorfen controlled horseweed 100%, and a combination of oxyfluorfen plus napropamide provided 93% control. Oxyfluorfen followed by oxadiazon or napropamide plus a sequential treatment of oxadiazon also completely controlled horseweed (Table 2).

The winter annual—slender foxtail—was controlled 97% by a single application of oxyfluorfen (Table 2); annual bluegrass and fall panicum were controlled over 80% by all treatments (data not shown).

Azalea growth. Periodic pruning each season reduced the total leaf canopy area. Measurements in height × width were made following each pruning (data not shown). None of the herbicide treatments caused significant phytotoxicity or differences in growth of 'Hinocrimson' azaleas during 1982 or 1983 or when compared to the untreated control

Table 2. Control of broadleaf weeds in 'Hinocrimson' azaleas[z] by multiple applications of napropamide, oxadiazon, and oxyfluorfen.

Herbicide applications[y]				Control (%)						
1982		1983		Chickweed		Horse weed	Knawel	Common purslane	Yellow wood-sorrel	Slender foxtail
27 May	26 Aug.	12 Apr.	15 Sept.	Common	Mouseear					
Untreated	---	---	---	0	0	0	0	0	0	0
Oxyfluorfen	None	Oxyfluorfen	None	64	100	50	25	100	100	97
Oxadiazon	None	Oxadiazon	None	8	20	0	45	97	86	49
Oxyfluorfen	Oxyfluorfen	Oxyfluorfen	Oxyfluorfen	100	100	100	98	100	100	90
Oxadiazon	Oxadiazon	Oxadiazon	Oxadiazon	26	69	55	50	95	97	61
Oxyfluorfen	Chlorpropham[x]	Oxyfluorfen	Chlorpropham	74	100	77	63	100	84	88
Oxadiazon	Chlorpropham[x]	Oxadiazon	Chlorpropham	38	49	50	41	98	97	72
Oxadiazon + napropamide	None	Oxadiazon + napropamide	None	81	100	93	83	100	100	92
Oxadiazon + napropamide	None	Oxadiazon + napropamide	None	41	100	50	80	97	100	77
Oxyfluorfen	Napropamide	Oxyfluorfen	Napropamide	84	75	63	88	100	100	94
Oxadiazon	Napropamide	Oxadiazon	Napropamide	24	87	45	62	99	100	72
Oxyfluorfen	Oxadiazon	Oxyfluorfen	Oxadiazon	63	23	100	46	100	100	83
Oxyfluorfen	Napropamide	Oxadiazon	Napropamide	69	100	100	67	99	100	89
Oxyfluorfen + oxadiazon + napropamide	Oxyfluorfen + oxadiazon + napropamide	Oxyfluorfen + oxadiazon + napropamide	Oxyfluorfen + oxadiazon + napropamide	100	100	100	100	100	100	92
Napropamide	Napropamide	Napropamide	Napropamide	97	100	79	98	70	52	57

[z]Newly planted azalea liners rooted in July 1981, grown in flats in the greenhouse, and transplanted in the field 27 May 1982. Herbicide treatments applied after planting.
[y]Herbicide treatments were oxyfluorfen (3.3 kg ai·ha^{-1}), oxadiazon (3.3 kg ai·ha^{-1}), napropamide (4.5 kg ai·ha^{-1}), and chlorpropham (1.1 kg ai·ha^{-1}).
[x]Applied 5 Oct. 1982.

plants at the end of the experiment (data not shown). Granular applications of oxyfluorfen seem to be more desirable than the 2 EC formulation that, while satisfactory for many species (4), has been reported to cause extensive injury to a variety of azaleas, Rhododendrons and other ericaceous species at rates as low as 1.5 kg a.i.$\cdot$ha^{-1} (5, 7, 10). The 'Hinocrimson' azaleas, which averaged 200 cm^2 of growth at the time of treatment, averaged 1570 cm^2 at the time they were dug. The means at harvest varied from 1455 to 1700 cm^2.

Two applications per year of oxyfluorfen at 3.3 kg a.i.$\cdot$ha^{-1} reduced total weed cover more than 93% in azaleas grown in the field. Oxyfluorfen applied twice annually was almost as effective as 2 applications of the 3-way combination of oxyfluorfen, oxadiazon, and napropamide in controlling the 9 most prevalent broadleaf weed species and the 3 major grass weed species. The combination of oxyfluorfen and napropamide was as effective as the 3-way combination on the 3 grass weed species.

No significant phytotoxicity or reduction in azalea growth was observed on 'Hinocrimson' azaleas from any treatment.

