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June 30, 2021

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THE PENNSYLVANIA STATE UNIVERSITY

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16. Abstract

This report details a cooperative research project performed for the Pennsylvania Department of Transportation's Bureau of Maintenance and Operations by Penn State. The report includes the following: Evaluation of Brush Herbicides on Canopy Reduction of Exotic Shrub Honeysuckle – Third Year, Evaluation of Brush Herbicides and Mixes on Canopy Reduction of Autumn Olive *(Elaeagnus umbellata)*-Second Year, Evaluation of Foliar Applications to Shrub Honeysuckle During Flowering for Canopy Reduction, Evaluation of TerraVue Applications to Amur Honeysuckle for Canopy Reduction, Evaluation of Telar XP, Segment II, and Assure II for Suppression Tall Fescue Around Cable Guiderail Systems in Grass Medians, Efficacy of Commonly Used Preemergence and Postemergence Herbicides for Control of Japanese Stiltgrass, Low Maintenance Turfgrass Species and Cultivar Comparison to Kentucky-31 Tall Fescue-Third Year, Evaluation of Native Grass and Pollinator Seed Mixes and Seeding Methods for Conversion and Establishment Along Roadsides, Comparison of Fall vs. Spring Applications of Commonly Used Tank Mixes to Achieve Season Long Total Vegetation Control.

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We are grateful for the assistance of the representatives of the various manufacturers providing products for the vegetation management industry, who have lent their time, expertise, and material support on many occasions. The following manufacturers assisted this research project during the 2020 season: Bayer Environmental Science, NuFarm, Jacklin Seed, and Corteva.

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INTRODUCTION

In October 1985, personnel at Penn State began a cooperative research project with the Pennsylvania Department of Transportation (PennDOT) to investigate several aspects of roadside vegetation management. An annual report has been submitted each year that describes the research activities and presents the data. The previous reports are listed below:

Report # PA86-018 + 85-08 - Roadside Vegetation Management Research Report

Report # PA87-021 + 85-08 - Roadside Vegetation Management Research Report
- Second Year Report

Report # PA89-005 + 85-08 - Roadside Vegetation Management Research Report
- Third Year Report

Report # PA90-4620 + 85-08 - Roadside Vegetation Management Research Report
- Fourth Year Report

Report # PA91-4620 + 85-08 - Roadside Vegetation Management Research Report
- Fifth Year Report

Report # PA92-4620 + 85-08 - Roadside Vegetation Management Research Report
- Sixth Year Report

Report # PA93-4620 + 85-08 - Roadside Vegetation Management Research Report
- Seventh Year Report

Report # PA94-4620 + 85-08 - Roadside Vegetation Management Research Report
- Eighth Year Report

Report # PA95-4620 + 85-08 - Roadside Vegetation Management Research Report
- Ninth Year Report

Report # PA96-4620 + 85-08 - Roadside Vegetation Management Research Report
- Tenth Year Report

Report # PA97-4620 + 85-08 - Roadside Vegetation Management Research Report
- Eleventh Year Report

Report # PA98-4620 + 85-08 - Roadside Vegetation Management Research Report
- Twelfth Year Report

Report # PA99-4620 + 85-08 - Roadside Vegetation Management Research Report
- Thirteenth Year Report

Report # PA00-4620 + 85-08 - Roadside Vegetation Management Research Report
- Fourteenth Year Report

Report # PA01-4620 + 85-08 - Roadside Vegetation Management Research Report
- Fifteenth Year Report

Report # PA02-4620 + 85-08 - Roadside Vegetation Management Research Report
- Sixteenth Year Report

Report # PA03-4620 + 85-08 - Roadside Vegetation Management Research Report
-Seventeenth Year Report

Report # PA04-4620 + 85-08 - Roadside Vegetation Management Research Report
-Eighteenth Year Report

Report # PA05-4620 + 85-08 - Roadside Vegetation Management Research Report
-Nineteenth Year Report

Report # PA-2008-003-PSU 005 Roadside Vegetation Management Research Report
-Twenty-second Year Report

Report # PA-4620-08-01 / LTI 2009-23 Roadside Vegetation Management Research Report
-Twenty-third Year Report

