Auburn University
Southern Forest Nursery
Management Cooperative

RESEARCH REPORT 16-04

EFFECT OF RATE OF OVER-THE-TOP APPLICATIONS OF MARENGO® (INDAZIFLAM) ON WEED CONTROL AND TOLERANCE IN BAREROOT AND CONTAINER-GROWN PINE SEEDLINGS AND OF TIMING OF DIRECTED SPRAY MARENGO® (INDAZIFLAM) APPLICATIONS ON WEED CONTROL AND TOLERANCE IN PIN OAK

by
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INTRODUCTION

In 2013 and 2014, the Southern Forest Nursery Management Cooperative installed herbicide studies in bareroot and container nurseries to study the effects of over-the-top applications of Marengo (7.4% indaziflam) on loblolly, slash, longleaf and shortleaf pine seedlings. This new herbicide, available in 2013, was targeted for use primarily in the ornamental horticulture market. The herbicide acts to prevent weed seed germination by inhibiting cell wall formation, division and elongation predominantly in roots. Because several of the most commonly found weeds in member nurseries are listed as controlled or suppressed on the Marengo® label (spurge, teaweed, doveweed, pigweed, horseweed, eclipta, coffeeweed, annual sedge and goosegrass), these studies were installed to determine four pine species' tolerance to the herbicide and its effect on weeds present. The results of the 2013 study, found in Research Report 14-05, showed that use of the herbicide at all rates applied at the time of sowing of bareroot loblolly pine significantly reduced seedling densities. However, when the herbicide was applied at either 6 or 12 weeks post sowing, the herbicide had no effect on seedling densities, shoot height and root-weight ratios when applied at low (3.25 oz/acre) and medium rates (7.5 oz/acre). Because the lower rate applied at 6weeks post-sowing may control nursery weeds AND have no negative effect on seedling quality, further studies were installed in 2014 in a container nursery. The 2014 trials were to evaluate the herbicide's effectiveness in controlling a prevalent weed (black willow Salix nigra) in container production systems and to determine the effect of Marengo® on container-grown loblolly, longleaf, slash and shortleaf pine. Results of these studies were reported in Research Report 15-01 and showed that the effect of Marengo® applied over the top of container conifers is species–dependent. Longleaf pine was the least tolerant of the four species tested. Stem swelling was also observed and recorded at a higher incidence in slash pine than on either loblolly or shortleaf pine. The long-term effect of Marengo® in containers, as measured by RGP through the production of new white root tips, was inconclusive.

To continue the evaluation of Marengo®'s suitability as part of conifer seedling production for weed control, in 2015, trials using Marengo® were expanded to include three conifer species at four bareroot nurseries, four species at two container nurseries and a directed spray study in one species at one nursery. The objectives of these Marengo® trials were to 1) evaluate bareroot eastern red cedar and loblolly and slash pine seedlings' tolerance to different post-emergent application

rates of Marengo®, 2) evaluate the tolerance of container-grown loblolly, longleaf, shortleaf and slash pine seedlings to different post-emergent application rates of Marengo®, 3) evaluate pin oak tolerance to directed spray applications of Marengo® at single and multiple applications, and 4) determine its efficacy on weed control, particularly black willow, with different post-emergent application rates.

METHODOLOGY

Bareroot seedling studies

Trials in bareroot nurseries were installed at the Georgia Forestry Commission's Flint River Nursery, the Tennessee Division of Forestry's East Tennessee Nursery, and Plum Creek's Pearl River (MS) and Jesup (GA) nurseries. Three species were included: eastern red cedar (at Flint River Nursery), loblolly pine (at Jesup, Pearl River and East Tennessee nurseries) and slash pine (at Jesup, Pearl River and Flint River nurseries). All nurseries received applications of Marengo® between 6 and 8 weeks post-sowing, using four rates of 0.0 oz/ac, 3.75 oz/ac, 7.5 oz/ac and 11.25 oz/ac. The exception to this spraying regime was the application of Marengo® to eastern red cedar at 20 weeks post-sowing due to its winter sowing.

All herbicide applications were made by Nursery Cooperative personnel with a CO_2 hand sprayer calibrated to broadcast spray 25 gallons per acre. Watering-in, as recommended on the Marengo® label, was done operationally on the nursery's irrigation schedule after the herbicide was applied. Weeds were counted prior to herbicide application and at the end of the growing season.

For each species tested, a treatment plot was one seedling bed wide by 10 feet in length and replicated 5 times; with eastern red cedar, plots were only five feet in length. Seedling density measurements were made from each plot at the end of the growing season in October or November in 2014 or January of 2015. A sample of 25 seedlings from each treatment plot (cedar sample size was 50 seedlings) were removed from the beds and transported to the SFNMC laboratory in Auburn for evaluation of seedling tolerance to the herbicide. These 25 seedlings were evaluated for shoot height, RCD, stem swellings and root and shoot dry weights for biomass determinations and compared to the non-treated (0.0 oz/ac) control seedlings. Differences in these seedling parameters from the control (no herbicide applications) would indicate Marengo® effect on the species tested.

