Auburn University
Southern Forest Nursery
Management Cooperative

RESEARCH REPORT 15-01

EFFECT OF TIMING AND RATE OF MARENGO® (INDAZIFLAM) APPLICATIONS ON WEED CONTROL AND TOLERANCE TO LOBLOLLY, LONGLEAF, SLASH AND SHORTLEAF PINE SEEDLINGS GROWN IN CONTAINERS

by
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INTRODUCTION

Marengo® (indaziflam) is a selective preemergent and early postemergent herbicide produced by OHP, Inc. and made available to the public in January 2013. Its active ingredient, indaziflam, is one of the first from Mode of Action Group 29, which includes herbicides that inhibit cellulose biosynthesis; in this case, the chemical inhibits cell wall formation, division and elongation primarily in growing roots. The current Marengo® label lists 23 grasses and sedges and 61 broadleaf weeds, including spurge (Euphorbia spp.), as those being controlled. Eastern white pine (Pinus strobus) and Scotch pine (Pinus sylvestrus) are currently the only pine species listed as tolerant, according the OHP's testing date of 2012. The current label includes pre-emergence weed control in conifer nurseries but suggests application as a directed spray to soil. The manufacturer's studies (Marengo® Technical Research Update, Summer 2013) showed that the herbicide offers significantly longer weed control in light or sandy soils compared to heavy soils. The current label recommends to water –in up to 21 days - following application. We could not find any trials that studied the effect of Marengo® on loblolly pine (Pinus taeda) and therefore began some of the first tests of this new action group herbicide in 2013. In those trials, the Nursery Cooperative tested Marengo® over the top of loblolly pine seedlings in a bareroot nursery in Shellman, Georgia (Research Report 14-05). The application of Marengo® significantly affected seedling densities at all rates (3.75, 7.5, 11.25 oz/ac) at the time of sowing (0 weeks, pre-emergent) resulting in reduced seedling densities and growth. However, when applied at least 6 weeks and 12 weeks post-sowing, there were no significant differences in seedling densities, shoot heights and root-weight ratios, at the low (3.75 oz/ac) and medium (7.5 oz/ac) spray rate applications. It was therefore possible that the lower rate of Marengo® could be used to control weeds that appear later in the growing season, such as black willow in container seedlings AND not affect seedling quality. Therefore, the objectives of this trial were to 1) evaluate container-grown loblolly, longleaf, shortleaf and slash pine seedlings' tolerance to different post-emergent application rates of Marengo® (7.4% indaziflam) and 2) determine its efficacy on weed control, particularly black willow, following three different post-emergent application times and rates.

METHODOLOGY

This trial was conducted at IFCO's container nursery in Moultrie, Georgia on containers sown to loblolly, slash, longleaf and shortleaf pine at four application rates (0.0 oz/ac, 3.75 oz/ac, 7.5 oz/ac

and 11.25 oz/ac) applied two different times (June or July) over the growing season (6 weeks after the appearance of willow seedlings in the trays). The seedlings were treated 7 weeks post sowing for slash and 9 weeks post sowing for loblolly, longleaf and shortleaf pine. Half of those trays treated at 7 and 9 weeks, were treated again 3 weeks later for a third treatment (June & July). 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 within the seedling trays were not uniformly distributed, thus, only loblolly and shortleaf trays had willow seedlings that were counted prior to treatment. At the end of the growing season, weeds (willow and other) were counted in all -trays.

Each treatment block was one seedling tray for each species and was replicated five times for each rate, species and time of application. Loblolly pine was sown in 120S (120 cells/tray), IPL110 for longleaf and shortleaf (45 cells/tray), and V93 for - slash pine (40 cells/tray). All weed and seedling density measurements were made from each tray at the end of the growing season in November 2014. A sample of 10 seedlings from each tray x rate x application time were removed from the tray and brought to the Nursery Cooperative laboratory for evaluation of seedling tolerance to the herbicide. 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. Differences in these parameters from the control would indicate Marengo® effect (positive, negative, none) on the conifer species tested. In addition, 25 seedlings from each conifer species that had been treated twice (June & July) were placed into RGP tanks to determine root growth potential and if there were any long-term effects from the Marengo® applications that would be seen at outplanting.

