Auburn University
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PENDULUM® AQUACAP™ (PENDIMETHALIN) APPLICATIONS ON WEED AND WILLOW CONTROL AND TOLERANCE TO BAREROOT AND CONTAINER-GROWN LOBLOLLY AND SLASH PINE AND BUTTONBUSH

by
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INTRODUCTION

The use of Pendulum® AquaCap™ (PAC) in bareroot forest tree nurseries has been examined since 2007 by the Southern Forest Nursey Management Cooperative for control of prostrate spurge (Chamaesyce maculate). Field trials that began on one species at one nursery have been expanded to nurseries in Alabama, Georgia, South Carolina and Tennessee in pine and hardwood. Results have shown that the herbicide can be safely used over loblolly and slash pine when applied **at the time of sowing** to provide good spurge control AND to prevent gall formation that can sometimes occur. In hardwood production systems, the tolerance of seedlings to PAC is species-dependent (Research Reports 13-03; 13-05). Care should be taken if one wants to use this material over an untested hardwood species. With any new herbicide, adoption of the treatment into the standard operating procedures takes time as each organization becomes familiar with the compound. A recent survey of SFNMC cooperating nurseries reported that approximately half of bareroot nurseries are using Pendulum® AquaCap™ in their weed control regimen.

While considerable effort was put into bareroot systems, little is known about the interaction of Pendulum® AquaCap™ with the organic media commonly used in containerized forest tree nurseries. In one of the few studies conducted with pendimethalin and organic matter, Lithuanian researchers reported in 2007 that peat acted to bind the herbicide so that the pendimethalin had a slow decomposition rate and half-life of 63 days (Lubytė et al, 2007). Most bareroot studies included soil types from clay to sandy soil rather than organic soils. Because some SFNMC nurseries have successfully used PAC for weed control in nursery beds, the use of the herbicide in containerized systems to target black willow (*Salix nigra*) is considered a logical next step. Willow is one of the more annoying weeds, as seed production and dispersal is difficult to predict in its timing, quantity and coverage over a nursery. Applications of PAC must be timed to coincide with estimated time of willow seed dispersal AND sowing dates of trays.

In order to further develop the potential use of Pendulum® AquaCap™, trials were installed at two nurseries in container-grown pine. In addition, two other bareroot trials were installed on conifer and hardwood species. The objectives of these trials were to 1) assess the effectiveness of PAC on control of weeds, notably black willow, at different pre-emergent application rates, 2) evaluate containerized loblolly and slash pine tolerance to pre-emergent application rates of Pendulum® AquaCap™ made at sowing and 3) follow-up results of previous trials by evaluating bareroot

buttonbush, loblolly and slash pine seedlings' tolerance to Pendulum® AquaCap™.

METHODOLOGY

Container seedling studies

In an attempt to coordinate herbicide applications with the simultaneous timing of willow seed dispersal, six installations of this experimental study were made at IFCO's container nursery in Moultrie, Georgia in either loblolly or slash pine (see Figure 1) and three installations of this experimental study were made at The Westervelt Company's container nursery near Eutaw, Alabama in loblolly pine (see Figure 2). Each of these installations were made one week apart at each nursery. All applications were made to trays on the day of sowing or one day post-sowing. Pendulum® AquaCap™ was applied at 3 rates (0, 34 oz/ac and 68 oz/ac) over cells that had been sown and topped with capping material (sawdust at IFCO and fine crushed rock at Westervelt). Locations of trays were dispersed throughout each nursery so no two weeks of treated trays were located on the same pad. This was an attempt to maximize the available treated area for willow seed dispersal (see Figure 3). All herbicide applications were made by Nursery Cooperative personnel with a CO_2 hand sprayer calibrated to broadcast spray 25 gallons per acre.

Each treatment was one container tray for each species that was replicated 25 times for each rate and week of application. While nine different installations of this experiment were made, only 3 of the 9 installations were examined for weed control and seedling tolerance to PAC (IFCO: 1 loblolly installation and 1 slash installation; Westervelt had 1 loblolly installation). At the end of the growing season, the installations with the most willow seedlings present in the control trays were analyzed for herbicide effectiveness. All willow, weed and seedling counts were made from those selected trays in November or December of 2014. A random sample of 10 seedlings from each tray x rate were removed from the trays and brought to the SFNMC laboratory in Auburn and evaluated for shoot height, RCD, stem galls and root and shoot dry weights for biomass determinations and compared to the non-treated (0.0 oz/ac) control seedlings. Differences between treated and non-treated seedlings would demonstrate inadequate tolerance to the herbicide.