Container seedling studies

These trials were conducted at IFCO's nursery in Moultrie, Georgia on containers sown to loblolly, slash, longleaf and shortleaf pine, at The Westervelt Company's nursery near Eutaw, Alabama on containers sown to loblolly pine and at Plum Creek's River Bend nursery near Hazlehurst, Mississippi on loblolly pine sown in both plastic and styroblock containers. Four application rates (0.0 oz/ac, 3.75 oz/ac, 7.5 oz/ac and 11.25 oz/ac) were used at each nursery on each species. The seedlings were treated at either 6 or 7 weeks post sowing for loblolly, 7 weeks post-sowing for slash and longleaf, and 8 weeks post sowing for shortleaf pine. All herbicide applications were made by Nursery Cooperative personnel with a CO_2 hand sprayer calibrated to broadcast spray 25 gallons per acre. Watering-in, as recommended on the Marengo® label, was done operationally on the nursery's irrigation schedule after the herbicide was applied. Prior to herbicide application,

pine seedling counts were made in each tray, as were the number of black willow and other weeds in each tray.

Each treatment was one seedling tray for each species that was replicated ten times for each herbicide rate. At IFCO, loblolly pine was sown in trays of 40 cells per tray, longleaf was sown in trays of 128 cells per tray, slash was sown in trays of 120 cells per tray and shortleaf was sown in trays of 45 cells per tray. At Westervelt, trays contained 204 cells. Plastic trays at Plum Creek's nursery contained 128 cells and styroblock trays contained 112 cells. All seedling, willow and weed counts were made from each tray in October, November or December of 2014. Due to nursery needs, the shortleaf study seedlings were removed and packed prior to seedling and weed counts, so information on shortleaf pine is unavailable for this trial. A random sample of 10 seedlings from each tray x rate application were removed and brought to the SFNMC laboratory in Auburn for evaluation of seedling growth characteristics. These 10 seedlings were evaluated for shoot height, RCD, stem swellings and root and shoot dry weights for biomass determinations and compared to the non-treated (0.0 oz/ac) control seedlings. Any differences between treated and non-treated seedlings wound indicate lack of tolerance to the herbicide. In addition, 30 seedlings from each species from each nursery (with the exception of seedlings from styroblock trays) were placed into treatment-designated aerated tanks to determine RGP as measured by the formation of white root tips 30 days later. Differences in RGP may suggest possible long-term effects from the Marengo® applications that may occur at outplanting.

Directed spray study

This study was conducted at the Tennessee Division of Forestry's East Tennessee Nursery near Delano, Tennessee in nursery beds sown to pin oak (*Quercus palustris*). A tractor-mounted directed spray attachment designed and built by the East Tennessee Nursery staff was used to apply a single rate (3 oz/ac) of Marengo® in single and multiple applications (0, at 20 weeks post-sowing, at 20 and 23 weeks post-sowing, and at 20, 23 and 26 weeks post-sowing) as seen in Figures 1 and 2. The first application was timed to be made when the majority of the seedlings were at least 6" in height.

Each treatment area was one seedling bed wide and 100' in length and replicated 5 times (500 ft. total). Five seedling beds were used in order to establish one block of each of the 4 treatments within a single bed. Within each treatment, 3 permanent plots were established in order to count weed density prior to the herbicide applications and to count weed and seedling density in December at the end of the growing season. The seedling density counts in December included both a total count and number of seedlings whose RCD < 0.25" or 6.4 mm (culls). Any differences in the percent culls from the control (no herbicide applications) when compared to treated areas would indicate an intolerance of Marengo® on pin oak.

RESULTS AND DISCUSSION

Bareroot seedling studies

The effect of Marengo® on the growth of bareroot loblolly pine, slash pine and eastern red cedar seedlings over the growing season was dependent on the tree species tested. Overall, loblolly and slash pine exhibited little to no negative effects on seedling quality when treated with the herbicide

(Tables 1-6) indicating a tolerance to the herbicide when sprayed over the top of seedlings. Surprisingly, red cedar had an increase in seedling characteristics measured when compared to the non-treated controls (Table 7). This included shoot height, RCD, shoot and shoot weight. None of the 3 rates of Marengo® applied over the top of loblolly and slash pine seedlings had any negative effect on density, shoot height, root weight and percent culls when compared to the untreated control seedlings. Shoot weights for both species were also unaffected by the herbicide except in the slash pine treated at the low rate at the Pearl River nursery, where a lower shoot weight was observed. Data for loblolly pine are found in Tables 1, 2 and 3, while data for slash pine are found in Tables 4, 5, and 6. As noted in Research Report 15-01, there appears to be a slight stem swelling on slash pine seedlings when the compound is sprayed over the top of seedlings. This possibility of gall formation or stem swelling was reported in previous SFNMC studies (Research Reports 09-01; 10-04; 11-05; 15-01) with the use of Pendulum® AquaCap™ (pendimethalin) or Marengo® (indaziflam). In these current studies, stem swelling was recorded for each treatment as 0=no stem swelling, 1=slight stem swelling, 2=moderate stem swelling and 3=obvious stem swelling. Slight stem swelling was seen in loblolly only at the Jesup nursery at the high rate; although some stem swelling was observed in slash pine at the high rate, it was an average of less than 1 (slight stem swelling) at all nurseries (Tables 4-6). Because the effect of stem swellings can result in larger RCD measurements, those seedlings with increased stem swelling had slightly increased RCD measurements than untreated controls. This was observed only at the high rate at the Jesup nursery in both loblolly and slash pine (Tables 1 and 4).