Report # PA-2010-005-PSU-016 Roadside Vegetation Management Research Report
-Twenty-fourth Year Report

Report # PA-2011-006-PSU RVM Roadside Vegetation Management Research
– 2011 Report

Report # PA-2012-007-PSU RVM Roadside Vegetation Management Research
– 2012 Report

Report # PA-2013-008-PSU RVM Roadside Vegetation Management Research
– 2013 Report

Report # PA-2014-009-PSU RVM Roadside Vegetation Management Research
– 2014 Report

Report # PA-2015-010-PSU RVM Roadside Vegetation Management Research
– 2015 Report

Report # PA-2016-011-PSU RVM Roadside Vegetation Management Research
– 2016 Report

Report # PA-2017-012-PSU RVM Roadside Vegetation Management Research
– 2017 Report

Report # PA-2018-013-PSU RVM Roadside Vegetation Management Research
– 2018 Report

Report # PA-2019-014-PSU RVM Roadside Vegetation Management Research
– 2019 Report

Report # PA-2020-015-PSU RVM Roadside Vegetation Management Research – 2020 Report

These reports are available by request from the authors and are available online in portable document format (PDF) at https://plantscience.psu.edu/research/projects/vegetative-management/annual-reports.

Use of Statistics in This Report

Many of the individual reports in this document make use of statistical analysis, particularly techniques involved in the analysis of variance. The use of these techniques allows for the establishment of criteria for significance. Numbers are said to be significantly different when the differences between them are most likely due to the different treatments, rather than chance. We have relied almost exclusively on the commonly used probability level of 0.05. When a treatment effect is significant at the 0.05 level, this indicates that there is only a five percent chance that the differences are due to chance alone. Once this level of certainty is reached with the analysis of variance, Tukey's HSD separation test is employed to separate the treatments into groups that are significantly different from each other. In many of our results tables, there is/are a letter or series of letters following each number and a notation which states, 'within each column, numbers followed by the same letter are not significantly different at the 0.05 level'. In addition, absence of letters within a column or the notation 'n.s.' indicates that the numbers in that column are not significantly different from each other at the 0.05 level.

This report includes information from studies relating to roadside brush control, herbaceous weed control, plant growth regulators, native species establishment, low maintenance groundcovers, and total vegetation control. Herbicides are referred to as product names for ease of reading. The herbicides used are listed on the following page by product name, active ingredients, formulation, and manufacturer.

Product Information Referenced in This Report

The following details additional information for products referred to in this report. DF = dry flowable, DG = dispersible granules, L = Liquid, EC = emulsifiable concentrate, ME = microencapsulated, RTU = ready to use, S = water soluble, SC = soluble concentrate, SG = soluble granule, SL = soluble liquid, WDG=water-dispersible granules, WE= water emulsion, XP= Extruded Paste.

Trade Name	Active Ingredients	Formulation	Manufacturer
Acclaim Extra	fenoxaprop p-ethyl	0.57 WE	Bayer Environmental Science
Assure II	quizalofop-Q	0.88 S	DuPont
Arsenal Powerline	imazapyr	2 S	BASF Corp.
DMA 4 IVM	2,4-D	3.8 S	Dow AgroSciences LLC
Esplanade 200 SC	indaziflam	1.67 SC	Bayer Environmental Science
Esplanade Sure	indazflam + rimsulfuron	24.3 + 16.7 WDG	Bayer Environmental Science
Facet L	quinclorac	1.5 SL	BASF Corp.
Freelexx	2,4-D choline	3.8 S	Dow AgroSciences LLC
Garlon 3A	triclopyr amine	3 S	Dow AgroSciences LLC
MSM 60	metsulfuron methyl	60 DF	Alligare LLC
Method 240SL	aminocyclopyrachlor	2 SL	Bayer Environmental Science
Milestone VM	aminopyralid	2 S	Dow AgroSciences LLC
Oust XP	metsulfuron-methyl	75 DG	Bayer Environmental Science
Payload	flumioxazin	51 WDG	NuFarm Inc.
Pendulum Aquacap	pendimethalin	3.8 ME	BASF Corp.
Piper	flumioxazin + pyroxasulfone	33.5+42.5 WDG	NuFarm Inc.
Plainview SC	indaziflam+aminocyclopyrachlor+imazapyr	0.18+0.5+1.51 SC	Bayer Environmental Science
Plateau	imazapic	2 S	BASF Corp.
ProClipse 65 WDG	prodiamine	65 WDG	NuFarm Inc.
RoundUp Pro	glyphosate	4 S	Monsanto Company
RoundUp Pro Concentrate	glyphosate	5 S	Monsanto Company
Segment II	sethoxydim	1.5 EC	BASF Corp.
Spyder Extra	sulfometuron + metsulfuron	56.25 + 15 WDG	NuFarm Inc.
Telar XP	chlorsulfuron	75 DF	Bayer Environmental Science
TerraVue	aminopyralid+florpyrauxifen-benzyl	71 + 6 WDG	Corteva Agrisciences
Triplet LO	2,4-D+mecoprop-p+dicamba	2.38+0.63+0.22 S	NuFarm Inc.
Vastlan	triclopyr choline	4 S	Dow AgroSciences LLC
Vanquish	dicamba	4 S	NuFarm Inc.

