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POSTEMERGENT HERBICIDE SCREENING TRIALS ON LOBLOLLY AND SLASH PINE SEEDBEDS

by
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INTRODUCTION

Weed control in forest tree nurseries has evolved from the total reliance on hand-weeding prior to World War II and the later use of mineral spirits to the development of herbicides available for use in conifer and hardwood nurseries. However, as chemical companies advance the formulation of new products for agriculture and turf uses, specialty crop markets such as forest tree nurseries are generally not included in testing because of economy of scale considerations. To that end, since the early 1980s one of the major objectives of the Southern Forest Nursery Management Cooperative (SFNMC) has been to conduct weed control trials to fill the research gap specifically for the forest tree nursery market.

The use of preemergent herbicides in forest tree nurseries has increased over time as eliminating weeds prior to their establishment in nursery beds has become easier to achieve. Weeds that appear later in the growing season present a more complex control problem as those weeds compete with actively growing seedlings. Therefore, the number of selective postemergent herbicides labelled for use in conifer and hardwood is limited, and is reduced even further when choosing herbicides to target specific weeds.

The SFNMC routinely tests postemergent herbicides selected for their ability to eliminate or suppress problematic later-season weeds found in member nurseries. In 2016, three herbicides selected from recommendations of the Department of Crop, Soil and Environmental Sciences in College of Agriculture at Auburn University were tested in over-the-top spray applications in four member nurseries. In 2017, this trial was expanded to include five additional herbicides. The objective of this trial was to determine tolerance of bareroot loblolly and slash pine seedlings to postemergent applications of the nine herbicides. Evaluation of weed control was not an objective of this trial as the assumption was made that each herbicide will control those species listed on its label as controlled or suppressed.

The nine herbicides tested were:

> **Bentazon** (used as Basagran®T/O) is a Photosystem II inhibitor (Group 6) that blocks electron transport during photosynthesis. It is used solely in postemergent applications to actively growing plants, including broadleaf weeds, annual sedge and yellow nutsedge. Bentazon does not control grasses. Basagran®T/O is produced by BASF in liquid formulation for use in the turf and ornamental horticulture markets.

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 two varieties of bluegrass, some broadleaf weeds and yellow nutsedge in turf. Valent is the manufacturer of both Velocity® and Regiment®, a bispyribac product labelled for use in rice.

Clethodim (used as TapOut®) acts to inhibit the enzyme ACCase (Group 1) to block production of lipids. It affects only grasses due to their sensitivity to this enzyme inhibition. Broadleaf weeds and sedges are not controlled by clethodim. TapOut® is marketed by Helena Chemical, Inc. Other formulations of clethodim are Select® and Envoy™ by Valent and Arrow® by MANA. It is labelled for postemergent use in conifer nurseries, as well as on agricultural crops, fallow land, and for vegetative management in rights-of-ways and other noncrop areas.

Florasulam (used as Defendor™) is an ALS inhibitor (Group 2), disrupting production of amino acids. Florasulam is a broadleaf herbicide produced by Corteva AgriScience (formerly DowDuPont) as Defendor™ in a suspension concentrate formulation for turf applications in the U.S. It is foliar and soil active and is used primarily in postemergent applications due to its short half-life in soil.

Flumioxazin (used as Valor®EZ) acts as a Protox or PPO inhibitor (Group 14) to block chlorophyll production. It can be used in preemergent burndown applications or postemergent applications in specific agricultural crops. Broadleaf weeds and grasses are listed as controlled, as well as rice flatsedge (*Cyperus iria*). It is manufactured by Valent.

Penoxsulam (used as Grasp® SC) is an ALS inhibitor (Group 2). It is used for control of specific sedges, grasses and broadleaf plants. Penoxsulam is made by Corteva AgriScience as Grasp® SC and Granite® SC in a suspension concentrate formulation for rice crops and as LockUp® and Sapphire® in turf applications. It is also sold as a postemergent herbicide for control of annual grass and broadleaf weeds in winter wheat and triticale under the trade name PowerFlex®.