In eastern red cedar beds, the use of Marengo® resulted in increased seedling growth when compared to untreated control plots (see Figure 3). Seedling densities, shoot heights, shoot weights and root weights increased with increasing rates of the herbicide, with significant increases in these 4 characteristics at the high rate (11.25 oz/ac) and in shoot and root weight at the medium rate (7.5 oz/ac) (Table 7). No significant differences were seen in RCD at any rate when compared to the untreated control. Related to this lack of RCD differences was the observation that no indication of stem swelling was found. Clearly, additional studies should be conducted in eastern red cedar to determine if this increase in seedling characteristics is real. Generally, one does not expect a herbicide to increase seedling growth when used, although eastern red cedar is a different Family, so perhaps the active ingredient of Marengo® when sprayed over the top just may increase overall production of different tree species.

Because common bareroot nursery weeds are listed as controlled or suppressed on the Marengo® label, it is expected that those listed weeds will be controlled under proper field conditions and application procedures. In these current studies, weed control data was collected at the installations in June and at the conclusion of the studies. Targeting a specific weed or weeds for control in a study will require additional, more frequent weed counts, such as at initial treatment and at 30, 45 and/or 60 DAT (days after treatment), and compared to control plots. In a 2014 study of 17 herbicides tested for weed control conducted by Hillsborough County (FL) Extension, Marengo® was shown to be the most effective at 30 days after treatment (http://fshs.org/proceedings-x/2014-vol-127/FSHS_vol_127/170-171.pdf). At all nurseries (Jesup, Pearl River, Flint River and East Tennessee) and in all 3 species (loblolly, slash and cedar), the use of Marengo® resulted in no difference in weed density. This is attributed to spring/summer weeds counted at study installation naturally not being present in late fall and winter and to hand-weeding in some study areas during the growing season.

Container seedling studies

As in the bareroot seedling studies, the effect of the herbicide on the growth of containerized conifer seedlings was dependent on the tree species tested. Additionally, within loblolly pine, the results varied by nursery and tray container type.

In the slash pine trial installed at IFCO, seedling survival, shoot height and shoot weight of seedlings from herbicide-treated trays showed no differences when compared to seedlings in untreated control trays. When applied over slash pine seedlings, the herbicide appears to cause stem swellings. This is evident in the RCD measurements as the root collar diameters of seedlings in trays at all rates resulted in an increase over non-treated control trays (Table 8). The increase in RCD is attributed to a corresponding increase in stem swelling at the medium and high rates, although the stem swelling increase at the low rate of Marengo® (3.75 oz/ac) was not significant. There appears to be an effect on root development as well as seedling plug weights (containing both roots and media) were significantly less at the high rate when compared to the non-treated and lower rates (Table 8). One method to determine long-term herbicide carry-over on root development is Root Growth Potential, RGP. Herbicide-treated slash pine seedlings were placed in aerated aquariums for 30 days to assess RGP. Treated slash pine seedlings resulted in no differences in the number of white root tips produced when compared to those of untreated control seedlings. So, while there appears to be less root growth in containers, the RGP test indicates no long-term carry-over and poor survival after outplanting related to the use of Marengo® over slash pine seedlings.

Longleaf pine seedlings treated at IFCO had no effect on seedling survival, shoot height and shoot weight when compared to untreated seedlings (Table 9). This is in sharp contrast with a previous study in 2014 when root weights showed significant decreases in treated trays when compared to untreated control trays (Research Report 15-01, Table 4c). Like slash pine, when longleaf pine was examined for RGP, there were no differences in the production of white root tips on untreated control seedlings compared to treated seedlings at all rates. While root growth potential (as indicated by white root tips) was not affected in this year's study, the decrease in longleaf seedling growth as measured by root collar diameter and root or plug weight in two studies indicates that this species is more sensitive to Marengo® when used for weed control in containerized longleaf seedlings.