EVALUATION OF BRUSH HERBICIDES ON CANOPY REDUCTION OF EXOTIC SHRUB HONEYSUCKLE-3RD YEAR

Herbicide trade and common names: DMA 4 IVM (*2,4-D*); RoundUp Pro (*glyphosate*); Garlon 3A (*triclopyr*)

Plant common name and scientific name: honeysuckle (*Lonicera spp.* L.)

ABSTRACT

Exotic shrub honeysuckle has become widespread along Pennsylvania roads disrupting vehicle sight lines and creating visibility hazards along roadside edges where wildlife cross. In a continuing effort to find an effective control strategy, this experiment evaluated six herbicide treatments including DMA 4 IVM, RoundUp Pro, Garlon 3A at increasing rates, and Garlon 3A tank mixed with DMA 4 IVM. RoundUp Pro at 128 oz/ac, DMA 4 IVM at 128 oz/ac, and Garlon 3A at 384 oz/ac resulted in at least 99% injury to honeysuckle 64 DAT (days after treatment). By 366 DAT, the most effective canopy reduction was found with RoundUp Pro at 128 oz/ac (100%), Garlon 3A at 384 oz/ac (95.56%), DMA 4 IVM at 128 oz/ac (95.22%), and Garlon 3A at 64 oz/ac + DMA 4 IVM at 128 oz/ac (95%). Garlon 3A at 64 oz/ac and Garlon 3A at 128 oz/ac reduced canopy by 72.78 and 78.33, respectively. The untreated check continued to show natural signs of canopy reduction of 22.89 percent. By 735 DAT the greatest canopy reduction was found with RoundUp Pro at 128 oz/ac and DMA 4 IVM at 128 oz/ac resulted in 100% canopy reduction, effectively killing honeysuckle. Garlon 3A at 384 oz/ac and Garlon 3A at 64 oz/ac + DMA 4 IVM at 128 oz/ac followed with over 90% permanent reduction in canopy.

INTRODUCTION

Exotic shrub honeysuckle species continue to spread along Pennsylvania transportation rights-of-way and remain difficult to control. Native to Europe, Asia, and Japan, exotic honeysuckle species were introduced in the 1800's as ornamentals and planted as a food and cover crop for wildlife even though native plants are higher in nutritional value than the exotic honeysuckle; until deemed invasive[1]. The exotic shrub honeysuckle species are further spread by birds feeding on the berries and depositing the seed, which remains viable for several years. Previous research applying a combination of brush control herbicides through a side trimming application to mimic a typical truck spray pattern employed along the roadside appeared partially effective on shrub honeysuckle; however, the results were inconclusive[2,3]. This experiment was designed to determine the effectiveness of RoundUp Pro, Garlon 3A, DMA 4 IVM and a mix of Garlon 3A plus DMA 4 IVM when applied to the entire shrub.

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[1] http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/dcnr_010229.pdf Shrub Honeysuckles. Viewed April 10, 2019.

