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Pendimethalin Influence on Azalea Shoot and Root Growth[1]

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Abstract

Preemergence herbicides, especially members of the dinitroaniline class, are commonly applied to container-grown nursery stock. Dinitroaniline herbicides inhibit the development of new roots in susceptible plants, and can injure nursery crops. The effect of pendimethalin on root and shoot growth of 'Tradition' azalea was evaluated at 4 and 8 weeks after treatment. Pendimethalin was applied to azalea tops (shoot exposure), the growing medium (root exposure), or to the tops plus growing medium. Initial plant heights and root volumes were used to calculate percent increase in growth as affected by application method. Four weeks after treatment, plant height of shoot-only and shoot plus root treatments increased by 17 and 25%, respectively, while height in root-only and untreated control plots increased by 34%. Eight weeks after treatment (WAT), plant height of shoot-only and shoot plus root treatment increased by 61 and 63%, respectively, compared to root-only and untreated control plots, which increased by 105 and 108%, respectively. Greatest reductions in root growth were found in the shoot plus root and root-only treatments at 4 and 8 WAT, likely due to pendimethalin movement into the upper 3 cm of the growing mix. Pendimethalin can directly affect azalea shoot growth following exposure to only the foliage, and directly reduce root development following application to the growing medium. Any stunting of growth following over-the-top application of a sprayable pendimethalin formulation likely results from impacts on both the root and shoot systems.

Index words: dinitroaniline, phytotoxicity, plant injury.

Species used in this study: 'Tradition' azalea (*Rhododendron obtusum* Planch.); large crabgrass [*Digitaria sanguinalis* (L.) Scop.]

Herbicides used in this study: Pendulum 3.3 EC (pendimethalin), N-(1 ethylpropyl)-3,4 dimethyl-2,6-dinitrobenzenamine.

Significance to the Nursery Industry

Preemergence herbicide application is an important means of weed control in container nursery production. The dinitroaniline herbicide class is commonly applied to herbaceous and woody nursery crops for control of annual grasses and certain annual broadleaf weeds. Since these herbicides are root inhibitors, and can affect nursery crop growth, information is needed on the potential for crop injury following application. The results of this study indicate that the emulsifiable concentrate formulation of pendimethalin directly inhibits shoot and root growth in 'Tradition' azalea. Alternative formulations, especially granular types, should limit the potential for adverse effects on shoot growth. Nursery producers utilizing pendimethalin or other dinitroaniline herbicides should monitor root growth in treated plants. Delaying application until azaleas have developed a sufficient root system should minimize any adverse impact on root growth.

Introduction

Although dinitroaniline herbicides are widely used in nursery production for control of annual grasses and certain annual broadleaf weed species, they can injure azaleas. Several variables determine the degree of injury from these compounds, including azalea cultivar, specific dinitroaniline herbicide, application rate, and formulation.

Several studies have evaluated plant injury from dinitroaniline herbicides with conflicting results (Table 1). Stamps and Neal (7) found that pendimethalin at 4.48 kg/ha (4.0 lb/A) did not significantly reduce shoot growth in 'Southern Charm' azalea (*Rhododendron indicum*). However, at the same rate, Skroch *et al*. (6) reported 79% shoot growth reduction in the deciduous azalea cultivar 'Flame' (*Rhododendron calendulaceum*). Prodiamine at 4.48 kg/ha (4.0 lb/A) was found to reduce shoot and root growth in 'Tradition' azalea (3), while others reported no significant root or shoot reductions in the cultivars 'Formosa' or 'Coral Bells' at the same application rate (5). Briggs and Whitwell (1) found that the granular formulation of prodiamine caused greater shoot injury to 'Pink Cascade' azalea than the water dispersable form. Singh *et al*. (5) also reported that a granular form of prodiamine caused no significant shoot effect compared to a sprayable form of oryzalin; however, significant root reductions were reported for the granular but not the suspension concentrate. Skroch *et al*. (6) reported the granular form of pendimethalin at 3.4 kg/ha (3.0 lb/A) had no effect on 'Hinocrimson' azalea shoot growth; however, at the same rate it reduced shoot growth of flame azalea by 58%. Prodiamine at 1.65 kg ai/ha (1.5 lb ai/A) did not reduce root weight in 'Hinocrimson' azalea at 30 and 60 DAT (2).