Bareroot seedling studies

As a sequel to previous bareroot trials of PAC, this study was established in loblolly and slash pine at Plum Creek's Jesup, Georgia nursery at the time of sowing. The trial was installed in beds at three application rates (0, 34 oz/ac and 68 oz/ac) and applied one day after sowing for both species. Sprays were made after operational applications of synthetic stabilizer but before pine bark mulch was spread over the beds. Another installation was made at the Tennessee Division of Forestry's East Tennessee Nursery near Delano in buttonbush (*Cephalanthus occidentalis*). Although this nursery had previously been included in a PAC trial studying its effect on three oak species (Research Report 13-05), a small-seeded species such as buttonbush (approx. 120,000 seeds per pound) was examined. Two application rates were used (0 and 34 oz/ac) in this trial and because buttonbush was sown 6 weeks prior to spray application, weeds present in the study areas were removed by hand to simulate 'at sowing' ground conditions (see Figure 4). All herbicide applications were made by Nursery Cooperative personnel with a CO_2 hand sprayer calibrated to broadcast spray 25 gallons per acre.

Each treatment was one seedling bed wide by 10 feet in length that was replicated 5 times. Seedling density was determined from each plot at the end of the growing season in November or December of 2014. From each treatment, a sample of either 25 pine seedlings or all of the buttonbush seedlings within the counting frame was removed from the beds and transported to the SFNMC laboratory in Auburn for evaluation of seedling tolerance to the herbicide. These sample seedlings were evaluated for shoot height, RCD, stem galls and root and shoot dry weights for biomass determinations and compared to the non-treated (0.0 oz/ac) control seedlings. Differences in these parameters from the control (no herbicide applications) would indicate PAC effect on the species tested.

RESULTS AND DISCUSSION

Container seedling studies

The SFNMC has conducted multiple studies of the effect of Pendulum® AquaCap™ in bareroot nurseries but none have been installed in containerized nursery systems. Of particular interest is the interaction of PAC with organic media or capping material in containers compared to those soil types found in bareroot nurseries. Another component of this study is the potential of PAC to stop black willow root and shoot growth after germination, which could provide an alternative to expensive hand-weeding or discarding of seedling plugs with black willow.

Similar to results of bareroot studies, results of this PAC trial showed that when PAC is applied to containerized loblolly or slash **at the time of sowing**, it has no negative effect on seedling survival (as measured by percent fill of trays), shoot height, or shoot weight (Tables 1, 2, 3). In loblolly, RCD was unaffected at one nursery and decreased at the high rate only at one nursery. Plug weights of treated and untreated loblolly seedlings showed no differences, although plug weights of treated slash pine were slightly negatively affected by PAC applications at both rates. No galls were detected on any seedlings. To compare any effect of PAC in containers with different capping materials, a study installed at one site, in one species and in one container type with both capping materials tested would be needed. Although this was not done in this current study, the use of PAC applied over sawdust at one nursery and fine crushed rock at a second nursery in loblolly-sown containers produced similar results on seedling growth characteristics, except for RCD measurements at the high rate.

Although black willow populations were reported as “light” by nursery managers this year, the analysis of willow seedlings in the treated vs control at IFCO showed a statistically significant decrease, in two installations (loblolly and slash pine) at both low and high rates of PAC. Willow populations in treated and untreated trays at Westervelt were statistically equal. Perhaps the most promising aspect of weed control in this study are the measures of control of ‘other’ weeds. The difference in the number of ‘other’ weeds recorded in treated trays at IFCO showed a significant decrease at both rates when compared to counts of ‘other’ weeds in untreated trays (Tables 1 and 3). These weeds, identified at the conclusion of the study in November, included annual sedge, spurge and grass. To adequately measure weed control (other than willow), counts of weeds should be made in more frequent intervals than only at the conclusion as in this study. More frequent weed counts such as at 30, 45, and 60 days after treatment would provide a more accurate account of PAC effect on weeds.

Bareroot seedling studies

Results of these trials in bareroot loblolly and slash pine are comparable to previous SFNMC studies using Pendulum® AquaCap™ (Research Reports 08-05; 09-01; 10-04; 12-01; 14-01). No differences in seedling growth were seen when comparing untreated control seedlings to those treated at either rate of PAC (Tables 4 and 5). No negative effects were indicated in measures of seedling density, shoot height, RCD, shoot weight, root weight or percent culls in either species, expressing a tolerance to PAC when applied over the top at the time of sowing. Additionally, no stem galls were evident in either species at either rate, which successfully demonstrates the recommendation to apply PAC at the time of sowing to avoid gall formation. Weed pressure was inadequate in beds of either species in November to conclude effect on weed control.