[2] Johnson et. al. 2015. 2012 Investigation of Morrow's Honeysuckle (Lonicera morrowii) Control with Herbicide Tank Mix Combinations. Roadside Vegetation Management Research-2015 Report. pp.1-5.

[3] Johnson et. al. 2016. Investigation of Herbicide Tank Mixes Using Increased Rates of 2,4-D for Control of Morrow's Honeysuckle (Lonicera morrowii) 2nd Year Results. Roadside Vegetation Management Research-2016 Report. pp1-4.

MATERIALS AND METHODS

The experiment was established on the apex of a road cut along Interstate 99 at the Pinecroft interchange near the ramp from SR 0764 to I-99 southbound. The herbicide treatments included DMA 4 IVM at 128 oz/ac, RoundUp Pro at 128 oz/ac (glyphosate acid 3 lbs./gal), Garlon 3A at 64 oz/ac, Garlon 3A at 128 oz/ac, Garlon 3A at 384 oz/ac, Garlon 3A at 64 oz/ac + DMA 4 IVM at 128 oz/ac, and an untreated check. All herbicide treatments included methylated seed oil at 1% v/v. The application was made at a carrier volume of 50 gallons per acre (GPA). The experiment was established as a randomized complete design with nine plants per treatment. Individual shrubs were measured, the average width was multiplied by the height then multiplied by 2 to determine the entire canopy area of each plant. The dose of the herbicide application to individual plants was based on the calculated canopy area. A complete table can be found in the appendix at the end of this report (Appendix Table 1). Treatments were applied using a CO_2-powered sprayer equipped with a handgun with one PPX6 nozzle at 30 psi. The honeysuckle was treated on July 7, 2018.

Treatments were visually rated for percent injury using the following rating system, 0=no injury–100=complete necrosis on August 8 and September 11, 2018; 30 and 64 DAT (days after treatment). Treatments were visually rated for percent canopy reduction using the following rating system, 0=no canopy reduction–100=complete canopy reduction on July 10, 2019, and July 13, 2020; 366, and 735 DAT (Table 1). All data were subject to analysis of variance and when treatment F-tests were significant ($p \leq 0.05$), treatment means were compared using Tukey's HSD separation test.

RESULTS AND DISCUSSION

Initial percent injury of the herbicide treatments ranged from 63.78 to 99.33 on August 8, 2018, 30 DAT. The untreated check plots averaged over 5 percent injury due to leaf spots. By 64 DAT, percent injury ranged from 86.67 to 99.89 and all herbicide treatments were statistically similar. Three treatments, Garlon 3A at 384 oz/ac, DMA 4 IVM at 128 oz/ac, and RoundUp Pro at 128 oz/ac, resulted in 99 percent injury by 64 DAT. Garlon 3A at 64 oz/ac resulted in the lowest percent injury at 86.67 while RoundUp Pro at 128 oz/ac resulted in the highest percent injury at 99.87. Interestingly, the untreated check increased to 29.44 percent injury by 64 DAT. The wet conditions during the summer of 2018 may have promoted foliar disease among the brush honeysuckle. To verify the presence of a leaf disease among the untreated control plants, several leaf samples were collected and submitted to the Penn State Plant Disease Clinic. The clinic identified *Alternaria* which can cause leaf spot on honeysuckle. By 366 DAT, the most effective treatments based on percent canopy reduction was RoundUp Pro at 128 oz/ac (100%), Garlon 3A at 384 oz/ac (95.56%), DMA 4 IVM at 128 oz/ac (95.22%), and Garlon 3A at 64 oz/ac + DMA 4 IVM at 128 oz/ac (95%). Garlon 3A at 64 oz/ac and Garlon 3A at 128 oz/ac produced canopy reduction of 72.78 and 78.33 percent, respectively. The untreated check continued to show signs of damage with 22.89 percent canopy reduction. The last rating for the experiment was on July 13, 2020. Two years after treatment, RoundUp Pro at 128 oz/ac and DMA 4 IVM at 128 oz/ac resulted in 100% canopy reduction of honeysuckle. Garlon 3A at 64 oz/ac + DMA 4 IVM at 128 oz/ac and Garlon 3A at 384 oz/ac produced a reduction in canopy of was 97.78% and 92.78%, respectively. The lowest reduction was found with Garlon 3A at 128 oz/ac was 78.33%, and Garlon 3A was 67.78%. Surprisingly, the untreated control plants continued to show an increase in canopy reduction (46.11%) compared to the previous year (22.89%). Leaf, twig and roots were collected from affected control plants and submitted in July 2020 to the Penn State Plant Disease Clinic. After analysis of leaf and twig samples followed by root samples no pathogens were found, and the roots tested negative for Phytophthora using Agdia's ImmunoStrip test. The Penn State Plant Disease Clinic stated the decline of the plants could be due to an abiotic agent or another root rot pathogen for which the clinic did not test. We have no explanation for the high percent canopy reduction of the untreated honeysuckles 2 years after initiation of this experiment.