Four installations of Marengo® were made over loblolly pine at IFCO, Plum Creek River Bend (2) and Westervelt nurseries. When compared to untreated seedlings, seedling survival was unaffected by the herbicide use at three nurseries, but decreased at the high rate of Marengo® in styroblock trays at River Bend (Table 13). Shoot height was unaffected at two nurseries and showed an increase at the medium rate (7.5 oz/ac) at two nurseries, IFCO (Table 10) and River Bend in styroblock trays (Table 13). Root collar diameters were larger in three trials when treated with Marengo®, but were unaffected at one nursery. Shoot dry weights were not different from the untreated control seedlings at three installations. The root or plug weights of treated seedlings resulted in decreasing root or plug weights at all rates of the herbicide at IFCO and Westervelt (Tables 10, 11) and at medium and high rates in River Bend styroblock trays (Table 13.). Similarly, the presence and amount of stem swelling on treated seedlings was consistent in all 4 installations. Stem swelling was identified at the high rate (11.25 oz/ac) at all nurseries but was limited (Tables 10-13). The number of white root tips produced after a 30-day period in treatment-assigned aerated

tanks varied by nursery. Results from one nursery showed an increasing trend in the number of white root tips on treated seedlings as the herbicide rate increased; one nursery had a significant decrease in the number of white root tips at the high rate of Marengo® (see Figure 4, Table 12) while another had a significant increase in white root tips at the medium rate (Table 10).

Measures of weed control were made by comparing willow and other weeds at installation and again at completion within each treatment. No differences were noted when comparing the increase or decrease in willow population of treated trays to untreated control trays. Rather than reporting this as evidence of a lack of Marengo® effect, this is a function of the relative absence of willow in the studies this year (see Figure 5). It was reported by all nurseries involved that this year was a light year for willow populations. Results from a previous study in containerized pine (Research Report 15-01) note that the use of Marengo® at all rates and times of application decreased the number of willow and weeds in treated trays. Similar results were found in the comparison of the presence or absence of other weeds in trays.

Because of the absence of willow during this trial and the inconclusive results on seedling characteristics, especially in loblolly pine, additional studies are needed before recommending use of Marengo® in containerized pine operations.

Directed spray study

In the production of ornamental plants, the label of Marengo® recommends that it be applied as a directed spray to the soil surface and to limit herbicide contact on foliage, especially young leaves. Four species of oak are listed as tolerant to Marengo® (live oak, northern red oak, Shumard oak and Nuttal oak). To determine Marengo's effectiveness as a direct spray, rather than over the top, this study was installed in pin oak (*Quercus palustris*) when the majority of seedlings were at least 6". When comparing seedlings in 100' control plots to those receiving a single application, there were no differences in seedling density or in percent culls (Table 14). However, when multiple applications were made in plots sprayed twice (on June 9 and June 30), oak seedling densities and percent culls were higher (Table 14). The number of plantable seedlings (RCD> 0.25") showed no differences across all treatments when compared to the control plots.

Comparing weed pressure among the plots resulted in no differences in the number of weeds. Few weeds were counted at the initiation of the study in any treatment, and by the conclusion of the study in December, few to no weeds were recorded in counting frames within each treatment. This nursery's standard weed control program was sufficient for controlling weeds before this study was installed and by the third application of Marengo® (June 21), crown closure of the pin oaks had occurred, limiting the amount of sunlight on the beds which prevented additional weed germination and growth.

MANAGEMENT IMPLICATIONS

- As part of a weed control program in bareroot nurseries, the application of Marengo® over the top of loblolly and slash pine seedlings appears to provide an additional herbicide option when applied at least 6 weeks post-sowing. Timing of sprays is important as applications made prior to 6 weeks post-sowing may damage seedlings (Research Report 14-05) and sprays made after weeds are well-established will have limited effect, according

to the herbicide label. Slash pine seems more sensitive to Marengo® at the high rates that appears as a slight stem swelling.

- Because the use of Marengo® in eastern red cedar seedling beds increased seedling density and size in all measured characteristics, it may be an option to consider for both weed control and increased production. Additional studies with larger treatment areas are warranted.
- Directed-spray applications of the herbicide are recommended on its label to minimize damage to young growing tissue. Directed spray applications in hardwood made after seedlings reach an acceptable height to avoid contact with herbicide spray and prior to crown closure may be an additional herbicidal option for weed control.
- For weed control in container-grown loblolly and slash pine, applications of Marengo® at lower rates made early enough in the season to stay ahead of weed establishment may provide adequate willow and weed control. Slash pine seems more sensitive to Marengo at the high rates that appears as a slight stem swelling.
- In both bareroot and container nurseries, applied over-the-top or by directed spray, Marengo® can be an important option when considering rotation of herbicides based on their modes of action. Because indaziflam (the active ingredient in Marengo®) is one of the first of Mode of Action Group 29, it can used in rotation with more frequently used herbicides to diminish the shifting of weed species composition.