The differences observed among researchers could be due to different sites of injury from sprayable versus granular applications of dinitroaniline herbicides. Sprayable applications of a dinitroaniline may directly affect azalea shoot growth, while granular applications probably have their initial effects on root development. The objectives of this study were to evaluate pendimethalin, utilizing an emulsifiable concentrate formulation, on 'Tradition' azalea growth and to distinguish between herbicide effects on the shoot system versus effects on root development at 4 and 8 weeks after treatment (WAT).

Materials and Methods

Experiment 1. On February 9, 2004, 'Tradition' azalea was planted in 3.8 liter (1 gal) containers comprised of 100% pine

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Table 1. Impact of dinitroaniline herbicides on azalea shoot and root growth in previous research trials.

Herbicide	Rate kg ai/ha	Formulation[z]	Growing medium[y]	Root reduction[x]	Shoot reduction[w]	Azalea cultivar	Source
Prodiamine	1.65	WG	PB:S	No		Rhododendron obtusum 'Hino-Crimson'	Briggs, Whitwell, Riley, Lee
Oryzalin	4.4	SC	PB:S	No		Rhododendron obtusum 'Hino-Crimson'	Briggs, Whitwell, Riley, Lee
Prodiamine	4.5	WDG	PB:S	Yes	Yes	Rhododendron obtusum 'Tradition'	Derr, Salihu
Oryzalin	4.5	SC	PB:S	Yes	Yes	Rhododendron obtusum 'Tradition'	Derr, Salihu
Pendimethalin	4.5	WDG	PB:P:S	No	No	Rhododendron indicum (L.) Sweet. 'Southern Charm'	Stamps, Neal
Pendimethalin	4.5	G	PB:P:S	No	No	Rhododendron indicum (L.) Sweet. 'Southern Charm'	Stamps, Neal
Prodiamine	4.5	WDG	PB:P:S	Yes	No	Rhododendron indicum (L.) Sweet. 'Southern Charm'	Stamps, Neal
Prodiamine	4.5	G	PB:P:S	Yes	No	Rhododendron indicum (L.) Sweet. 'Southern Charm'	Stamps, Neal
Oryzalin	4.5	AS	PB:P:S	Yes	Yes	Rhododendron indicum (L.) Sweet. 'Southern Charm'	Stamps, Neal
Prodiamine	1.7	G	PB:S	Yes	Yes	Rhododendron 'Pink Cascade'	Briggs.Whitwell
Prodiamine	3.4	G	PB:S	Yes	Yes	Rhododendron 'Pink Cascade'	Briggs.Whitwell
Prodiamine	1.7	WG	PB:S	Yes	Yes	Rhododendron 'Pink Cascade'	Briggs.Whitwell
Prodiamine	3.4	WG	PB:S	Yes	Yes	Rhododendron 'Pink Cascade'	Briggs.Whitwell
Prodiamine	1.7	SC	PB:S	Yes	Yes	Rhododendron 'Pink Cascade'	Briggs.Whitwell
Prodiamine	3.4	SC	PB:S	Yes	Yes	Rhododendron 'Pink Cascade'	Briggs.Whitwell
Prodiamine	1.7	SC	PB:S	No	No	Rhododendron (L.) x 'Renee Michelle'	Prevete, Legnani, Whitwell, Femandez
Prodiamine	3.4	SC	PB:S	No	No	Rhododendron (L.) x 'Renee Michelle'	Prevete, Legnani, Whitwell, Femandez
Prodiamine	1.7	SC	PB:S	Yes	No	Rhododendron indicum 'Gulf Ray'	Prevete, Legnani, Whitwell, Femandez
Prodiamine	3.4	SC	PB:S	Yes	Yes	Rhododendron indicum 'Gulf Ray'	Prevete, Legnani, Whitwell, Femandez
Oryzalin	2.2	SC	PB:P:S		Yes	Rhododendron indicum 'Formosa'	Singh, Glaze, Phatak
Oryzalin	4.5	SC	PB:P:S		Yes	Rhododendron indicum 'Formosa'	Singh, Glaze, Phatak
Oryzalin	9.0	SC	PB:P:S		Yes	Rhododendron indicum 'Formosa'	Singh, Glaze, Phatak
Oryzalin	17.9	SC	PB:P:S		Yes	Rhododendron indicum 'Formosa'	Singh, Glaze, Phatak
Prodiamine	4.5	G	PB:P:S		No	Rhododendron indicum 'Formosa'	Singh, Glaze, Phatak
Prodiamine	9.0	G	PB:P:S		Yes	Rhododendron indicum 'Formosa'	Singh, Glaze, Phatak
Prodiamine	13.4	G	PB:P:S		Yes	Rhododendron indicum 'Formosa'	Singh, Glaze, Phatak
Oryzalin	2.2	SC	PB:P:S		Yes	Rhododendron obtusum. 'Coral Bells'	Singh, Glaze, Phatak
Oryzalin	4.5	SC	PB:P:S		Yes	Rhododendron obtusum. 'Coral Bells'	Singh, Glaze, Phatak
Oryzalin	9.0	SC	PB:P:S		Yes	Rhododendron obtusum 'Coral Bells'	Singh, Glaze, Phatak
Oryzalin	17.9	SC	PB:P:S		Yes	Rhododendron obtusum 'Coral Bells'	Singh, Glaze, Phatak
Prodiamine	4.5	G	PB:P:S		No	Rhododendron obtusum. 'Coral Bells'	Singh, Glaze, Phatak
Prodiamine	9.0	G	PB:P:S		Yes	Rhododendron obtusum 'Coral Bells'	Singh, Glaze, Phatak
Prodiamine	13.4	G	PB:P:S		Yes	Rhododendron obtusum 'Coral Bells'	Singh, Glaze, Phatak
Pendimethalin	2.2	WDG	PB		No	Rhododendron obtusum 'Hinocrimson'	Skroch, Warren, Gallitano
Pendimethalin	4.5	WDG	PB		Yes	Rhododendron obtusum 'Hinocrimson'	Skroch, Warren, Gallitano
Pendimethalin	3.4	G	PB		No	Rhododendron obtusum 'Hinocrimson'	Skroch, Warren, Gallitano
Pendimethalin	2.2	WDG	PB		Yes	Rhododendron calendulaceum	Skroch, Warren, Gallitano
Pendimethalin	4.5	WDG	PB		Yes	Rhododendron calendulaceum.	Skroch, Warren, Gallitano
Pendimethalin	3.4	G	PB		Yes	Rhododendron calendulaceum	Skroch, Warren, Gallitano