The inclusion of buttonbush in this PAC trial was made to determine its effect on a hardwood species with small seed, as seed size is generally seen as affecting germination rate, establishment and plant vigor. A 2012 SFNMC study (Research Report 13-03) was installed to determine the effect of PAC on large and small-seeded hardwood species and included large-seeded species of silver maple and blackgum and small-seeded species of sycamore, sweetgum, red maple, green ash and pear. Of these, sycamore (150,000 seed/lb.) and sweetgum (82,000 seed/lb.) are the most comparable to buttonbush (120,000 seed/lb.) in seed size. In the 2012 study, sycamore did not germinate so no results were available. Sweetgum seedling density and size was negatively affected by two rates of PAC applied three days after sowing. In comparison, results of this buttonbush trial using only the low rate of PAC (34 oz/ac) showed no effects of PAC on treated seedlings compared to untreated control seedlings (Table 6). Differences in results of the 2012 and current study may be attributed to species or soil type, but are likely due to the different times of PAC application. The 2012 study PAC application was made only three days after sowing, where this buttonbush trial PAC application was made at 6 weeks post-sowing. Numerical comparisons of the two trials cannot be made since the 'at sowing' study and '6 weeks post-sowing' study were not made in the same sowing season, nursery or species. However, the results of the buttonbush study are species-specific and show that PAC has no negative effect on seedling density, shoot height, RCD, shoot weight and root weight when applied 6 weeks post-sowing. The effect of PAC on weed control was not included as the study area was hand-weeded during operational weed removals in the nursery.

MANAGEMENT IMPLICATIONS

- As reported in previous SFNMC studies, the use of Pendulum® AquaCap™ in bareroot loblolly and slash pine applied **at the time of sowing** has no detrimental effect on seedling growth.
- The effect of PAC in small-seeded hardwood species may be species-dependent, so small test areas should be installed in each species of interest to nursery managers. The low rate (34 oz/ac) of PAC should be used and applied at sowing and at 6 weeks post-sowing to compare effects on germination and growth. When using PAC in hardwood, the inclination to wait at least 6 weeks post-sowing for seedlings to grow as a precaution against herbicide damage also provides a window of opportunity for weeds to germinate and grow. Pendulum® AquaCap™ is labelled as a preemergent herbicide.

- Most containerized seedling growth characteristics were unaffected by PAC applications made **at sowing** over loblolly and slash pine containers. Measurements of lower loblolly RCD at the high rate and lower slash plug weights at both rates indicate a possible negative effect on root growth. Additional studies in these two species and expansion to include other species are planned for 2016 studies by the SFNMC.
- The use of PAC **at sowing** to control black willow in containerized systems shows promise as quantities of willow were reduced in treated trays. However, the population of willow during this study was insufficient to make a recommendation specifically for its control. Additional installations of this study made one week apart during willow seed fall could provide control information if willow populations are adequate.
- For control of weeds other than willow, the application of Pendulum® AquaCap™ **at sowing** on containerized loblolly and slash pine is an option to consider. Further studies are warranted to follow up on the success of weed control with PAC in this study before operational recommendations can be made.

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Table 1. Container loblolly pine seedling characteristics treated with Pendulum® AquaCap™, IFCO Nursery, Moultrie, GA.

Rate	Survival[1] (% Fill)	Shoot Height (cm)	Seedling RCD (mm)	Shoot Weight (g)	Plug Weight[2] (g)	Willow[3] (No./container)	Other Weeds[3] (No./container)
Control	89.4	24.8	4.19 a	2.3	10.5	0.5 a	2.2 a
Low	93.0	25.1	4.08 ab	2.2	10.6	0.1 b	0.7 b
High	92.1	24.8	4.01 b	2.2	10.6	0.0 b	0.3 b

Different letters (a, b) within a seedling characteristic column indicate significant treatment difference in rates according to Duncan's Multiple Range test at alpha = 0.05. Underlined means within a seedling characteristic indicate significant treatment difference from that of the non-treated Control at that rate according to Dunnett's T-test at alpha = 0.05.

[1] Percent survival based on tray seedling count made in November compared to total number of cells initially sown.

[2] Plug weight includes both media and root dry weight.

[3] Counts of willow or other weeds per tray were made in November at the conclusion of the study.

Table 2. Container loblolly pine seedling characteristics treated with Pendulum® AquaCap™, Westervelt Nursery, Eutaw, AL.