However:

- In all 3 containerized pine species included in this study, the herbicide tends to lower root or plug weights when used. This may indicate a negative effect in container plugs. Additional studies are needed to measure this root growth effect, which may discount the use of Marengo® in containerized systems.
- Longleaf pine is sensitive to Marengo®. Because this study and a previous study (Research Report 15-01) report negative effects of Marengo® on longleaf pine seedling characteristics (lower shoot heights and weights in one study, smaller root collar diameters in one study and lower root or plug weights in both studies) when compared to the control, Marengo® should not be considered for weed control in longleaf container production systems. An additional study may confirm these observations and clarify which seedling characteristics are most affected.
- In container studies, the use of counts of white root tips to measure root growth potential showed low possibility of Marengo® carryover in the root plugs in slash and longleaf pine. Loblolly pine results were inconclusive. Because this study was designed to isolate seedlings in aerated tanks by treatment, it should be repeated for additional information. Also, two outplanting studies have been established to determine any carryover Marengo® effects on survival and seedling growth after outplanting (see Figure 6).
- Staff at nurseries interested in using Marengo® for weed control, especially those interested in its use as a rotational herbicide to minimize weed shifts, should establish a small test treatment area within each species using the herbicide at low rates at least 6 weeks post-sowing. Application with a directed sprayer will provide additional desired species protection and increased herbicide application to the soil as its recommended application location.

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Table 1. Bareroot loblolly pine seedling characteristics treated with Marengo®, Jesup Nursery, Jesup, GA.

Rate	Density (ft^2)	Shoot Height (cm)	Seedling RCD (mm)	Root weight (g)	Shoot weight (g)	Swelling[1]	Percent Culls[2]	Weeds (ft^2)[3] June	Nov
Control	22.1	29.1	4.44 b	0.5	3.0	0.0 b	5.6	0	0
Low	22.5	29.1	4.81 b	0.6	3.4	0.0 b	2.4	0	0
Medium	21.5	28.9	4.93 ab	0.6	3.2	0.1 b	6.4	0	0
High	19.8	27.3	5.51 a	0.5	3.2	1.1 a	4.8	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 swelling at the ground line based on 0-3 scale with 0=none, 1=slight, 2=moderate, 3=obvious.

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

[3] June 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 2. Bareroot loblolly pine seedling characteristics treated with Marengo®, Pearl River Nursery, Hazlehurst, MS.

Rate	Density (ft^2)	Shoot Height (cm)	Seedling RCD (mm)	Root weight (g)	Shoot weight (g)	Swelling[1]	Percent Culls[2]	Weeds (ft^2)[3] June	Oct
Control	24.6	37.8 a	4.34	0.4	3.3	0	8.0	0.1	0.0
Low	22.8	37.8 a	4.52	0.5	3.6	0	5.6	0.2	0.1
Medium	23.3	36.8 b	4.46	0.5	3.4	0	5.6	0.1	0.0
High	23.4	37.7 ab	4.58	0.5	3.6	0	2.4	0.0	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 swelling at the ground line based on 0-3 scale with 0=none, 1=slight, 2=moderate, 3=obvious.

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

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

Table 3. Bareroot loblolly pine seedling characteristics treated with Marengo®, East Tennessee Nursery, Delano, TN.

Rate	Density (ft²)	Shoot Height (cm)	Seedling RCD (mm)	Root weight (g)	Shoot weight (g)	Swelling[1]	Percent Culls[2]	Weeds (ft²)[3] June	Weeds (ft²)[3] Nov
Control	45.2	32.2	4.71	0.45 b	3.2 b	0.0 b	5.6	0	0
Low	43.0	31.5	4.72	0.53 a	4.0 a	0.0 b	5.6	0	0
Medium	44.7	31.9	4.79	0.49 ab	3.4 b	0.0 b	3.2	0	0
High	47.9	33.3	4.77	0.46 ab	3.0 b	0.2 a	4.0	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 swelling at the ground line based on 0-3 scale with 0=none, 1=slight, 2=moderate, 3=obvious.

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

[3] June 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 4. Bareroot slash pine seedling characteristics treated with Marengo®, Jesup Nursery, Jesup, GA.

Rate	Density (ft²)	Shoot Height (cm)	Seedling RCD (mm)	Root weight (g)	Shoot weight (g)	Swelling[1]	Percent Culls[2]	Weeds (ft²)[3] June	Weeds (ft²)[3] Nov
Control	18.6	30.4	4.98 b	0.5	3.9	0.0 b	5.6	0.0 b	0.1
Low	19.1	30.4	4.91 b	0.4	3.8	0.0 b	4.8	0.0 b	0.0
Medium	18.0	29.7	5.24 ab	0.5	4.0	0.1 b	4.0	0.0 b	0.0
High	17.4	29.9	5.54 a	0.5	4.0	0.5 a	1.6	0.1 a	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 swelling at the ground line based on 0-3 scale with 0=none, 1=slight, 2=moderate, 3=obvious.

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

[3] June 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 Marengo®, Pearl River Nursery, Hazlehurst, MS.

