Southern Forest
Nursery Management Cooperative

RESEARCH REPORT 19-04

POSTEMERGENT HERBICIDE SCREENING TRIALS ON LOBLOLLY AND SLASH PINE SEEDBEDS II

by
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INTRODUCTION

Since the early 1980s, the Southern Forest Nursery Management Cooperative has conducted herbicide trials to identify products capable of eliminating or reducing populations of undesired plants while causing no damage to desired conifer crop seedlings. While the use of preemergent herbicides is now a common forest-tree nursery practice, the use of postemergent herbicides later in the growing season applied over-the-top of seedlings is limited. Few postemergent herbicides are tested and labeled for the conifer seedling nursery market by manufacturers as the market share of this specialty crop is small compared to the size of agricultural and turf markets. Also, economic analyses of weed density thresholds have been made for most major agricultural crops. However, since little research on the economic threshold of weed density in forest-tree nurseries has been conducted, identification of appropriate herbicides to control weed population continues.

Towards the goal of identifying postemergent herbicides that can be safely used on conifer seedlings grown in nursery beds, the SFNMC has continued and expanded trials conducted in 2016 and 2017 with postemergent herbicides labeled for agricultural and turf applications. The objective of this trial was to determine tolerance of loblolly and slash pine seedlings to 11 postemergent herbicides, six of which were tested in 2017. Because weed populations vary by type and quantity in each nursery, evaluations of weed control are generally not included as an objective of this study. The assumption was made that each product tested will suppress or control those targeted weed species identified on each label.

The eleven herbicides tested were:

Bispyribac (used as Velocity®) is an ALS inhibitor (Group 2) and stops plant growth by disrupting amino acid production. It is used in postemergent applications to control bluegrass, some broadleaf weeds and yellow nutsedge in turf but is not currently labeled for use in conifer nurseries. Valent is the manufacturer of both Velocity® and Regiment®, a bispyribac product labeled for use in rice. This product was tested at two SFNMC member nurseries in 2017.

Clethodim (used as TapOut®) acts to inhibit the enzyme ACCase (Group 1) to block production of lipids. Grasses are the target weed of this herbicide due to their sensitivity to this enzyme inhibition. Broadleaf weeds and sedges

are not controlled by clethodim. TapOut® is labeled for use in conifer seedling nurseries and is marketed by Helena Agri-Enterprises (formerly Helena Chemical). Other formulations of clethodim are Select® and Envoy™ by Valent and Arrow® by MANA. It is also labeled for use on agricultural crops, fallow land, and vegetative management in rights-of-ways and other noncrop areas. This product was tested at four SFNMC member nurseries in 2017.

Flazasulfuron (used as Mission®) is an ALS inhibitor (Group 2) which disrupts the production of amino acids in plants as it is absorbed through foliage and roots. It is produced by Summit Agro USA and is labeled for pre- and postemergent control of broadleaf weeds and grasses in grapes, citrus, olives, tree nuts and container and field grown conifers. However, it is restricted from use on conifer seedbeds.

Florasulam (used as Defendor™) is also an ALS inhibitor (Group 2), disrupting production of amino acids. It is used for broadleaf weed control and is produced by Corteva AgriScience (formerly DowDuPont) as Defendor™ for turf applications in the U.S. This herbicide is both foliar and soil active and is used primarily in postemergent applications due to its short half-life in soil. Defendor™ is not currently labeled for use in conifer seedling nurseries. This product was tested at four SFNMC member nurseries in 2017 and three member nurseries in 2016.

Imazapic (used as Plateau®) controls targeted weeds by disrupting production of amino acids as an ALS inhibitor (Group 2). Manufactured by BASF, it is labeled for use in pastureland, turf, noncrop areas and for site preparation prior to planting of conifer plantations. Plateau® controls broadleaf weeds, grasses and sedges in both pre- and postemergent applications. Imazapic is also made by BASF as Cadre® for use in peanuts. Other imazapic products include Impose® (Adama), Open Range®G (Wilbur-Ellis), Panoramic 2SL (Alligare), and Imazapic 2SL (Nufarm).