Rate	Survival[1] (% Fill)	Shoot Height (cm)	Seedling RCD (mm)	Shoot Weight (g)	Plug Weight[2] (g)	Willow[3] (No./container)	Other Weeds[3] (No./container)
Control	95.9	29.1 b	3.85	1.7	7.9 a	1.5	0.1
Low	95.7	29.8 a	3.80	1.7	7.7 b	1.7	0.2
High	96.0	30.2 a	3.84	1.7	7.8 ab	1.1	0.1

Different letters (a, b) within a seedling characteristic column indicate significant treatment difference in rates according to Duncan's Multiple Range test at alpha = 0.05. Underlined means within a seedling characteristic indicate significant treatment difference from that of the non-treated Control at that rate according to Dunnett's T-test at alpha = 0.05.

[1] Percent survival based on tray seedling count made in November compared to total number of cells initially sown.

[2] Plug weight includes both media and root dry weight.

[3] Counts of willow or other weeds per tray were made in November at the conclusion of the study.

Table 3. Container slash pine seedling characteristics treated with Pendulum® AquaCap™, IFCO Nursery, Moultrie, GA.

Rate	Survival[1] (% Fill)	Shoot Height (cm)	Seedling RCD (mm)	Shoot Weight (g)	Plug Weight[2] (g)	Willow[3] (No./container)	Other Weeds[3] (No./container)
Control	90.1	30.7	4.18	2.2	10.0 a	0.3 a	5.0 a
Low	91.5	30.3	4.19	2.1	9.8 b	0.0 b	1.3 b
High	93.0	29.8	4.17	2.1	9.8 b	0.0 b	0.8 b

Different letters (a, b) within a seedling characteristic column indicate significant treatment difference in rates according to Duncan's Multiple Range test at alpha = 0.05. Underlined means within a seedling characteristic indicate significant treatment difference from that of the non-treated Control at that rate according to Dunnett's T-test at alpha = 0.05.

[1] Percent survival based on tray seedling count made in November compared to total number of cells initially sown.

[2] Plug weight includes both media and root dry weight.

[3] Counts of willow or other weeds per tray were made in November at the conclusion of the study.

Table 4. Bareroot loblolly pine seedling characteristics treated with Pendulum®AquaCap™, Jesup Nursery, Jesup, GA.

Rate	Density (ft^2)	Shoot Height (cm)	Seedling RCD (mm)	Root Weight (g)	Shoot Weight (g)	Galls[1]	Percent Culls[2,3]	Weeds[4] (ft^2)	
								May	Nov
Control	16.5	26.5	4.34	0.4	2.7	0	20.0	0	0.1
Low	19.5	29.2	4.36	0.4	2.9	0	14.4	0	0.1
High	17.7	27.4	4.34	0.4	2.7	0	11.2	0	0.4

Different letters (a, b) within a seedling characteristic column indicate significant treatment difference in rates according to Duncan's Multiple Range test at alpha = 0.05.Underlined means within a seedling characteristic indicate significant treatment difference from that of the non-treated Control at that rate according to Dunnett's T-test at alpha = 0.05.

[1] Stem gall code assigned to each stem within 25-tree sample per replication; 0 = no gall present 1 = gall present.

[2] Percent Culls based on number of seedlings with RCD<3.5mm within 25-tree sample per replication.

[3] Beds within this study were heavily washed-out during the summer and contain a higher number of culls than would normally be expected.

[4] May data are initial weed counts per square foot at time of herbicide application; November data are weed counts per square foot at time of field study completion.

Table 5. Bareroot slash pine seedling characteristics treated with Pendulum®AquaCap™, Jesup Nursery, Jesup, GA.

Rate	Density (ft^2)	Shoot Height (cm)	Seedling RCD (mm)	Root Weight (g)	Shoot Weight (g)	Galls[1]	Percent Culls[2]	Weeds[3] (ft^2)	
								May	Nov
Control	15.5	27.0	5.53	0.7	4.8	0	2.4	0	0
Low	13.5	25.0	5.24	0.6	4.3	0	5.6	0	0
High	13.9	27.1	5.68	0.7	4.9	0	1.6	0	0

Different letters (a, b) within a seedling characteristic column indicate significant treatment difference in rates according to Duncan's Multiple Range test at alpha = 0.05.Underlined means within a seedling characteristic indicate significant treatment difference from that of the non-treated Control at that rate according to Dunnett's T-test at alpha = 0.05.

[1] Stem gall code assigned to each stem within 25-tree sample per replication; 0 = no gall present 1 = gall present.

[2] Percent Culls based on number of seedlings with RCD<3.5mm within 25-tree sample per replication.