Rate	Density (ft²)	Shoot Height (cm)	Seedling RCD (mm)	Root weight (g)	Shoot weight (g)	Swelling[1]	Percent Culls[2]	Weeds (ft²)[3] June	Weeds (ft²)[3] Oct
Control	20.3	28.6	4.22	0.3	3.1 a	0.0	20.0	0.4	0.5
Low	21.3	24.5	4.07	0.3	2.2 b	0.1	21.6	0.9	0.4
Medium	21.4	30.0	4.51	0.3	3.1 a	0.1	10.4	1.0	0.1
High	19.1	25.6	4.56	0.3	2.6 ab	0.5	7.2	0.6	0.3

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 swelling at the ground line based on 0-3 scale with 0=none, 1=slight, 2=moderate, 3=obvious.

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

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

Table 6. Bareroot slash pine seedling characteristics treated with Marengo®, Flint River Nursery, Byromville, GA.

Rate	Density (ft²)	Shoot Height (cm)	Seedling RCD (mm)	Root weight (g)	Shoot weight (g)	Swelling[1]	Percent Culls[2]	Weeds (ft²)[3] June	Weeds (ft²)[3] Jan
Control	29.7	30.4	4.48	0.7	2.6	0.0 b	8.0	0.1	0.1
Low	30.7	31.2	4.51	0.7	2.7	0.1 b	4.8	0.0	0.1
Medium	31.6	30.4	4.68	0.6	2.7	0.1 b	7.2	0.0	0.0
High	31.4	29.8	4.61	0.6	2.5	0.3 a	7.2	0.1	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] Stem swelling at the ground line based on 0-3 scale with 0=none, 1=slight, 2=moderate, 3=obvious.

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

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

Table 7. Bareroot eastern red cedar seedling characteristics treated with Marengo®, Flint River Nursery, Byromville, GA.

Rate	Density (ft^2)	Shoot Height (cm)	Seedling RCD (mm)	Root weight (g)	Shoot weight (g)	Swelling[1]	Weeds (ft^2)[2]	
							June	Jan
Control	20.1 b	14.2 b	2.13	0.8 b	1.5 b	0.0	0.7	0.5
Low	22.5 b	16.5 ab	2.24	1.0 ab	1.9 ab	0.0	1.3	0.5
Medium	20.1 b	17.2 a	2.48	1.1 a	2.2. a	0.0	1.1	1.0
High	28.1 a	18.7 a	2.48	1.1 a	2.3 a	0.0	1.0	0.3

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 swelling at the ground line based on 0-3 scale with 0=none, 1=slight, 2=moderate, 3=obvious.

[2] June data are initial weed counts per square foot at time of herbicide application; January data are weed counts per square foot at time of field study completion.

Table 8. Container slash pine seedling characteristics treated with Marengo®, IFCO Nursery, Moultrie, GA.

Rate	Survival[1] (% Fill)	Shoot Height (cm)	Seedling RCD (mm)	Shoot weight (g)	Plug weight[2] (g)	Swelling[3]	No. White Root Tips	Change in Weeds No./Container[4]	
								Willow	Other
Control	99.6	20.7	3.81 c	1.9 b	10.0 a	0.0 c	26.1	0.0	1.0 a
Low	99.2	21.5	4.26 b	2.2 a	9.9 a	0.1 c	26.9	-0.1	0.1 b
Medium	99.5	20.9	4.26 b	2.0 b	9.8 a	0.5 b	26.7	-0.4	-0.2 b
High	99.3	20.9	5.02 a	2.1 ab	9.3 b	1.8 a	28.8	-0.2	0.0 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 October compared to initial tray seedling count made in June.

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

[3] Stem swelling at the ground line based on 0-3 scale with 0=none, 1=slight, 2=moderate, 3=obvious.

[4] Counts of willow or other weeds per tray were made in June and October. Negative numbers indicate fewer willows or weeds in October count.

Table 9. Container longleaf pine seedling characteristics treated with Marengo®, IFCO Nursery, Moultrie, GA.

Rate	Survival[1] (% Fill)	Shoot Height (cm)	Seedling RCD (mm)	Shoot weight (g)	Plug weight[2] (g)	No. White Root Tips	Change in Weeds No./Container[3]	
							Willow	Other
Control	97.1	24.0	8.24 a	3.0 ab	12.0 a	28.5	-0.8	2.0 a
Low	98.1	23.9	8.16 a	3.2 a	12.0 a	31.9	-0.7	0.4 ab
Medium	97.2	24.3	7.30 b	3.0 ab	11.2 b	29.5	-1.1	-0.4 b
High	97.9	23.8	6.86 b	2.8 b	11.7 a	26.1	-1.1	-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 October compared to initial tray seedling count made in June.

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

[3] Counts of willow or other weeds per tray were made in June and October. Negative numbers indicate fewer willows or weeds in October count.

Table 10. Container loblolly pine seedling characteristics treated with Marengo®, IFCO Nursery, Moultrie, GA.