Orthosulfamuron (used as Strada®) is an ALS inhibitor (Group 2) and controls targeted weeds by disrupting production of amino acids. Applied as a postemergent herbicide, it controls broadleaf weeds and sedges in rice production areas. It is manufactured by Nichino America.

Oxadiazon (used as Ronstar®FLO) is labeled as a preemergent herbicide for control of broadleaf weeds and grasses in turf, landscape ornamentals and conifer nurseries. Labeled limitations on its use in conifer nurseries include its use as a directed spray only or as an over-the-top spray on certain species. Longleaf, loblolly, slash and shortleaf pine are not included in the label's list of species tolerant to over-the-top applications. Ronstar®FLO is manufactured by Bayer. Oxadiazon is a PPO inhibitor (Group 14) and acts to inhibit chlorophyll enzymes in targeted plants.

Pyraflufen (used as Venue®) is a nonselective herbicide which acts on contact with weeds including pigweed and morningglory. Because it is nonselective, tolerant plants are not listed on the label; however, plantback intervals are listed for agricultural crops including corn, cotton, soybeans, grapes, and wheat. Venue® is not labeled for use in conifer nurseries. It is a PPO inhibitor (Group 14) and acts to inhibit chlorophyll enzymes in targeted plants. Other pyraflufen products include Edict® (Nichino America), ET® (Nichino America) and Vida® (Gowan).

Tolpyralate (used as Shieldex®400SC) is a fairly new herbicide registered in the U.S. in 2017. It is a HPPD inhibitor (Group 27) and works to block pigment synthesis resulting in bleaching

symptoms appearing on leaf growth. Shieldex® is labeled for use as a postemergent herbicide in corn. Conifer nurseries are not listed on the label. Broadleaf weeds listed as controlled or suppressed include Palmer amaranth, marestail, morningglory, pigweed, crabgrass, and goosegrass among others. It is distributed by Summit Agro USA.

Topramezone (used as Frequency®) is manufactured by BASF and is a HPPD inhibitor, blocking pigment synthesis (Group 27). This results in bleaching symptoms appearing on new leaf growth. It is used in both pre- and postemergent applications in conifer plantations and for vegetative management on rights-of-way and noncropland areas. Topramezone controls or suppresses broadleaf weeds and grasses but not sedges. Although conifers are listed on the label, it is not currently labeled for conifer nursery use. This product was tested at four SFNMC member nurseries in 2017.

Trifloxysulfuron (used as Envoke®) is an ALS inhibitor (Group 2) produced by Syngenta as Envoke® for use in cotton and sugarcane and as Monument® in turf. It is used for control of sedges, grasses and broadleaf plants but is not currently labeled for use in conifer nurseries. This herbicide was tested in a total of seven SFNMC member nurseries in 2016 and 2017.

METHODOLOGY

Two member nurseries of the SFNMC participated in this trial in the summer of 2018. The K & L Forest Nursery in Buena Vista, Georgia provided 440 feet of bed space in loblolly pine, and the Rayonier Nursery in Elberta, Alabama provided 480 feet of loblolly pine bed space and 480 feet of slash pine bed space. Soil types of the specific study area used at each nursery are listed in Table 1. Herbicides were sprayed on June 27 at the K & L Nursery and July 3 at the Rayonier Nursery, at approximately 8 weeks post-sowing at both nurseries. Where indicated, surfactants or adjuvants were included in the application process. If watering-in was required by the herbicide label, water was applied to those plots using handheld equipment. Irrigation could not be used due to drying requirements of other herbicides in the study. Each nursery followed their operational protocols in establishing and maintaining the seedling beds involved in this study, including the use of soil stabilizer, mulch, preemergent herbicides, irrigation, fertilizer and mechanical treatments.