Sulfentrazone (used as Dismiss®) acts as a Protox or PPO inhibitor (Group 14) to block chlorophyll production and break down cell membranes. PPO inhibitors can be applied in preemergent or postemergent applications. It is used for control of specific broadleaf plants, sedges and goosegrass. Sulfentrazone is produced by FMC as Dismiss® in a suspension concentrate formulation for turf and ornamentals and as Spartan® for tobacco, sunflower, soybean, vegetable and oil crops.

Topramezone (used as Frequency®) is a carotenoid biosynthesis inhibitor (Group 27) that 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, its only labelled uses are for site preparation and pine release. It is manufactured by BASF.

Trifloxysulfuron (used as Envoke®) is an ALS inhibitor (Group 2). It is used for control of certain sedges, grasses and broadleaf plants. Trifloxysulfuron is produced by Syngenta as

Envoke® in a water dispersible granular formulation for cotton and sugarcane crops and as Monument® in turf.

METHODOLOGY

This trial was established in June 2017 at four SFNMC member bareroot nurseries: the ArborGen SuperTree nursery in Blenheim, South Carolina, the South Carolina Forestry Commission Nursery in Trenton, South Carolina, the ArborGen SuperTree Nursery in Shellman, Georgia and the K & L Forest Nursery in Buena Vista, Georgia. Soil types of each nursery are listed in Table 1. All herbicide applications were made between 9 and 10 weeks post- sowing on loblolly pine beds, with an additional study of slash pine at the Shellman site. Each nursery had applied their operational treatments of pre-emergent herbicides, soil stabilizer and/or bark mulch prior to the establishment of this trial.

The study was installed in a randomized block design with each treatment being one seedling bed wide by 10 feet in length and replicated five times. Due to space limitations, four replications were made at the Buena Vista site, and treatments of five feet were used in the loblolly pine study at the Shellman site. The two South Carolina trials contained eight treatments (no Velocity® used) and a non-treated control; the two Georgia trials contained nine treatments and a non-treated control. All herbicides were applied at the lowest label rate (Table 2) by SFNMC staff using a CO_2 hand sprayer calibrated to broadcast spray 25 gallons per acre.

In October and November 2017, collections of sample seedlings were made by placing a counting frame in each treatment plot and removing all seedlings within the frame, bundling seedlings from rows 2, 4 and 6 separately for further evaluation. After transporting seedlings to the SFNMC laboratory, counts of all seedlings were made for measurements of density, then samples from rows 2, 4 and 6 were measured for shoot height, root collar diameter, stem swelling, 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.

RESULTS AND DISCUSSION

All herbicides, unless noted, were tested at four bareroot loblolly pine sites and one bareroot slash pine site.

Bentazon (used as Basagran®T/O) had negative effects on loblolly seedling density and shoot height in two nurseries, and root collar diameter in a third nursery (Table 3). In contrast, bentazon-treated slash pine seedlings exhibited no negative effects when compared to the non-treated control seedlings (Table 4).

Bispyribac (used as Velocity®) was tested in loblolly pine in two nurseries and slash pine in one nursery. No significant differences in seedling characteristics were noted when treated seedlings were compared to non-treated seedlings, except reduced loblolly and slash pine shoot heights (Tables 5 and 6).

Clethodim (used as TapOut®) applied over the top of loblolly and slash pine seedlings at all sites resulted in no significant differences in seedling characteristics when compared to non-treated seedlings, except reduced loblolly pine shoot heights at one nursery (Tables 7 and 8).

Florasulam (used as Defendor™) applications on loblolly and slash pine seedlings also resulted in no significant differences in seedling characteristics when compared to non-treated seedlings, with the exception of reduced loblolly pine shoot heights at one nursery (Tables 9 and 10). In a 2016 SFNMC herbicide screening study, no negative effects of florasulam were measured in either loblolly or slash pine when applied at 8, 13 or 16 weeks after sowing (Research Report 17-02). The nursery exhibiting negative effects in the 2017 study was not included in the 2016 trial.