[z]Formulation: WDG/WG = water dispersible granule, G = granular, SC = suspension concentrate, AS = aqueous suspension.

[y]Growing medium: PB = pine bark, P = peat, S = sand.

[x]Root reduction: significant reduction in root weigh or growth index.

[w]Shoot reduction: significant reduction in either shoot weight or growth index.

Table 2. Pendimethalin impact on 'Tradition' azalea shoot height at 2 and 4 weeks after treatment and shoot fresh weight 4 weeks after treatment.

Treatment	Large crabgrass shoot fresh weight (g)	Percent increase in azalea shoot height[z]		Azalea shoot fresh weight (g)
		2 WAT	4 WAT	
Shoot	—	4	17	2.80
Root	11.24	19	34	2.88
Shoot+Root	5.81	9	25	2.80
Control	51.06	19	34	3.37
LSD (0.05)	10.59	5	8	0.45

[z]Mean initial plant height = 9.5 cm.

bark. In additional pots containing no azaleas, large crabgrass was seeded at 0.6 ml (1/8 tsp) seed per pot prior to herbicide application. Pots containing azaleas were kept weed-free to prevent any effects from weed competition. Azaleas were treated over-the-top with pendimethalin (Pendulum 3.3 EC) at 3.4 kg/ha (3.0 lb ai/A) using a CO_2-pressurized backpack sprayer broadcast at 230 liters/ha (25 gal/A). Pendimethalin was applied to the azalea top (shoot exposure) only, growing medium only (root exposure), or the top plus growing medium, and an untreated control was included for comparison. Shoot treatment consisted of adding a 2.5 cm (1 in) depth of perlite to the surface of each pot prior to herbicide application, then removing the perlite after application. Root treatment consisted of adding 1 ml (0.03 fl oz) of Pendulum EC to 500 ml (0.13 gal) of water, then pipetting 12.1 ml (0.41 fl oz) of this solution over the entire pine bark surface. Pendulum was sprayed over the azalea tops for the shoot plus root exposure treatment. Plants were irrigated within two hours after treatment.