CONCLUSIONS

RoundUp Pro at 128 oz/ac, DMA 4 IVM at 128 oz/ac, Garlon 3A at 384 oz/ac and Garlon 3A at 64 oz/ac + DMA 4 IVM at 128 oz/ac resulted in over 90% canopy reduction two years after treatment. RoundUp Pro at 128 oz/ac and DMA 4 IVM at 128 oz/ac were the only treatments that effectively killed the treated honeysuckle. Increasing the rate of Garlon 3A alone will increase canopy reduction in honeysuckle. The addition of Garlon3A at 64 oz/ac to DMA 4 IVM at 128 oz/ac did not increase canopy reduction of honeysuckle compared to DMA 4 IVM at 128 oz/ac alone.

MANGEMENT IMPLICATIONS

Herbicide treatments of Garlon 3A at 384 oz/ac and Garlon 3A at 64 oz/ac + DMA 4 IVM at 128 oz/ac provided greater than 90 percent honeysuckle canopy reduction two years after treatments were applied. The most effective treatments, RoundUp Pro at 128 oz/ac as well as DMA 4 IVM at 128 oz/ac, were 100 percent effective. Garlon 3A and DMA 4 IVM are grass safe broadleaf herbicides. However, RoundUp Pro is a total vegetation herbicide that will control desirable vegetation as well and may create bareground below shrubs when applied as a foliar application. Mixes containing glyphosate as a targeted application or broadcast over sites with little or no desirable vegetation may be an option in certain situations. If herbicide applications create or increase bareground, integrated vegetation management practices recommend seeding a low growing grass groundcover such as formula L. This approach will assure a competitive low growing grass groundcover that will facilitate the use of broadleaf weed control products without damaging the grass groundcover.

Table 1. Percent injury and canopy reduction of honeysuckle (Lonicera spp.). Treatments were visually rated for percent injury using the following rating system, 0=no injury–100=complete necrosis on August 8 and September 11, 2018; 30 and 64 DAT (days after treatment) and percent canopy reduction using the following rating system, 0=no canopy reduction–100=complete canopy reduction on July 10, 2019, and July 13, 2020; 366, and 735 DAT. Treatments were applied July 9, 2018. All treatments included methylated seed oil at 1% v/v. Each value is the mean of nine replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/ac	% Injury 8/8/18 30 DAT	% Injury 9/11/18 64 DAT	% Canopy Reduction 7/10/19 366 DAT	% Canopy Reduction 7/13/20 735 DAT
Untreated	---	5.56 a	29.44 a	22.89 a	46.11 a
DMA 4 IVM	128	91.78 bc	99.78 b	95.22 b	100 b
RoundUp Pro	128	99.33 c	99.89 b	100 b	100 b
Garlon 3A	64	63.78 b	86.67 b	72.78 b	67.78 ab
Garlon 3A	128	75.33 bc	93.67 b	78.33 b	77.78 ab
Garlon 3A	384	97.33 c	99 b	95.56 b	92.78 b
Garlon 3A DMA 4 IVM	64 128	87 bc	98.78 b	95 b	97.78 b

EVALUATION OF BRUSH HERBICIDES AND MIXES ON CANOPY REDUCTION OF AUTUMN OLIVE *(ELAEAGNUS UMBELLATA),* 2ND YEAR

Herbicide trade and common names: Freelexx (2,4-D choline); Method 240SL (*aminocyclopyrachlor*); MSM 60 (*metsulfuron methyl*); Garlon 3A (*triclopyr amine*); Vanquish (*dicamba*)