Flumioxazin (used as Valor®EZ) had negative effects on loblolly pine shoot height in two nurseries and loblolly seedling density in a third nursery (Table 11). Its use in slash pine resulted in no differences in any seedling characteristic when compared to untreated seedlings (Table 12).

Penoxsulam (used as Grasp® SC) applications resulted in reduced loblolly shoot heights at two nurseries and smaller root collar diameters at one of these (Table 13). Reduced slash pine heights were also measured at the single site used in this study (Table 14). Similar applications made in 2016 at 8, 13 or 16 weeks after sowing resulted in no negative effects on any loblolly or slash pine seedling characteristic measured (Research Report 17-02). However, the sites exhibiting negative effects in the 2017 study were not included in the 2016 trial.

Sulfentrazone (used as Dismiss®) had negative effects on loblolly root collar diameter in all four nurseries, shoot height in two nurseries and root and shoot dry weights in two nurseries (Table 15). Smaller root collar diameters were also measured in slash pine at the single site used (Table 16). In 2016, no significant differences were found in loblolly or slash pine seedling characteristics when applications were made at 8, 13 or 16 weeks after sowing at a site not included in this study (Research Report 17-02).

Topramezone (used as Frequency®) applications resulted in no significant damage to loblolly or slash pine seedlings when compared to non-treated control seedlings (Tables 17 and 18).

Trifloxysulfuron (used as Envoke®) use resulted in no significant differences in either loblolly or slash pine seedling characteristics measured (Tables 19 and 20). These results are comparable to those found in a 2016 SFNMC herbicide screening study (Research Report 17-02).

MANAGEMENT IMPLICATIONS

- As is often observed in bareroot nursery trials, effects of herbicides can be dependent on nursery site and soil type. The assortment and range of results in this trial are no exception. Of the nine postemergent herbicides tested, bentazon (Basagran®T/O), flumioxazin (Valor®EZ), penoxsulam (Grasp® SC) and sulfentrazone (Dismiss®) negatively affected at

least one seedling characteristic at two or more loblolly pine nurseries. Most often affected were seedling shoot heights. Because of the possibility of reduced seedling heights, lower densities and smaller root collars, caution should be used with these herbicides prior to any operational post-emergent use.

- At the single slash pine site, three of the nine herbicides tested resulted in smaller root collars or reduced shoot heights when compared to non-treated control seedlings. These herbicides were bispyribac (Velocity®), penoxsulam (Grasp® SC) and sulfentrazone (Dismiss®). Use of any of the nine herbicides should be preceded by testing in small areas at individual nursery locations because these results were obtained at a single site.

- With any herbicide not previously used at a nursery site, testing in a small trial area should be conducted to ensure tolerance of seedlings with the particular site's soil type, irrigation water, weather and operational treatments.

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

Nursery	Soil Type
A	Foxworth sand
B	Lucy loamy sand
C	Lucy loamy sand
D	Wagram sand

Table 2. Rates of nine postemergent herbicides tested at 9 – 10 weeks post-sowing at four nurseries.

Herbicide	Rate (oz./ac)
bentazon (Basagran®T/O)	24
bispyribac (Velocity®)	6
clethodim (TapOut®)	9
florasulam (Defendor™)	4
flumioxazin (Valor®EZ)	2
penoxsulam (Grasp® SC)	2
sulfentrazone (Dismiss®)	4
topramezone (Frequency®)	4
trifloxysulfuron (Envoke®)	0.1

bentazon (Basagran®T/O)

Table 3. Bareroot loblolly pine seedling characteristics treated with bentazon (Basagran®T/O) at 9 – 10 weeks post-sowing at four nurseries.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)
A	control	25.4	24.5	4.34	0.64	2.68
	Basagran®T/O	24.3	25.0	4.39	0.72	2.74
B	control	22.9	28.2	4.86	0.69	2.47
	Basagran®T/O	22.2	27.5	4.54	0.66	2.73
C	control	21.8	30.7	4.26	0.36	3.07
	Basagran®T/O	12.8	27.9	4.40	0.46	3.32
D	control	36.5	27.0	3.64	0.37	2.24
	Basagran®T/O	23.5	23.6	3.44	0.37	2.21

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.