RESULTS AND DISCUSSION

The effect of Marengo® on the growth of conifer seedlings over the growing season and final seedling biomass was dependent upon the tree species tested. Overall, the least tolerant conifer species to applications of Marengo® was longleaf, followed by shortleaf pine seedlings. The most tolerant species to applications of Marengo® were loblolly and slash pine seedlings. Looking at seedling shoot heights, shoot weights and root weights, none of the rates or time of application had an effect on loblolly, slash or shortleaf pine seedlings when compared to the non-treated control seedlings of the same species. Data for each seedling species is shown in Tables 1-4, for loblolly, slash, shortleaf and longleaf pine respectively. Thus, the use of Marengo® did not have a negative effect on seedling root or shoot biomass for Loblolly and slash In sharp contrast to these three conifer species, the application of Marengo® on longleaf pine seedlings resulted in shorter shoots (needles), lower shoot biomass and lower root biomass when compared to the non-treated control longleaf seedlings (Table 4a, b, c). One observation while measuring seedling quality was that the root ball was loose and crumbly and was confirmed by the lower root biomass over the non-treated controls. Thus, due to the decrease in seedling growth of longleaf when treated with the herbicide, the use of Marengo® to control weeds, especially the troublesome black willow in container longleaf seedlings would not be recommended.

As far as weed control, the use of Marengo® reduced the number black willow seedlings in the containers for loblolly and shortleaf when applied over the top of the container conifer seedlings.

Willow tops appeared to be burned back by the herbicide and, the smaller the willow at the time of treatment, the better the herbicide was at completely killing the weeds. Thus, the early application in June resulted in better weed control than the application in July (Table 1b). Control trays average 9.2 willow seedlings per tray with all treatments resulting in significantly fewer willow seedlings in the loblolly trays (Table 1b) and shortleaf seedling trays (Table 3b). Higher rates (11.25 oz/ac) of Marengo® tended to have fewer willows than either the medium (7.5 oz/ac) or low (3.25 oz/ac) rate for both tree species indicating a rate affect. The effect of Marengo® on weeds and seedling growth applied in June was evident 3 weeks later when the second application was to be applied. Non-treated seedlings were slight taller and had more weeds (Figure 1). At the end of the growing season in November 2014, it was observed that the control (non-treated trays) in loblolly, slash and shortleaf pine had a number of weeds within the seedling trays (prostrate spurge, flathead sedge) while the herbicide-treated trays did not. Thus, all weeds were counted within each tray and recorded as "others". Like the black willow weed control, the use of Marengo® at all rates and time of application decreased the number weeds in those tree species (Table 1b, 2b, 3b). For some reason, there were no black willow or other weeds present in any of the longleaf trays (non-treated or treated) Table 4b.

When using herbicides over the top of seedlings, it is possible to induce stem swellings at the ground line where the seedling tissue comes in contact with the active ingredient of the herbicide. For this reason, Nursery Cooperative members have been cautioned since 2009 about herbicide galls forming on pine seedlings following the use of Pendulum® AquaCap™ (PAC) (pendimethalin) after germination to control prostrate spurge (*Chamaesyce maculate*). It has been speculated that factors such as heat, soil texture, or seedling genetics may contribute to gall formation (Research Reports 09-01; 10-04; 11-05). While measuring seedling characteristics for this Marengo® herbicide trial at the end of the experiment, the amount of 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 (Figures 2 and 3). For loblolly, slash and shortleaf pine, for each treatment, and time of application, as the rate and number of applications increased, so did the amount of stem swelling (Tables 1b, 2b, 3b). Non-treated control seedlings had an average of 0.0 stem swelling with loblolly, slash and shortleaf pine with slight to moderate swelling. Slash pine was the most sensitive to Marengo® applications with the higher rates and multiple applications resulting in obvious stem swellings (Table 2b). Not surprisingly, the effect of stem swellings on seedling characteristics resulted in greater RCD measurements for those same tree species. Thus, treated seedlings had artificially greater RCD measurements than non-treated controls (Table 1a, 2a, 3a) for loblolly, slash and shortleaf pine, respectively.