Containers were topdressed with 9 g (0.32 oz) of a controlled-release fertilizer 17N–2.6P–9.9K (17–6–12) containing micronutrients (Osmocote, The Scotts Co., Marysville, OH) and placed in a greenhouse with average daily temperatures between 16 and 29C (62F and 85F). The study was repeated on February 13, 2004. Experimental design was a randomized complete block with four replications per treatment and three azalea pots and one large crabgrass pot in each plot.

Initial plant height and root volume were recorded at treatment. Plant height and percent injury, on a 0 (no injury) to 100 (plant death) scale, were recorded 2 and 4 weeks after treatment (WAT). Plants were harvested on March 8, 2004, and March 12, 2004, for the first and second trial, respectively. Root volume was determined by water displacement. Length of the new root zone was measured from the depth at which new roots began to growth, to the maximum depth of each root ball. Root circumference was measured at the maximum width of the root ball. Roots were separated from pine bark and allowed to air dry in a greenhouse for one week. Fresh and dry weights were recorded for both top and root tissue of each plant.

Experiment 2. This experiment was similar to experiment 1, except plant harvest was 8 WAT. 'Tradition' azalea was planted and treated with Pendulum 3.3 EC at 3.4 kg/ha (3.0 lb/A) on March 18, 2004, and harvested on May 13, 2004. This study was repeated on March 24, 2004, and harvested on May 19, 2004. Plant height and percent injury were recorded 2, 4 and 8 WAT.

Similar results were observed in the two runs of each trial so results were combined into one analysis. All data were subjected to analysis of variance, factorial analysis was preformed on treatment effects, and means were separated using Fisher's Protected LSD (0.05). Percent increase was calculated for plant height and new root volume using the equation: [(final – initial) / initial] × 100.

Results and Discussion

Experiment 1. No visible injury was noted at any time. Compared to untreated plants, pendimethalin reduced large crabgrass shoot weight by 78 and 89% when pipetted or sprayed over the growing medium, respectively (Table 2). Similar increases in azalea height were noted for the untreated plants and when pendimethalin was applied only to the growing medium (root treatment) at 2 and 4 WAT. Azalea height increase was significantly less when pendimethalin was applied only to the tops or to the tops and roots. Shoot fresh weight was significantly greater in the untreated compared to all other treatments. Skroch *et al*. (6) reported pendimethalin at 2.2 and 4.48 kg/ha (2.0 and 4.0 lb/A) reduced 'Flame' azalea fresh shoot weight by 93 and 79% respectively. They also found pendimethalin had no significant effect on 'Hinocrimson' azalea shoot growth at 2.2 kg/ha (2.0 lb/A); however at 4.48 kg/ha (4.0 lb/A), shoot growth was reduced by 51%.

Table 3. Pendimethalin impact on 'Tradition' azalea new root volume, length of new root zone, root circumference, and dry root weight at 4 weeks after treatment.

Treatment	Percent increase in new root volume[z]	Length of new root zone (cm)	Root circumference (cm)	Root dry weight (g)
Shoot	59	7.5	20.7	0.38
Root	36	6.2	17.3	0.36
Shoot+Root	39	6.5	17.4	0.45
Control	55	7.5	22.4	0.35
LSD (0.05)	10	0.9	2.8	NS

[z]Mean initial root volume = 37 cm^3.

Table 4. Pendimethalin impact on 'Tradition' azalea shoot height at 2, 4 and 8 weeks after treatment and fresh shoot weight 8 weeks after treatment.

Treatment	Large crabgrass shoot fresh weight (g)	Percent increase in azalea shoot height[z]			Azalea shoot fresh weight (g)
		2 WAT	4 WAT	8 WAT	
Shoot	—	4	6	61	8.16
Root	8.29	11	34	105	8.60
Shoot + Root	4.11	4	7	63	9.31
Control	46.60	12	39	108	10.20
LSD (0.05)	10.24	3	8	12	1.11

[z]Mean initial plant height 10.2 cm.