Rate	Survival[1] (% Fill)	Shoot Height (cm)	Seedling RCD (mm)	Shoot weight (g)	Plug weight[2] (g)	Swelling[3]	No. White Root Tips	Change in Weeds No./Container[4]	
								Willow	Other
Control	95.9	22.6 b	3.77 b	1.6	11.6 a	0.0 c	17.2 b	0.0	-2.7
Low	98.4	22.4 b	3.91 b	1.6	10.8 bc	0.0 c	20.7 ab	0.0	-2.2
Medium	97.8	24.6 a	4.28 a	1.7	10.6 c	0.6 b	26.3 a	-0.1	-1.3
High	96.7	23.0 b	4.27 a	1.6	11.2 ab	0.9 a	21.8 ab	0.0	-1.8

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 October compared to initial tray seedling count made in June.

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

[3] Stem swelling at the ground line based on 0-3 scale with 0=none, 1=slight, 2=moderate, 3=obvious.

[4] Counts of willow or other weeds per tray were made in June and October. Negative numbers indicate fewer willows or weeds in October count.

Table 11. Container loblolly pine seedling characteristics treated with Marengo®, Westervelt Nursery, Eutaw, AL.

Rate	Survival[1] (% Fill)	Shoot Height (cm)	Seedling RCD (mm)	Shoot weight (g)	Plug weight[2] (g)	Swelling[3]	No. White Root Tips	Change in Weeds No./Container[4]	
								Willow	Other
Control	98.5	28.2	3.70	1.7	8.6 a	0.0 b	21.5	-3.1	0.0
Low	98.2	28.6	3.68	1.8	8.4 ab	0.0 b	21.9	-2.6	0.0
Medium	98.4	28.5	3.66	1.7	8.5 ab	0.0 b	23.2	-3.1	-0.1
High	97.8	29.0	3.78	1.7	8.2 b	0.1 a	26.1	-3.3	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] Percent survival based on tray seedling count made in October compared to initial tray seedling count made in June.

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

[3] Stem swelling at the ground line based on 0-3 scale with 0=none, 1=slight, 2=moderate, 3=obvious.

[4] Counts of willow or other weeds per tray were made in June and October. Negative numbers indicate fewer willows or weeds in October count.

Table 12. Container (plastic) loblolly pine seedling characteristics treated with Marengo®, River Bend Nursery, Hazlehurst, MS.

Rate	Survival[1] (% Fill)	Shoot Height (cm)	Seedling RCD (mm)	Shoot weight (g)	Swelling[2]	No. White Root Tips	Change in Weeds No./Container[3]	
							Willow	Other
Control	99.0 b	34.8	4.14 b	2.3	0.0 b	20.6 a	-0.1	0.0
Low	99.6 ab	34.9	4.29 ab	2.4	0.0 b	25.3 a	-0.2	-0.3
Medium	99.6 a	34.9	4.39 a	2.4	0.0 b	20.6 a	-0.1	-0.1
High	99.8 a	34.1	4.27 ab	2.3	0.4 a	9.4 b	-0.3	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] Percent survival based on tray seedling count made in October compared to initial tray seedling count made in June.

[2] Stem swelling at the ground line based on 0-3 scale with 0=none, 1=slight, 2=moderate, 3=obvious.

[3] Counts of willow or other weeds per tray were made in June and October. Negative numbers indicate fewer willows or weeds in October count.

Table 13. Container (styroblock) loblolly pine seedling characteristics treated with Marengo®, River Bend Nursery, Hazlehurst, MS.

Rate	Survival[1] (% Fill)	Shoot Height (cm)	Seedling RCD (mm)	Shoot weight (g)	Root weight[2] (g)	Swelling[3]	Change in Weeds No./Container[4]	
							Willow	Other
Control	98.9 a	32.0 b	4.46 c	2.6 c	1.0 ab	0.00 b	-0.1	0.0
Low	98.9 a	32.6 b	4.70 b	2.8 b	1.2 a	0.00 b	0.0	0.0
Medium	97.8 ab	34.3 a	5.02 a	3.2 a	0.8 bc	0.00 b	0.0	0.0
High	97.1 b	32.7 b	4.88 ab	2.7 bc	0.7 c	0.04 a	-0.1	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] Percent survival based on tray seedling count made in October compared to initial tray seedling count made in June.

[2] Root weight does not include dry weight of media in plug.

[3] Stem swelling at the ground line based on 0-3 scale with 0=none, 1=slight, 2=moderate, 3=obvious.

[4] Counts of willow or other weeds per tray were made in June and October. Negative numbers indicate fewer willows or weeds in October count.

Table 14. Pin oak seedling characteristics treated with Marengo®, East Tennessee Nursery, Delano, TN.