With respect to stem swellings and RCD, longleaf pine seedlings behaved differently than the other three conifer species tested to applications of Marengo®. Their unique growth habit made it difficult to determine and quantify if or any stem swelling had occurred. Thus, their stem swelling numbers were all 0.0 (Table 4b) for all rates and time of applications. Ironically, like that of the biomass measurements (shoot height, shoot weight, root weight) the use of Marengo® on longleaf pine resulted in significantly smaller RCD's than the non-treated control trays (Table 4a). Non-treated RCD's were 6.68 mm while treated longleaf seedlings ranged from 4.92 to 5.75 mm, all significantly smaller. Examining the effects of Marengo® on all the longleaf seeding characteristics, it is clear that longleaf seedlings should not be treated with this herbicide to control weeds in container production systems (Figure 4).

While the formation of stem swellings is/was unfortunate (especially given the efficacy of weed control), one of the most common questions about the herbicide gall formation has been: "what will happen to pine seedlings with herbicide galls after outplanting?" This is an important question as 40+ years of landowner, planter and consulting forester education has taught everyone to avoid planting 'galled seedlings' due to the threat of fusiform rust infection. In 2013, a large replicated trial of galled and non-galled seedlings that were outplanted and placed under moisture stress (Research Report 14-02) found that there was no effect of herbicide gall presence on seedling survival, ground line diameter or growth planted either deep or shallow. In fact, when planted shallow without the benefit of water, the presence of herbicide galls increased seedling ground line diameter, seedling growth and seedling survival over non-galled seedlings planted under the same growing conditions. The management implications were such that seedlings with herbicide-induced galls on the main stem had similar survival and growth rates as non-galled seedlings and could be outplanted with minimal risk.

Another way to determine if there are any effects of stem swellings and herbicide on seedling vigor is through a RGP test. Thus, seedlings from all four species, treated twice were placed into RGP tanks in the greenhouse and one month later all seedlings were examined for the number white root tips and RCD. Differences in white root tips between treated and non-treated seedlings will give a general indication of seedling vigor. Those seedlings (treatments) with more white root tips would be considered more vigorous - than seedlings with less white root tips. When measuring the white root tips, two things stood out. First, there were not many root tips on any of the seedlings, much less (5-20 root tips) than what is normally observed (100's) and second, there were no differences among the treatments. Controls had just as few root tips as did the high rate treatments (Tables 1c, 2c, 3c, 4c). Therefore, the RGP test was inconclusive with respect to determining seedling vigor of the herbicide-treated seedlings as measured by white root tips. While there is no proof (water sample tests looking for indaziflam) but that there may have been some of the active ingredient still present in the rooting zone, media plug of the seedlings when they were placed into the water tanks. The Marengo® label says to avoid planting transplants into soil that has been treated with Marengo® in the last 12 months – it persists in the soil and inhibits new root growth. The experimental design was such that both treated and non-treated seedlings were placed together and that any herbicide within the rooting zone was then distributed among all the seedlings in that tank. This would result in 1) very few white root tips observed, and 2) the lack of treatment differences among the non-treated and treated seedlings.

While Marengo® has been shown to be an effective herbicide in controlling weeds in both bareroot and container seedling production systems, there are still a number of unanswered questions that need to be addressed before one should use this material operationally in forest-tree nurseries.

MANAGEMENT IMPLICATIONS

- The use of Marengo® for the control of weeds in container-grown loblolly, slash, and shortleaf pine may be possible if applied at the lower rates, early in the growing season (6+ weeks post sowing) to catch the weeds in a smaller growth stage. Repeated applications would give season-long weed control.

- The label indicates that Marengo® should be applied as a directed spray, avoiding the stems and leaves not over the top in conifer nurseries. This doesn't help container operations, especially on longleaf but it may bareroot nurseries with weed control.

However:

- The herbicides' effect on stem swelling was dependent upon species treated. The most tolerant species was loblolly and shortleaf pine with slash pine the least tolerant.
- While previous studies have shown no negative effects of stem swellings on seedling survival, more studies with Marengo® and outplanting survival is needed.
- Because of the negative, detrimental effects of Marengo® on longleaf pine seedling characteristics (shoot height, shoot weight, root weight) when compared to the control, Marengo® should not be considered for weed control in container production systems.
- The possibility of carry-over (as determined by the RGP experiment) needs to be examined further. Lack of seeding root-growth after outplanting is not a desired trait.
- Anyone interested in using Marengo® as part of their weed control practices, should try small areas, on a number of different genotypes and the low to medium rate, at least 6 weeks post-germination.