[3] May data are initial weed counts per square foot at time of herbicide application; November data are weed counts per square foot at time of field study completion.

Table 6. Bareroot buttonbush seedling characteristics treated with Pendulum®AquaCap™, East Tennessee Nursery, Delano, TN.

Rate	Density (ft^2)	Shoot Height (cm)	Seedling RCD (mm)	Root Weight (g)	Shoot Weight (g)
Control	6.3	62.4	7.09	6.2	6.7
Low	6.3	63.2	7.76	6.8	7.6

Different letters (a, b) within a seedling characteristic column indicate significant treatment difference in rates according to Duncan's Multiple Range test at alpha = 0.05.Underlined means within a seedling characteristic indicate significant treatment difference from that of the non-treated Control at that rate according to Dunnett's T-test at alpha = 0.05.

Figure 1. Trays of Week 6 of Pendulum®AquaCap™ application made one day post-sowing at IFCO Nursery near Moultrie, GA.

Figure 2. Application of Pendulum®AquaCap™ to Week 1 trays made on day of sowing at The Westevelt Company Nursery near Eutaw, AL.

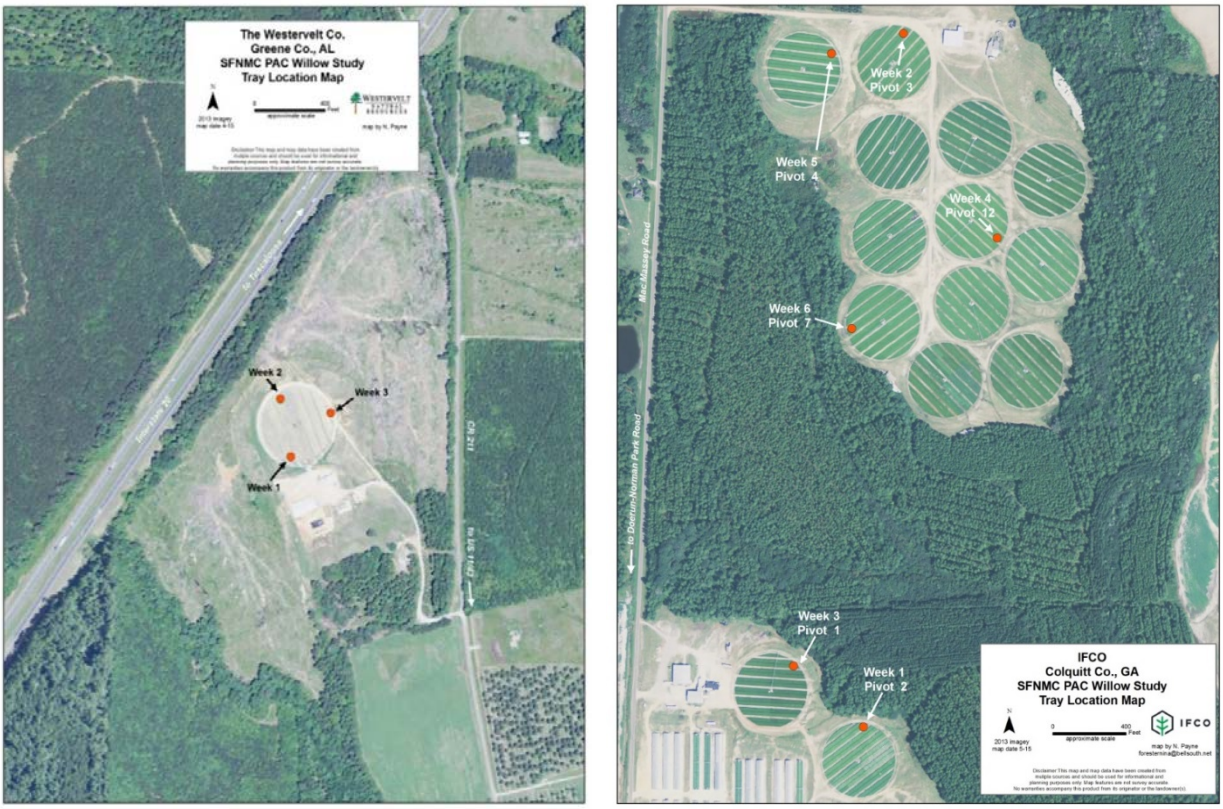

Figure 3. Locations of Pendulum®AquaCap™ installations at IFCO (6 weeks) and Westervelt (3 weeks).

Figure 4. Buttonbush trial prior to Pendulum®AquaCap™ application at East Tennessee Nursery near Delano, TN. Seedlings are six weeks old