Number of Sprays	Density (ft²)	Plantables (ft²)[1]	Percent Culls[2]	Weeds (ft²)[3]	
				June	December
Control	9.0 ab	5.4	40 b	0.0	0.0
One	8.4 b	4.8	43 ab	0.1	0.0
Two	9.7 a	4.9	49 a	0.3	0.0
Three	9.0 ab	5.3	41 b	0.0	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] Plantables are seedlings with RCD>6.4 mm (0.25 inches).

[2] Percent Culls based on total number of seedlings and those with RCD<6.4 mm (0.25 inches) within counting frame per replication.

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

Figure 1. Front view of directed sprayer used in Marengo® directed spray study at East Tennessee Nursery near Delano, TN.

Figure 2. Top view of directed sprayer applying Marengo® in beds of pin oak.

Figure 3. Eastern red cedar beds treated with Marengo® (left) and untreated (right). Treated areas appear to have higher densities and larger seedlings than untreated areas. Measurements of untreated control plots and treated plots located in the left bed confirm higher seedling densities and seedling characteristics in treated plots.

Figure 4. Container loblolly pine seedlings from River Bend Nursery after 30 days in aerated tanks (L to R - control, and Marengo® treated seedlings at low, medium, high rates). Seedlings treated at high rate of Marengo® produced fewer new white root tips. This installation was the only one showing any negative effect of Marengo® on growth of new white root tips.

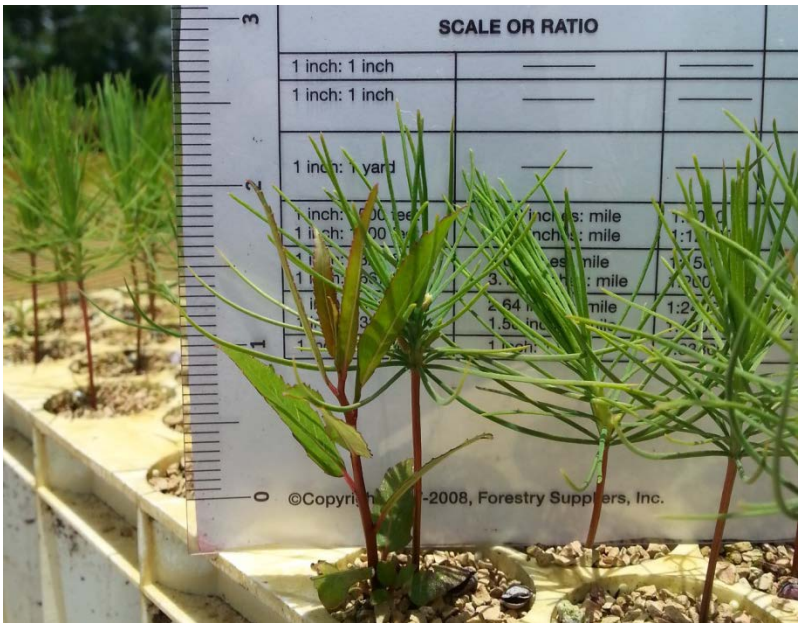

Figure 5. Container loblolly pine tray with one willow present at installation of Marengo® study. Lack of willows is indicative of willow populations at all nurseries.

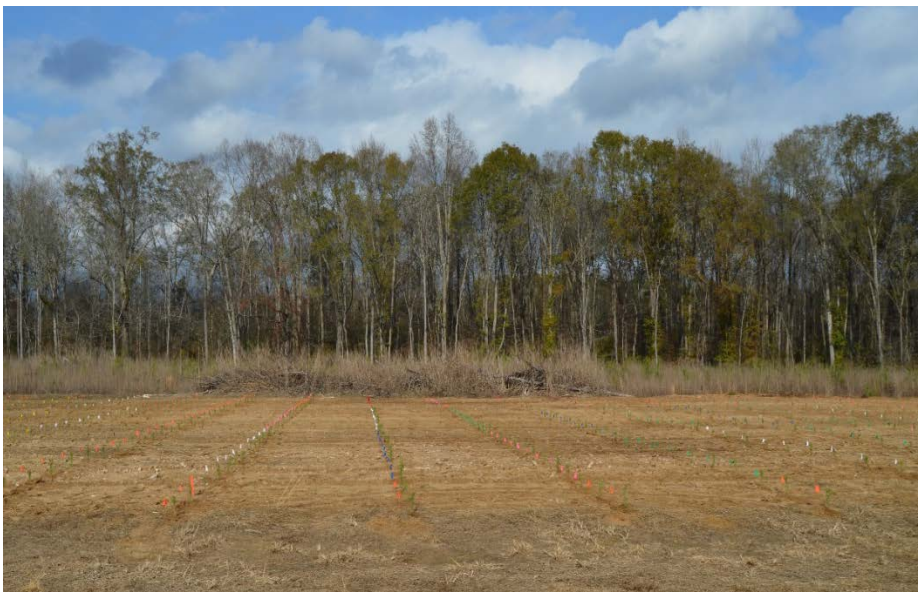
Figure 6. Outplanting study of container loblolly pine treated with Marengo® in Greene Co., AL.