Table 1a. Container loblolly pine seedling characteristics treated with three rates of the herbicide Marengo® at two times over the growing season, Moultrie, GA 2014.

	Seedling Shoot Height (cm)			Seedling Shoot Weight (g)			Seedling RCD (mm)		
Rate	Time of Application			Time of Application			Time of Application		
	June	July	June&July	June	July	June&July	June	July	June&July
Check	25.9	25.9	25.9	20.1	20.1	20.1	4.00	4.00	4.00
Low	27.1	26.4	25.3	20.9	23.5	21.3	4.12	4.36	4.41
Medium	27.5 a	24.2 b	24.6 b	21.9 a	19.2 ab	19.0 b	4.39	4.29	4.50
High	26.2	24.3	25.1	21.4	19.6	21.6	4.56 b	4.47 b	5.60 a

Different letters (a, b, c) within a Seedling Characteristic row indicate significant treatment difference in Time of Application within a Rate according to Duncan's mean separation test at $P < 0.05$.

Underlined Means within a Seedling Characteristic indicate significant treatment difference from that of the non-treated Check at that Rate and Time of Application according to Dunnett's mean separation test at $P < 0.05$.

Table 1b. Container loblolly pine seedling characteristics treated with three rates of the herbicide Marengo® at two times over the growing season, Moultrie, GA 2014.

	Willows (No/Container)			Other Weeds (No/Container)			Seedling Stem Swelling[1]		
Rate	Time of Application			Time of Application			Time of Application		
	June	July	June&July	June	July	June&July	June	July	June&July
Check	9.2	9.2	9.2	1.0	1.0	1.0	0.0	0.0	0.0
Low	4.0 a	6.6 b	4.8 ab	0.0	0.2	0.0	0.6 b	0.6 b	0.8 a
Medium	4.4	2.4	4.8	0.6	0.4	0.0	0.8	0.7	0.8
High	2.0	3.4	2.2	0.0	0.0	0.0	1.0 b	0.8 b	1.6 a

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Underlined Means within a Seedling Characteristic indicate significant treatment difference from that of the non-treated Check at that Rate and Time of Application according to Dunnett's mean separation test at $P < 0.05$.

[1] Stem swelling at the ground line based on 0-3 scale with 0=None, 1=Slight; 2=Moderate; 3=Obvious Swelling at ground line.

Table 1c. Container loblolly pine seedling characteristics treated with three rates of the herbicide Marengo® at two times over the growing season, Moultrie, GA 2014.

	Seedling Root Weight (g)			RGP (No. White Root Tips)			RCD after RGP Test (mm)		
Rate	Time of Application			Time of Application			Time of Application		
	June	July	June&July	June	July	June&July	June	July	June&July
Check	0.79	0.79	0.79	-*	-	5.1	-*	-	4.3
Low	0.82	0.90	0.86	-	-	5.7	-	-	4.5
Medium	0.73	0.75	0.76	-	-	6.0	-	-	4.6
High	0.81	0.77	0.76	-	-	8.1	-	-	5.2

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Underlined Means within a Seedling Characteristic indicate significant treatment difference from that of the non-treated Check at that Rate and Time of Application according to Dunnett's mean separation test at $P < 0.05$.

* Only seedling trays treated with Marengo® in both June and July were examined for Root Growth Potential and RCD (RGP).

Table 2a. Container slash pine seedling characteristics treated with three rates of the herbicide Marengo® at two times over the growing season, Moultrie, GA 2014.

	Seedling Shoot Height (cm)			Seedling Shoot Weight (g)			Seedling RCD (mm)		
Rate	Time of Application			Time of Application			Time of Application		
	June	July	June&July	June	July	June&July	June	July	June&July
Check	33.8	33.8	33.8	31.5	31.5	31.5	4.90	4.90	4.90
Low	33.6	33.6	35.2	32.0	31.3	33.4	5.51 ab	5.34 b	5.84 a
Medium	32.9	33.3	35.3	33.0	33.5	38.3	6.12 a	5.57 b	6.74 a
High	34.4	35.2	32.2	31.3	34.4	34.0	6.66 a	6.40 a	7.31 b

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Underlined Means within a Seedling Characteristic indicate significant treatment difference from that of the non-treated Check at that Rate and Time of Application according to Dunnett's mean separation test at $P < 0.05$.