New root volume increased at a slower rate in the root-only and shoot plus root treatments, 36 and 39% respectively, than in shoot-only exposure or in untreated plants, where new root volume increased 59 and 55%, respectively (Table 3). Length of the new root zone and root circumference were also greater in the shoot-only treatment and untreated plants than in plants where the growing medium was treated. In the root-only and shoot plus root treatments, new roots began to develop between 3 and 5 cm below the surface of the growing medium, indicating that pendimethalin had leached to this depth, thus inhibiting azalea root development in the upper 3 cm of the pine bark. Prevete *et al.* (4) reported prodiamine (Factor) decreased root and shoot dry weight in 'Gulfray' azalea at 1.7 and 3.4 kg ai/ha (1.5 and 3.0 lb ai/A), with the higher rate resulting in severe stunting.

Dry root weight was unaffected by the treatments, since the majority of the root mass was in the older roots present at treatment (Table 3). Stamps and Neal (7) observed that pendimethalin caused slight root reductions in 'Southern Charm' azalea at 4.48 kg/ha (4.0 lb/A).

Experiment 2. Slight, temporary chlorosis of new leaf tissue was noted at 4 WAT following application of pendimethalin to the shoot system (data not shown). Pendimethalin reduced large crabgrass shoot weight by 82 and 91% when pipetted or sprayed over the growing medium, respectively (Table 4). Effects on azalea shoots were similar to the 4 week study (Table 2); shoot height increase was less in shoot-treated plants than in root-only exposure or in untreated plants at 2 and 4 WAT, and this pattern was still apparent at 8 WAT (Table 4). No height reduction was noted for root-treated plants compared to untreated ones. Shoot fresh weight was lower in root-only or shoot-only treated plants, while shoot weight was numerically highest in untreated plants.

Eight WAT, new azalea root volume was least in the root plus shoot treated plants, and highest in untreated plants (Table 5). Increase in new root volume was higher in shoot-only exposure treatments than in root-only exposure. A similar pattern was observed for the length of the new root zone and root circumference. It appears that application of pendimethalin to the growing medium directly affects root development, while application to the shoot system also has a detrimental, but indirect effect, on root growth. Exposing both the top and root system to pendimethalin has an additive, adverse effect on root development. New root development occurred directly below the surface of the pine bark for the shoot-only treatment, unlike the root-only and shoot plus root where roots were formed 3 to 5 cm below the surface. In the 4 week study, roots were not adversely affected by the shoot-only treatment (Table 3); however at 8 WAT, root development was affected by shoot exposure to pendimethalin, possibly due to an overall reduction in plant growth. Briggs *et al.* found no reduction in azalea root weight using a pine bark:sand mix (4:1) 30 and 60 days after treatment (DAT) (2). However they did report the presence of prodiamine at a depth of 2 to 4 cm (0.8 to 1.6 in) depth 14 DAT, based on a bentgrass (*Agrostis palustris* var. Penncross) bioassay (2).

Pendimethalin caused reduction in both shoot and root growth in 'Tradition' azalea at 4 and 8 WAT. Herbicide contact with only leaf tissue resulted in a slower increase in azalea height and shoot weight; treated plants were still shorter 8 WAT. Direct effects on shoot growth therefore needs to be considered when evaluating the impact of sprayable formulations of dinitroaniline herbicides. Root suppression was noted in the top 3 cm (1.2 in) of the growing medium when pendimethalin was applied to the media surface. Nursery producers need to monitor root growth in treated plants to ensure sufficient root system development. Observing a waiting period after transplanting to allow for additional root development prior to application should increase azalea tolerance to dinitroaniline herbicides. This would adversely affect weed control, since some weed germination could occur prior to application. A granular dinitroaniline product may be more appropriate for azaleas, which reduces or eliminates the potential for direct foliar damage.

Table 5. Pendimethalin impact on 'Tradition' azalea new root volume, length of new root zone, root circumference, and dry root weight at 8 weeks after treatment.

Treatment	Percent increase in new root volume[z]	Length of new root zone (cm)	Root circumference (cm)	Root dry weight (g)
Shoot	667	10.1	31.6	0.73
Root	457	9.4	28.1	1.02
Shoot+Root	263	8.5	24.1	1.05
Control	941	12.0	35.6	1.64
LSD (0.05)	161	1.1	3.3	0.37

[z]Mean initial root volume 37 cm^3.

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