Table 4. Bareroot slash pine seedling characteristics treated with bentazon at 9 – 10 weeks post-sowing at one nursery.

Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)
control	24.1	28.3	4.67	0.62	3.56
Basagran®T/O	20.5	27.9	4.93	0.75	4.03

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.

bispyribac (Velocity®)

Table 5. Bareroot loblolly pine seedling characteristics treated with bispyribac at 9 – 10 weeks post-sowing at two nurseries.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)
A	control	22.9	28.2	4.86	0.69	2.47
	Velocity®	23.9	27.1	4.75	0.57	2.42
B	control	21.8	30.7	4.26	0.36	3.07
	Velocity®	22.3	30.4	4.14	0.35	2.97

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.

Table 6. Bareroot slash pine seedling characteristics treated with bispyribac at 9 – 10 weeks post-sowing at one nursery.

Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)
control	24.1	28.3	4.67	0.62	3.56
Velocity®	23.5	25.4	4.67	0.58	3.59

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.

clethodim (TapOut®)

Table 7. Bareroot loblolly pine seedling characteristics treated with clethodim at 9 – 10 weeks post-sowing at four nurseries.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)
A	control	25.4	24.5	4.34	0.64	2.68
	TapOut®	25.9	24.1	4.32	0.70	2.58
B	control	22.9	28.2	4.86	0.69	2.47
	TapOut®	22.8	28.8	4.92	0.63	2.46
C	control	21.8	30.7	4.26	0.36	3.07
	TapOut®	20.4	31.0	4.45	0.38	3.25
D	control	36.5	27.0	3.64	0.37	2.24
	TapOut®	37.3	27.7	3.61	0.33	2.12

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.

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

Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)
control	24.1	28.3	4.67	0.62	3.56
TapOut®	23.3	28.8	4.70	0.61	3.65

florasulam (Defendor™)

Table 9. Bareroot loblolly pine seedling characteristics treated with florasulam at 9 – 10 weeks post-sowing at four nurseries.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)
A	control	25.4	24.5	4.34	0.64	2.68
	Defendor™	26.7	25.2	4.48	0.65	2.66
B	control	22.9	28.2	4.86	0.69	2.47
	Defendor™	23.2	28.5	4.78	0.59	2.49
C	control	21.8	30.7	4.26	0.36	3.07
	Defendor™	20.4	30.1	4.37	0.40	3.05
D	control	36.5	27.0	3.64	0.37	2.24
	Defendor™	36.2	26.7	3.64	0.38	2.02

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.

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

Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)
control	24.1	28.3	4.67	0.62	3.56
Defendor™	20.9	28.0	4.98	0.65	3.76

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.

flumioxazin (Valor®EZ)

Table 11. Bareroot loblolly pine seedling characteristics treated with flumioxazin at 9 – 10 weeks post-sowing at four nurseries.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)
A	control	25.4	24.5	4.34	0.64	2.68
	Valor®EZ	27.5	24.0	4.37	0.69	2.66
B	control	22.9	28.2	4.86	0.69	2.47
	Valor®EZ	18.2	28.3	5.10	0.74	2.45
C	control	21.8	30.7	4.26	0.36	3.07
	Valor®EZ	18.3	30.3	4.39	0.42	3.24
D	control	36.5	27.0	3.64	0.37	2.24
	Valor®EZ	36.5	24.7	3.52	0.35	2.09

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.

Table 12. Bareroot slash pine seedling characteristics treated with flumioxazin at 9 – 10 weeks post-sowing at one nursery.

Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)
control	24.1	28.3	4.67	0.62	3.56
Valor®EZ	25.0	28.0	4.66	0.68	3.66

penoxsulam (Grasp® SC)

Table 13. Bareroot loblolly pine seedling characteristics treated with penoxsulam at 9 – 10 weeks post-sowing at four nurseries.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)
A	control	25.4	24.5	4.34	0.64	2.68
	Grasp® SC	23.9	24.6	4.45	0.77	2.71
B	control	22.9	28.2	4.86	0.69	2.47
	Grasp® SC	24.8	27.0	4.40	0.71	2.15
C	control	21.8	30.7	4.26	0.36	3.07
	Grasp® SC	22.4	30.4	4.34	0.43	2.99
D	control	36.5	27.0	3.64	0.37	2.24
	Grasp® SC	36.6	23.5	3.46	0.41	2.03

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.

Table 14. Bareroot slash pine seedling characteristics treated with penoxsulam at 9 – 10 weeks post-sowing at one nursery.

Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)
control	24.1	28.3	4.67	0.62	3.56
Grasp® SC	24.1	26.8	4.68	0.63	3.25

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.

sulfentrazone (Dismiss®)

Table 15. Bareroot loblolly pine seedling characteristics treated with sulfentrazone at 9 – 10 weeks post-sowing at four nurseries.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)
A	control	25.4	24.5	4.34	0.64	2.68
	Dismiss®	26.3	25.4	3.90	0.59	2.23
B	control	22.9	28.2	4.86	0.69	2.47
	Dismiss®	24.6	26.9	4.42	0.51	2.56
C	control	21.8	30.7	4.26	0.36	3.07
	Dismiss®	20.1	29.8	4.10	0.34	2.93
D	control	36.5	27.0	3.64	0.37	2.24
	Dismiss®	34.9	23.4	3.15	0.29	1.75

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.

Table 16. Bareroot slash pine seedling characteristics treated with sulfentrazone at 9 – 10 weeks post-sowing at one nursery.

Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)
control	24.1	28.3	4.67	0.62	3.56
Dismiss®	21.6	26.9	4.44	0.62	3.50

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.

topramezone (Frequency®)

Table 17. Bareroot loblolly pine seedling characteristics treated with topramezone at 9 – 10 weeks post-sowing at four nurseries.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)
A	control	25.4	24.5	4.34	0.64	2.68
	Frequency®	27.3	24.9	4.33	0.65	2.52
B	control	22.9	28.2	4.86	0.69	2.47
	Frequency®	22.8	29.9	4.82	0.57	2.62
C	control	21.8	30.7	4.26	0.36	3.07
	Frequency®	19.7	31.3	4.36	0.38	3.32
D	control	36.5	27.0	3.64	0.37	2.24
	Frequency®	37.3	26.9	3.71	0.38	2.16

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.

Table 18. Bareroot slash pine seedling characteristics treated with topramezone at 9 – 10 weeks post-sowing at one nursery.

Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)
control	24.1	28.3	4.67	0.62	3.56
Frequency®	23.7	28.8	4.64	0.62	3.44

trifloxysulfuron (Envoke®)

Table 19. Bareroot loblolly pine seedling characteristics treated with trifloxysulfuron at 9 – 10 weeks post-sowing at four nurseries.

Nursery	Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)
A	control	25.4	24.5	4.34	0.64	2.68
	Envoke®	25.4	25.1	4.46	0.70	2.68
B	control	22.9	28.2	4.86	0.69	2.47
	Envoke®	22.4	28.8	4.93	0.70	2.44
C	control	21.8	30.7	4.26	0.36	3.07
	Envoke®	19.9	30.2	4.15	0.35	2.71
D	control	36.5	27.0	3.64	0.37	2.24
	Envoke®	36.1	26.3	3.48	0.34	2.04

Table 20. Bareroot slash pine seedling characteristics treated with trifloxysulfuron at 9 – 10 weeks post-sowing at one nursery.

Treatment	Density/ft^2	Shoot Height (cm)	RCD (mm)	Root Weight (g)	Shoot Weight (g)
control	24.1	28.3	4.67	0.62	3.56
Envoke®	22.3	28.2	4.71	0.67	3.52