Table 2b. Container slash pine seedling characteristics treated with three rates of the herbicide Marengo® at two times over the growing season, Moultrie, GA 2014.

	Willows (No/Container)			Other Weeds (No/Container)			Seedling Stem Swelling[1]		
Rate	Time of Application			Time of Application			Time of Application		
	June	July	June&July	June	July	June&July	June	July	June&July
Check	-[Z]	-	-	0.3	0.3	0.3	0.0	0.0	0.0
Low	-[Z]	-	-	0.0	0.2	0.0	0.52 a	0.38 a	0.93 b
Medium	-[Z]	-	-	0.0	0.7	0.2	1.84 a	0.72 b	2.34 a
High	-[Z]	-	-	0.0	0.0	0.0	3.0 a	1.6 b	2.8 a

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[1] Stem swelling at the ground line based on 0-3 scale with 0=None, 1=Slight; 2=Moderate; 3=Obvious Swelling at ground line.

[Z]Willow seedlings were not present in Slash Pine container trays.

Table 2c. Container slash pine seedling characteristics treated with three rates of the herbicide Marengo® at two times over the growing season, Moultrie, GA 2014.

	Seedling Root Weight (g)			RGP (No. White Root Tips)			RCD after RGP Test (mm)		
Rate	Time of Application			Time of Application			Time of Application		
	June	July	June&July	June	July	June&July	June	July	June&July
Check	1.26	1.26	1.26	-*	-	7.8	-	-	4.9
Low	1.35	1.29	1.08	-	-	6.9	-	-	5.5
Medium	1.19 ab	1.40 a	1.10 b	-	-	6.3	-	-	6.7
High	1.19	1.16	1.16	-	-	7.7	-	-	7.2

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* Only seedling trays treated with Marengo in both June and July were examined for Root Growth Potential and RCD (RGP).

Table 3a. Container shortleaf pine seedling characteristics treated with three rates of the herbicide Marengo® at two times over the growing season, Moultrie, GA 2014.

	Seedling Shoot Height (cm)			Seedling Shoot Weight (g)			Seedling RCD (mm)		
Rate	Time of Application			Time of Application			Time of Application		
	June	July	June&July	June	July	June&July	June	July	June&July
Check	31.6	31.6	31.6	24.6	24.6	24.6	4.14	4.14	4.14
Low	31.2	30.2	31.5	24.8 a	20.8 b	24.6 a	4.66 a	3.78 b	4.84 a
Medium	31.6	30.4	31.7	24.3	22.0	24.5	4.77	5.03	5.00
High	31.5	31.2	31.4	23.5	23.1	24.1	4.74 a	4.12 b	5.41 c

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Underlined Means within a Seedling Characteristic indicate significant treatment difference from that of the non-treated Check at that Rate and Time of Application to Dunnett's mean separation test at $P < 0.05$.

Table 3b. Container shortleaf pine seedling characteristics treated with three rates of the herbicide Marengo® at two times over the growing season, Moultrie, GA 2014.

	Willows (No/Container)			Other Weeds (No/Container)			Seedling Stem Swelling[1]		
Rate	Time of Application			Time of Application			Time of Application		
	June	July	June&July	June	July	June&July	June	July	June&July
Check	2.4	2.4	2.4	0.2	0.2	0.2	0.0	0.0	0.0
Low	0.2	0.0	0.0	0.0	0.0	0.0	0.82 a	1.50 b	1.32 ab
Medium	0.0 a	2.6 b	0.0 a	0.0	0.4	0.0	0.64 a	0.60 a	1.04 b
High	0.0	0.0	0.0	0.0	0.0	0.0	1.42 a	0.88 b	2.12 c

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[1] Stem swelling at the ground line based on 0-3 scale with 0=None, 1=Slight; 2=Moderate; 3=Obvious Swelling at ground line.

Table 3c. Container shortleaf pine seedling characteristics treated with three rates of the herbicide Marengo® at two times over the growing season, Moultrie, GA 2014.