The study was installed in a randomized block design with each treatment being one seedling bed wide by 8 feet in length and replicated five times. The Georgia trial included nine treatments and a non-treated control; the Alabama trial included ten treatments and a non-treated control. SFNMC staff applied herbicides at the lowest labeled rate (Table 2) using a CO_2 hand sprayer calibrated to broadcast spray 25 gallons per acre.

On October 16, 2018, sample seedlings were collected at the Rayonier Nursery by removing all seedlings within a counting frame in each treatment plot, bundling seedlings from outside drills separately from those from interior drills. At the SFNMC laboratory, counts of all seedlings were made for measures of density, then a 25-tree random sample from interior drills was measured for shoot height, root collar diameter, shoot dry weight and root dry weight. Measurements of treated seedlings were compared to those of non-treated control seedlings to determine tolerance to applications of the herbicides. Data was analyzed and examined using Dunnett's T-test and

Wilcoxon Method for Nonparametric Comparisons, all at alpha = 0.05. The same process was followed at the K & L Nursery when seedlings were collected on November 19, 2018.

RESULTS AND DISCUSSION

All herbicides, unless noted, were tested at two bareroot loblolly pine nurseries and one bareroot slash pine nursery.

Bispyribac (used as Velocity®) was tested by the SFNMC in 2017 and 2018. The over-the-top application of Velocity® on loblolly pine seedlings at one nursery in 2018 resulted in significantly lower shoot heights and root collar diameters than non-treated seedlings. In contrast, the same over-the-top application of Velocity® in the second nursery resulted in no differences in seedling characteristics between treated and non-treated control loblolly seedlings. The 2018 trial in slash pine resulted in shorter shoot heights in treated plots than in non-treated plots. All other seedling characteristics showed no differences when compared to the non-treated control plots. (Tables 3 and 4).

Velocity® was tested at two SFNMC member nurseries in 2017. In those trials, loblolly pine seedlings showed tolerance to the herbicide in all seedling characteristics measured with the exception of shorter seedling height at one nursery. Slash pine seedlings tested in one nursery exhibited the same tolerance (Research Report 18-04).

Clethodim (used as TapOut®) was tested in 2017 and 2018. Its use in 2018 resulted in no significant differences in either loblolly or slash pine seedling characteristics measured (Tables 5 and 6).

TapOut® was tested in 2017 at four SFNMC member nurseries. In those trials, loblolly pine seedlings showed tolerance to the herbicide in all seedling characteristics measured with the exception of shorter seedling height at one nursery. Slash pine seedlings tested in one nursery showed no negative effects of the herbicide application (Research Report 18-04).

Flazasulfuron (used as Mission®) was tested in 2018. The herbicide had negative effects on seedling shoot heights and root collar diameters in loblolly pine and on shoot heights in slash pine (Tables 7 and 8). All other seedling characteristics showed no differences when compared to the non-treated control plots in both loblolly and slash pine.

Florasulam (used as Defendor™) was tested in 2016, 2017 and 2018. When used in loblolly pine in two nurseries in 2018, no differences in seedling characteristics were measured with the exception of smaller seedling root collar diameters at one nursery. In slash pine, shoot heights of treated seedlings were statistically significantly shorter than non-treated seedlings, although numerically were less than one centimeter shorter (Tables 9 and 10).

Defendor™ was tested at one SFNMC member nursery in 2016 and four member nurseries in 2017. In those trials, loblolly pine seedlings showed tolerance to the herbicide in all seedling characteristics measured with the exception of shorter seedling height at one nursery in 2017. Slash

pine seedlings exhibited tolerance to the herbicide in all seedling characteristics measured in both years (Research Reports 17-02 and 18-04).

Imazapic (used as Plateau®) was tested at one nursery in 2018. Significantly lower shoot heights, root collar diameters, shoot weights and root weights were measured in treated plots of both loblolly and slash pine when compared to non-treated plots (Tables 11 and 12).