Plant common and scientific name: autumn olive (*Elaeagnus umbellata*)

ABSTRACT

Autumn olive is an invasive plant in Pennsylvania and has proven to be difficult to control through mowing and cutting activities without the use of herbicides. An experiment was conducted at the Penn State Russell E. Larson Agricultural Research Center, Agronomy Farm near Rock Springs, PA to compare commonly used brush herbicides for canopy reduction of autumn olive. In a continuing effort to develop effective brush herbicide mixes, this experiment evaluated ten herbicide treatments including Freelexx at rates of 96 oz/ac and 128 oz/ac, Freelexx at 96 oz/ac tank mixed with Method 240SL at 16 oz/ac and MSM 60 at 0.5 oz/ac, Freelexx at 96 oz/ac tank mixed with Garlon 3A at 64 oz/ac and MSM 60 at 0.5 oz/ac, Method 240SL at 16 oz/ac, MSM 60 at 0.5 oz/ac, Garlon 3A at rates of 64 oz/ac, 128 oz/ac, and 384 oz/ac, and Vanquish at 64 oz/ac. By 14 days after treatment (DAT), Freelexx at 96 oz/ac, Freelexx at 96 oz/ac tank mixed with Method 240SL at 16 oz/ac and MSM 60 at 0.5 oz/ac, and Garlon 3A at 64 oz/ac provided a minimum of 99% injury of autumn olive. At 229 DAT, treatments of MSM 60 at 0.5 oz/ac resulted in the highest canopy reduction of autumn olive at 100% while Vanquish at 64 oz/ac resulted in 99.7% canopy reduction, Freelexx at 96 oz/ac + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac resulted in 97.22% canopy reduction, Method 240SL at 16 oz/ac resulted in 96.9% canopy reduction, Freelexx at 96 oz/ac resulted in 91.7% canopy reduction, and Garlon 3A at 384 oz/ac resulted in 91.3% canopy reduction. However, by 370 DAT, MSM 60 at 0.5 oz/ac reduced canopy size by 100% while Method 240SL at 16 oz/ac did by 97.5%. All other herbicide treatments showed lower percent canopy reduction of autumn olive when compared to data collected 229 DAT indicating regrowth of autumn olive.

INTRODUCTION

Autumn olive (*Elaeagnus umbellata*) is a spreading and colonizing invasive shrub found along roadsides in Pennsylvania. Introduced to the United States from East Asia in 1830 autumn olive was planted extensively in Pennsylvania and other states to revegetate severely disturbed sites such as stripe mines[4]. *Elaeagnus umbellata* is a small tree or multi-stem shrub, capable of fixing nitrogen, which aids its establishment and growth in poor soil conditions found along the roadside[5]. Plants can grow 20 feet in height and spread 30 feet wide[6]. Autumn olive matures

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[4] Ann F Rhoads and Timothy A Block Morris Arboretum of the University of Pennsylvania 2011. Autumn Olive and Russian Olive. http://paflora.org/original/pdf/INV-Fact%20Sheets/Elaeagnus%20spp.pdf

[5] Jeffrey C Jodon et al 2018. Comparison of Aminocyclopyrachlor, Aminopyralid, and Two Formulations of Triclopyr for Control of Autumn Olive *(Elaeagnus umbellata)* Using Low Volume Foliar Treatments. Roadside Vegetation Management Research – 2018 Report. pp 1-5.

[6] Autumn Olive. https://extension.psu.edu/autumn-olive

quickly and can produce fruit in as little as three years. This shrub will fruit prolifically with birds dispersing the seeds[4]. After mowing or cutting autumn olive vigorously resprouts, crowding out desirable vegetation, and reducing visibility for motorists and impeding maintenance operations. In order to effectively manage autumn olive, the root system must be controlled. This experiment evaluated the effectiveness of Freelexx, Method 240SL, MSM 60, Garlon 3A, Vanquish, a mix of Freelexx plus Method 240SL and MSM 60, and a mix of Freelexx plus Garlon 3A and MSM 60 applied to the entire autumn olive shrub.