Rate	Seedling Root Weight (g)			RGP (No. White Root Tips)			RCD after RGP Test (mm)		
	Time of Application			Time of Application			Time of Application		
	June	July	June&July	June	July	June&July	June	July	June&July
Check	0.92	0.92	0.92	-*	-	23.4	-*	-	4.41
Low	0.88	0.76	0.85	-	-	20.2	-	-	4.12
Medium	0.77	0.75	0.66	-	-	26.0	-	-	4.55
High	0.72	0.81	0.78	-	-	27.0	-	-	4.81

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* Only seedling trays treated with Marengo in both June and July were examined for Root Growth Potential and RCD (RGP).

Table 4a. Container longleaf pine seedling characteristics treated with three rates of the herbicide Marengo® at two times over the growing season, Moultrie, GA 2014.

Rate	Seedling Shoot Height (cm)			Seedling Shoot Weight (g)			Seedling RCD (mm)		
	Time of Application			Time of Application			Time of Application		
	June	July	June&July	June	July	June&July	June	July	June&July
Check	31.3	31.3	31.3	46.2	46.2	46.2	6.68	6.68	6.68
Low	38.3 a	29.2 b	28.3 b	38.4	36.7	34.2	5.47	5.32	5.05
Medium	33.9	32.0	30.8	38.4 ab	39.9 a	35.0 b	5.45	5.28	4.92
High	35.5 a	29.1 b	30.7 b	32.9 a	41.0 b	35.5 a	5.12	5.31	5.75

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Table 4b. Container longleaf pine seedling characteristics treated with three rates of the herbicide Marengo® at two times over the growing season, Moultrie, GA 2014.

	Willows (No/Container)			Other Weeds (No/Container)			Seedling Stem Swelling[1]		
Rate	Time of Application			Time of Application			Time of Application		
	June	July	June&July	June	July	June&July	June	July	June&July
Check	-[Z]	-	-	-[Z]	-	-	0.0	0.0	0.0
Low	-[Z]	-	-	-[Z]	-	-	0.0	0.0	0.0
Medium	-[Z]	-	-	-[Z]	-	-	0.0	0.0	0.0
High	-[Z]	-	-	-[Z]	-	-	0.0	0.0	0.0

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Underlined Means within a Seedling Characteristic indicate significant treatment difference from that of the non-treated Check at that Rate and Time of Application to Dunnett's mean separation test at $P < 0.05$.

[1] Stem swelling at the ground line based on 0-3 scale with 0=None, 1=Slight; 2=Moderate; 3=Obvious Swelling at ground line.

[Z]Willow seedlings were not present in Longleaf Pine container trays.

Table 4c. Container longleaf pine seedling characteristics treated with three rates of the herbicide Marengo® at two times over the growing season, Moultrie, GA 2014.

	Seedling Root Weight (g)			RGP (No. White Root Tips)			RCD after RGP Test (mm)		
Rate	Time of Application			Time of Application			Time of Application		
	June	July	June&July	June	July	June&July	June	July	June&July
Check	9.00	9.00	9.00	-*	-	9.0	-*	-	7.81
Low	5.36	5.52	4.67	-	-	7.7	-	-	6.14
Medium	5.26	4.87	4.35	-	-	11.2	-	-	6.74
High	4.61	6.41	5.81	-	-	8.1	-	-	7.34

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Underlined Means within a Seedling Characteristic indicate significant treatment difference from that of the non-treated Check at that Rate and Time of Application according to Dunnett's mean separation test at $P < 0.05$.

* Only seedling trays treated with Marengo in both June and July were examined for Root Growth Potential and RCD (RGP).