Orthosulfamuron (used as Strada®) was tested in two nurseries in 2018. No negative effects of herbicide use were quantified in loblolly or slash pine, with the exception of shorter shoot heights in slash pine (Tables 13 and 14).

Oxadiazon (used as Ronstar®FLO) is labeled as a preemergent herbicide for control of grasses and broadleaf weeds in conifer nurseries. Its label allows for spraying over the top of labeled tolerant species, although neither loblolly nor slash pine are included in this list. In postemergent applications, overhead irrigation or rainfall of least one-half inch is needed to move the herbicide from the foliage of sprayed plants to the soil. Ronstar®FLO was tested in 2018 as a postemergent herbicide in these loblolly and slash pine, resulting in no negative effects on either species when compared to non-treated seedlings (Tables 15 and 16). However, anecdotal reports from one SFNMC nursery testing Ronstar®FLO as a postemergent over-the-top spray on loblolly pine were of damage to seedlings.

Pyraflufen (used as Venue®) was tested in 2018. Although it is labeled as a nonselective herbicide, no negative effects of herbicide use were quantified in loblolly or slash pine (Tables 17 and 18).

Tolpyralate (used as Shieldex®400SC) was tested in 2018. No negative effects of herbicide use were quantified in loblolly or slash pine (Tables 19 and 20).

Topramezone (used as Frequency®) was tested in 2017 and 2018. When used in loblolly pine in two nurseries in 2018, no differences in seedling characteristics were measured with the exception of smaller seedling root collar diameters at one nursery. In slash pine, no differences in seedling characteristics were quantified when comparing treated seedlings to non-treated seedlings (Tables 21 and 22).

Frequency® was tested at four SFNMC member nurseries in 2017. In that trial, loblolly and slash pine seedlings showed tolerance to the herbicide in all seedling characteristics measured (Research Report 18-04).

Trifloxysulfuron (used as Envoke®) was tested in 2016, 2017 and 2018. No negative effects of herbicide use were quantified in loblolly or slash pine in the 2018 trial (Tables 23 and 24). Trials from 2016 and 2017 produced similar results of tolerance by both loblolly and slash pine when applied at approximately 8 to 9 weeks post-sowing. (Research Reports 17-02 and 18-04).

***NOTE**: Prior to the publication of this report in 2019, reports of possible herbicide carryover were reported in the 2018 study area at the K & L Nursery in Buena Vista, Georgia. From field examination and germination counts made in June 2019, it is probable that several herbicides tested affected both germination and seedling development of subsequent seedling crops. These*

include flazasulfuron (Mission®), which negatively affected seedling growth in the 2018 study, and orthosulfamuron (Strada®), which showed no negative effects on seedlings except for lower shoot height in slash pine in the 2018 study. However, the Strada® label does specify a one to twelve-month plantback period for certain agricultural crops, depending on crop to be planted.

MANAGEMENT IMPLICATIONS

- It is well-documented that herbicidal effectiveness is a function of weeds targeted, herbicide selection, application quantity, timing and method, as well as soil type, soil organic matter, soil moisture, soil and irrigation water pH, rainfall or irrigation after application, wind, and other environmental factors. The results of this trial show that applications of the same herbicide on the same species at the same rate and time, using the same application method and applicator, can result in different seedling tolerances being quantified at different nurseries. Of the eleven herbicides tested on loblolly pine in this trial, three had mixed results from one nursery to another (seedling tolerance at one nursery but seedling damage at another). **This outcome underscores the importance of testing any new herbicide in a small trial at the nursery site where its use is being considered.**

- Because significant damage to seedlings was visible and quantified, imazapic (Plateau®) should not be used in an over-the-top spray application on loblolly or slash pine seedlings (Tables 11 and 12).