Literature Cited

1. Ahrens, J.F. 1962. Annual applications of preemergence herbicides on four woody ornamentals. Abst., Weed Sci. Soc. Amer. p. 34–35.
2. Ahrens, J.F. and M. Cubanski. 1981. Herbicide trials in newly seeded hemlock, white spruce, white pine and Douglas fir. Proc. Northeast Weed Sci. Soc. 35:213–217.
3. Frank, J.R. and C.E. Beste. 1984. Weed control in azaleas grown in raised field beds. J. Amer. Soc. Hort. Sci. 109:654–659.
4. Fretz, T.A. and W.J. Sheppard. 1978. USB-3153 and oxyfluorfen: Two new experimental herbicides for container nursery stock, p. 48–50. In: Ornamental plants 1978, a summary of research, Ohio Agr. Res. & Dev. Ctr. Res. Circ. Vol. 236. 48–50.
5. Glaze, N.C., M. Singh, and S.C. Phatak. 1980. Response of pampasgrass and two azalea cultivars to alachlor, oxadiazon, and oxyfluorfen. Abstr., Weed Sci. Soc. Amer. p. 41–42.
6. Haramaki, C., L.J. Kuhns, and A. Fine. 1982. Selected herbicides and combinations on ornamental liners. Proc. Northeast Weed Sci. Soc. 36:266–270.
7. Kuhns, L.J. and C. Haramaki. 1980. An evaluation of 5 herbicides applied over liners representing 8 genera of ornamental plants. Proc., Northeast Weed Sci. Soc. 34:340–346.
8. Reavis, R. and C.E. Whitcomb. 1980. Preemergent herbicide combinations for field nursery stock. Okla. Agr. Expt. Sta. Res. Rpt. No. P-803.
9. Saidak, W.J. and S.H. Nelson. 1962. Weed control in ornamental nurseries. Weeds 10:311–315.
10. Smith, E.M. 1981. Weed control in horticultural crops — woody ornamentals. North Cent. Weed Contr. Conf. Res. Rpt. 38:9–10.

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Growth and Nutrition of Pecan Seedlings from Potassium Phosphate Foliar Sprays

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Abstract. **Response from foliar-applied P (0.0%, 0.50%, 0.75%, or 1.00% P from KH_2PO_4) was compared to that from root-supplied P (Hoagland's solution) in pecan [*Carya illinoinensis* (Wangenh.) C. Koch] seedlings. Compared with no applied P, foliar-applied P suppressed or prevented P deficiency symptoms; increased the P concentration in the leaf, trunk, and root; and increased tree growth. However, P in all 3 organs and growth of plants treated with foliar sprays were less than for plants with root-supplied P. Furthermore, P sprays eventually produced leaf scorch. Compared to root-supplied P, omitting P affected N, P, K, Ca, Mg, Fe, Mn, B, Cu, Zn, Na, and Al in the plant. These imbalances induced by P deficiency were only partially alleviated by foliar-applied P.**

In pecan, P deficiency can be expected when leaf P is less than 0.11% (1, 15). The leaf P concentrations—0.14–0.30% (4) and 0.12–0.30% (9)—proposed for optimum growth and yield, have not been confirmed. However, results suggest that the minimum values may be too low for maximum tree performance (2). Furthermore, heavy fruit production can suppress leaf P (8, 11, 14) that, in some instances, is to the deficient level. Correction of insufficient P is often difficult, partially due to the variability of P uptake by tree roots (6, 7, 12, 13, 17). This problem with P uptake by roots might be partially circumvented by using foliar applications of P. As a consequence, this study was designed to determine: a) the degree to which the P requirement of pecan can be satisfied by foliar sprays of P and b) the effect of P sprays on leaf elemental concentration. Seedling pecans grown under greenhouse conditions were used in the study.

Stratified seeds (16) of 'Curtis' pecan were planted in 25-cm plastic pots filled with perlite. One seed was planted per pot. Prior to planting, the perlite in each pot was prewetted 3 times with 1 liter of Hoagland's solution without P (5). Following planting, 13 additional applications of 1 liter of Hoagland's solution were made over an 18-day period. Thereafter, water and Hoagland's solution were applied as previously described (15). Seventeen days after initial seedling emergence, 5 differential P treatments were initiated. At this stage, all seedlings had about 1–3 leaves.

Four groups of seedlings continued to receive Hoagland's solution without P. In addition, the foliage of these seedlings were sprayed weekly with a 0% (deionized water), 0.5%, 0.75%, or 1.00% P solution (P source was KH_2PO_4). All sprays contained a phosphate-free detergent [0.1% (v/v)]. A fifth seedling group was supplied P via roots by switching from a minus P to a complete Hoagland's solution. The foliar sprays were applied weekly for 10 consecutive weeks. Leaves were sprayed to runoff on both the lower and upper surface. Contamination of the perlite during spraying was prevented by covering the top of the pots with Saran Wrap and by wrapping about a 2-cm section of the trunk just above the Saran with cotton. The experimental design was a randomized complete block replicated 5 times with 4 plants per plot (i.e., 20 plants per treatment).

Notations of P deficiency symptoms were made just prior to harvesting the plants. The percentage of seedlings with deficiency symptoms and the percentage of leaves defoliated from P deficiency were determined. In addition, percentages of leaves with spray burn were computed. Seedlings were harvested 14 weeks after sprouting. Leaves, trunks, and roots were separated, washed (1 min in a phosphate-free detergent followed by a deionized water rinse), oven-dried for 72 hr at 70°C, and weighed. These organs were ground, redried, and analyzed for N using a Technicon Auto-Analyzer, and for P, K, Ca, Mg, Fe, Mn, B, Cu, Zn, Al, and Na using a Jarrell-Ash plasma-emission spectrometer (10).

Omitting P induced P deficiency symptoms (i.e., pale green leaves). In severe cases of P deficiency, the leaves scorched and defoliated (Table 1). Foliar application of KH_2PO_4 of 0.75% P or above prevented deficiency symptoms. Growth (number of leaves

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