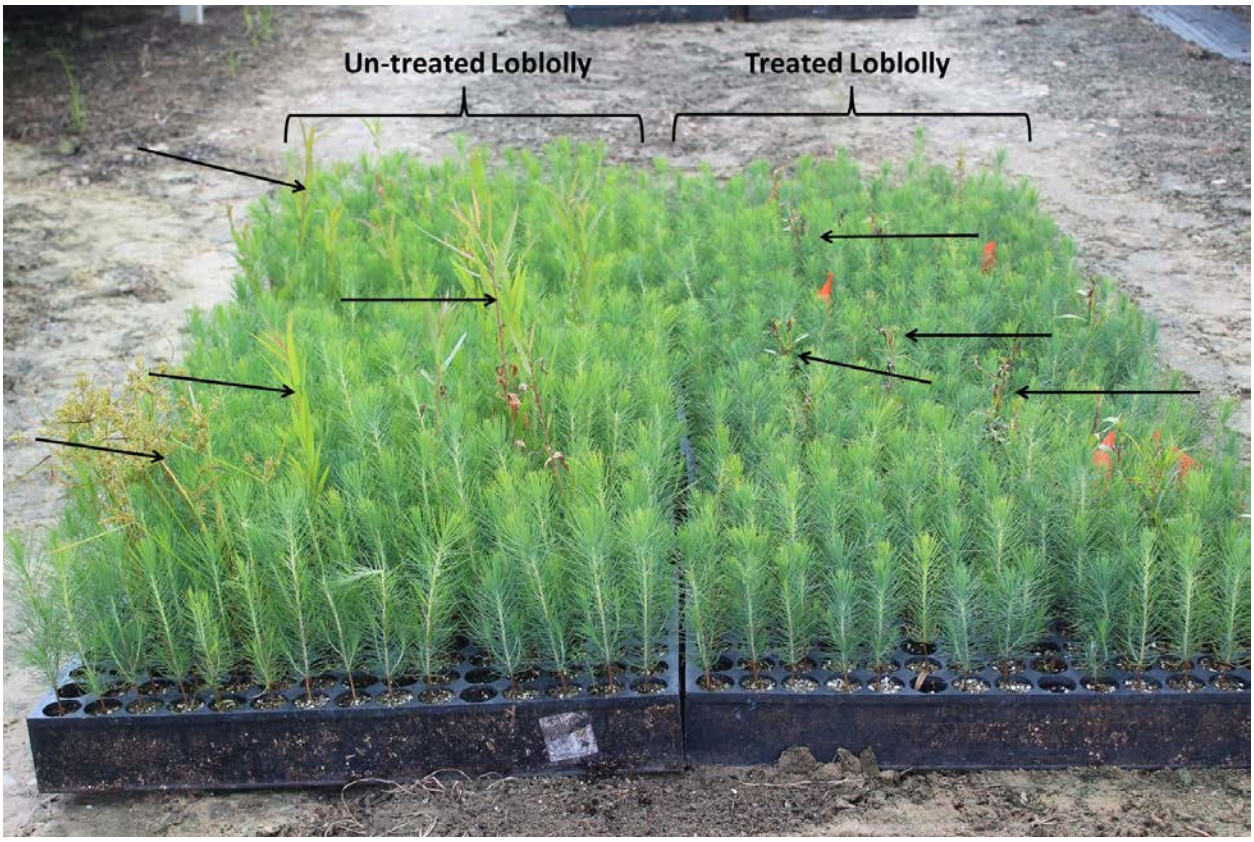

Figure 1. Loblolly pine trays in July 2014, 3 weeks after treatment with 7.5 oz/ac of Marengo® in June 2014.

Treated loblolly (right row of trays) appeared shorter than un-treated loblolly (left row of trays) pine seedlings, willow seedlings were dead or dying in the treated trays when compared to the un-treated trays. A few of the weeds present in the trays are noted with arrows. At the end of the growing season there was no difference in seedling shoot height, stem or root biomass between the two treatments.

Figure 2. Shortleaf pine seedlings untreated and treated with 7.5 oz/ac of Marengo® in June and July 2014, 9 and 12 weeks post sowing.

Untreated seedling exhibiting typical stem formation with treated seedlings exhibiting stem swelling at the ground line due to Marengo® applications.

Figure 3. Slash pine seedlings treated and untreated with 7.5 oz/ac of Marengo® in June 2014, 7 weeks post sowing.

Untreated seedling exhibiting typical stem formation of slash pine with treated seedlings exhibiting stem swelling at the ground line due to Marengo® applications.

Figure 4. Longleaf pine seedlings treated and untreated with -11.25 oz/ac of Marengo® in June 2014, 9 weeks post sowing.

Root biomass of longleaf pine was the smallest of the four conifer species tested. Root ball did not hold up well during extraction and soilless media was easily removed from the plug.