- Because one or more seedling characteristic was negatively affected in at least one nursery over at least two years of study, caution should be used when testing the following herbicides on loblolly and slash pine in postemergent applications:

    - bispyribac (Velocity®) – Tables 3 and 4
    - flazasulfuron (Mission®) - Tables 7 and 8

- Clethodim is currently labeled for use in conifer nurseries (page 40 of TapOut® label) to control grasses. After two years of trials by the SFNMC, the results of applications of this product described in this report (Tables 5 and 6) and in Research Report 18-04 confirm this chemical may be suitable for use in conifer forest-tree nurseries.

- Because of labeled replanting intervals and the potential for herbicide carryover, additional testing with an emphasis on the condition of subsequent crops is recommended for the following postemergent herbicides:

    - orthosulfamuron (Strada®) - tested in 2018, Tables 13 and 14
    - trifloxysulfuron (Envoke®) – tested in 2016, 2017, and 2018, Tables 23 and 24
    - tolpyralate (Shieldex®400SC) - tested in 2018, Tables 19 and 20
    - pyraflufen (Venue®) – tested in 2018, Tables 17 and 18

- Because of the initial positive results (i.e. seedling damage in one or fewer seedling characteristics over one to two years of testing or anecdotal evidence of seedling damage),

additional testing in postemergent applications is recommended for the following herbicides:

- florasulam (Defendor™) – Tables 9 and 10
- oxadiazon (Ronstar®FLO) - tested as postemergent in 2018, Tables 15 and 16
- topramezone (Frequency®) - tested in 2017 and 2018, Tables 21 and 22

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Table 1. Soil types of study areas in two nurseries used in postemergent herbicide screening study 2018.

Nursery	Soil Type
A	Lakeland loamy fine sand
B	Lucy loamy sand

Table 2. Rates of eleven postemergent herbicides tested at approximately 8 weeks post-sowing at two nurseries.

Herbicide	Rate per acre
bispyribac (Velocity®)	6 oz.
clethodim (TapOut®)	9 oz.
flazasulfuron (Mission®)	2.14 oz.
florasulam (Defendor™)	4 oz.
imazapic (Plateau®)	4 oz.
orthosulfamuron (Strada®)	1.7 g
oxadiazon (Ronstar®FLO)	80 oz.
pyraflufen (Venue®)	2 oz.
tolpyralate (Shieldex®400SC)	1 oz.
topramezone (Frequency®)	4 oz.
trifloxysulfuron (Envoke®)	0.1 g

bispyribac (Velocity®)

Table 3. Bareroot loblolly pine seedling characteristics treated with bispyribac at 8 – 9 weeks post-sowing at two nurseries.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	20.1	26.6	4.34	0.39	2.73	12.7	63:1
	Velocity®	19.4	24.6	4.04	0.35	2.55	12.0	62:1
B	control	18.5	31.2	5.15	0.81	4.03	16.6	62:1
	Velocity®	18.2	31.9	5.05	0.82	3.99	16.9	65:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

Table 4. Bareroot slash pine seedling characteristics treated with bispyribac at 8 – 9 weeks post-sowing at one nursery.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	25.2	27.0	4.00	0.38	2.84	11.9	68:1
	Velocity®	23.8	25.4	3.81	0.33	2.66	11.1	67:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

clethodim (TapOut®)

Table 5. Bareroot loblolly pine seedling characteristics treated with clethodim at 8 – 9 weeks post-sowing at two nurseries.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	20.1	26.6	4.34	0.39	2.73	12.7	63:1
	TapOut®	18.7	25.6	4.26	0.37	2.72	12.0	61:1
B	control	18.5	31.2	5.15	0.81	4.03	16.6	62:1
	TapOut®	17.8	31.3	5.20	0.86	4.24	16.8	62:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

Table 6. Bareroot slash pine seedling characteristics treated with clethodim at 8 – 9 weeks post-sowing at one nursery.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	25.2	27.0	4.00	0.38	2.84	11.9	68:1
	TapOut®	24.9	26.9	3.92	0.37	2.79	11.9	69:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

flazasulfuron (Mission®)

Table 7. Bareroot loblolly pine seedling characteristics treated with flazasulfuron at 8 – 9 weeks post-sowing at two nurseries.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	20.1	26.6	4.34	0.39	2.73	12.7	63:1
	Mission®	18.6	25.0	4.11	0.39	2.64	12.9	62:1
B	control	18.5	31.2	5.15	0.81	4.03	16.6	62:1
	Mission®	19.7	31.2	4.84	0.77	3.59	17.6	66:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

Table 8. Bareroot slash pine seedling characteristics treated with flazasulfuron at 8 – 9 weeks post-sowing at one nursery.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	25.2	27.0	4.00	0.38	2.84	11.9	68:1
	Mission®	25.7	25.3	3.91	0.35	2.52	12.4	65:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

florasulam (Defendor™)

Table 9. Bareroot loblolly pine seedling characteristics treated with florasulam at 8 – 9 weeks post-sowing at two nurseries.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	20.1	26.6	4.34	0.39	2.73	12.7	63:1
	Defendor™	19.9	25.6	4.10	0.37	2.49	13.0	64:1
B	control	18.5	31.2	5.15	0.81	4.03	16.6	62:1
	Defendor™	18.2	31.3	5.13	0.85	4.01	17.4	63:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

Table 10. Bareroot slash pine seedling characteristics treated with florasulam at 8 – 9 weeks post-sowing at one nursery.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	25.2	27.0	4.00	0.38	2.84	11.9	68:1
	Defendor™	25.1	26.1	4.05	0.37	2.80	11.6	65:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

imazapic (Plateau®)

Table 11. Bareroot loblolly pine seedling characteristics treated with imazapic at 8 – 9 weeks post-sowing at one nursery.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	20.1	26.6	4.34	0.39	2.73	12.7	63:1
	Plateau®	21.1	8.4	3.08	0.27	0.57	33.1	27:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

Table 12. Bareroot slash pine seedling characteristics treated with imazapic at 8 – 9 weeks post-sowing at one nursery.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	25.2	27.0	4.00	0.38	2.84	11.9	68:1
	Plateau®	25.7	10.3	3.41	0.22	0.81	21.0	30:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

orthosulfamuron (Strada®)

Table 13. Bareroot loblolly pine seedling characteristics treated with orthosulfamuron at 8 – 9 weeks post-sowing at two nurseries.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	20.1	26.6	4.34	0.39	2.73	12.7	63:1
	Strada®	19.7	26.1	4.18	0.36	2.69	11.8	64:1
B	control	18.5	31.2	5.15	0.81	4.03	16.6	62:1
	Strada®	18.5	<u>32.4</u>	5.15	0.79	4.09	16.1	65:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

Table 14. Bareroot slash pine seedling characteristics treated with orthosulfamuron at 8 – 9 weeks post-sowing at one nursery.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	25.2	27.0	4.00	0.38	2.84	11.9	68:1
	Strada®	24.5	<u>25.5</u>	3.88	0.38	2.79	12.1	66:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

oxadiazon (Ronstar®FLO)

Table 15. Bareroot loblolly pine seedling characteristics treated with oxadiazon at 8 – 9 weeks post-sowing at two nurseries.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	20.1	26.6	4.34	0.39	2.73	12.7	63:1
	Ronstar®FLO	20.0	26.9	4.22	0.37	2.69	12.1	65:1
B	control	18.5	31.2	5.15	0.81	4.03	16.6	62:1
	Ronstar®FLO	17.7	32.0	5.02	0.78	4.02	16.3	65:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1] Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

Table 16. Bareroot slash pine seedling characteristics treated with oxadiazon at 8 – 9 weeks post-sowing at one nursery.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	25.2	27.0	4.00	0.38	2.84	11.9	68:1
	Ronstar®FLO	24.9	27.9	4.05	0.39	2.73	12.8	69:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

pyraflufen (Venue®)

Table 17. Bareroot loblolly pine seedling characteristics treated with pyraflufen at 8 – 9 weeks post-sowing at two nurseries.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	20.1	26.6	4.34	0.39	2.73	12.7	63:1
	Venue®	21.4	26.4	4.28	0.41	2.78	12.9	62:1
B	control	18.5	31.2	5.15	0.81	4.03	16.6	62:1
	Venue®	17.7	31.6	5.18	0.81	3.99	16.9	63:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

Table 18. Bareroot slash pine seedling characteristics treated with pyraflufen at 8 – 9 weeks post-sowing at one nursery.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	25.2	27.0	4.00	0.38	2.84	11.9	68:1
	Venue®	25.8	27.3	3.95	0.35	2.77	11.4	70:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

tolpyralate (Shieldex®)

Table 19. Bareroot loblolly pine seedling characteristics treated with tolpyralate at 8 – 9 weeks post-sowing at two nurseries.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	20.1	26.6	4.34	0.39	2.73	12.7	63:1
	Shieldex®	19.1	<u>27.6</u>	4.35	0.39	2.94	11.8	65:1
B	control	18.5	31.2	5.15	0.81	4.03	16.6	62:1
	Shieldex®	17.8	<u>32.0</u>	5.26	0.85	4.36	16.4	62:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

Table 20. Bareroot slash pine seedling characteristics treated with tolpyralate at 8 – 9 weeks post-sowing at one nursery.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	25.2	27.0	4.00	0.38	2.84	11.9	68:1
	Shieldex®	25.1	26.9	3.84	0.38	2.56	13.0	70:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

topramezone (Frequency®)

Table 21. Bareroot loblolly pine seedling characteristics treated with topramezone at 8 – 9 weeks post-sowing at two nurseries.

Nursery	Treatment	Density/ ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	20.1	26.6	4.34	0.39	2.73	12.7	63:1
	Frequency®	19.9	26.2	4.10	0.37	2.64	12.4	65:1
B	control	18.5	31.2	5.15	0.81	4.03	16.6	62:1
	Frequency®	17.3	31.6	5.34	0.92	4.37	17.2	60:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

Table 22. Bareroot slash pine seedling characteristics treated with topramezone at 8 – 9 weeks post-sowing at one nursery.

Nursery	Treatment	Density/ ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	25.2	27.0	4.00	0.38	2.84	11.9	68:1
	Frequency®	24.6	27.5	3.93	0.38	2.72	12.2	70:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

trifloxysulfuron (Envoke®)

Table 23. Bareroot loblolly pine seedling characteristics treated with trifloxysulfuron at 8 – 9 weeks post-sowing at two nurseries.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	20.1	26.6	4.34	0.39	2.73	12.7	63:1
	Envoke®	19.7	26.2	4.20	0.37	2.67	12.2	63:1
B	control	18.5	31.2	5.15	0.81	4.03	16.6	62:1
	Envoke®	18.1	31.8	5.13	0.82	4.09	16.8	64:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.

Table 24. Bareroot slash pine seedling characteristics treated with trifloxysulfuron at 8 – 9 weeks post-sowing at one nursery.

Nursery	Treatment	Density/ ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)	Root Weight Ratio (%)	Height: Diameter Ratio[1]
A	control	25.2	27.0	4.00	0.38	2.84	11.9	68:1
	Envoke®	23.7	26.8	4.05	0.38	2.98	11.3	66:1

Single 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.

Double underlined means within a seedling characteristic indicate a significant treatment difference from that of the non-treated control at that rate according to nonparametric Wilcoxon test at alpha = 0.05.

[1]Height:diameter ratio is used as a measure of seedling 'sturdiness'. A higher ratio is interpreted as a more 'spindly' seedling; a lower ratio is interpreted as a more 'stout' seedling.