MATERIALS AND METHODS

The experiment was established at the Penn State Russell E. Larson Agricultural Research Center, Agronomy Farm in Rock Springs, PA. The herbicide treatments included Freelexx at 96 oz/ac and 128 oz/ac; Freelexx at 96 oz/ac + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac; Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac; Method 240SL at 16 oz/ac; MSM 60 at 0.5 oz/ac; Garlon 3A at 64 oz/ac, 128 oz/ac, and 384 oz/ac; Vanquish at 64 oz/ac; and an untreated check. Methylated seed oil at 1% v/v was added to all herbicide treatments. The experiment was established as a complete randomized design with ten plants per treatment. Individual shrubs were measured, the average width was multiplied by the height which was then multiplied by 2 to determine the entire canopy area of each plant. The dose of the herbicide application to individual plants was based on the calculated canopy area. A complete table can be found in the appendix at the end of this report (Appendix Table 2). At application, the sky was mostly sunny with some cloud coverage and air speed of 0-5 mph, temperature 70° F, with 50% relative humidity. Treatments were applied using a CO_2-powered backpack sprayer equipped a handgun and one PPX 6 nozzle. The application was made at a carrier volume of 35 gallons per acre (GPA) and a pressure of 35 pounds per square inch (psi). The autumn olive was treated on September 19, 2019.

Treatments were visually rated for percent injury where 0 = no injury–100 = complete injury on October 3, 2019, 14 days after treatment (DAT) and for percent canopy reduction where 0 = no canopy reduction–100 = complete canopy reduction on May 5, 2020, 229 DAT and September 22, 2020, 370 DAT. All data were subject to analysis of variance and when treatment F-tests were significant ($p \leq 0.05$), treatment means were compared using Tukey's HSD separation test.

RESULTS AND DISCUSSION

Percent injury was rated on October 3, 2019, 14 DAT. Usually, injury ratings are conducted 1 month after treatment. However, to avoid rating after a killing frost, injury ratings were conducted 14 DAT, before the frost event. By 14 DAT, MSM 60 at 0.5 oz/ac showed less injury (4%) than untreated plants (6.5%) and were not statistically similar (Table 1). Freelexx at 128 oz/ac, Method 240SL at 16 oz/ac and Garlon 3A at 128 oz/ac resulted in injury ratings of 80.6%, 81.4%, and 89.2%, respectively. Vanquish at 64 oz/ac, Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac, and Garlon 3A at 384 oz/ac showed injury ratings of 96.4%, 96.8%, and 97.3%, respectively. Freelexx at 96 oz/ac, Freelexx at 96 + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac, and Garlon 3A at 64 oz/ac resulted in 99.2%, 99.6%, and 99.7% injury, respectively.

By 229 DAT, MSM 60 at 0.5 oz/ac resulted in 100% canopy reduction followed by Vanquish at 64 oz/ac resulted in 99.7% canopy reduction and Method 240SL at 16 oz/ac resulted in 96.9% canopy reduction. Freelexx at 96 oz/ac showed greater canopy reduction (91.7%) than Freelexx at 128 oz/ac (71.11%). The treatment effects of two commonly used brush mixes of Freelexx at 96 oz/ac tank + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac showed 97.22% canopy reduction and Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac showed 82.8% canopy reduction. Garlon 3A at increasing rates of 64 oz/ac, 128 oz/ac, and 384 oz/ac, ranged from 82.89%-91.3% and showed mixed results. Canopy reduction only slightly increased as rates of Garlon 3A increased from 64 oz/ac to 384 oz/ac. However, results showed that Garlon 3A at 128 oz/ac had less canopy reduction than Garlon 3A at 64 oz/ac.

On September 22, 2020, 370 DAT, MSM 60 at 0.5 oz/ac continued to show the highest autumn olive canopy reduction at 100%. When compared to the May rating, Method 240SL at 16 oz/ac increased percent canopy reduction from 96.9 to 97.22. All other treatments showed less canopy reduction than the rating in May indicating the ability of autumn olive to grow despite the herbicide treatments. Commonly used brush tank mixes of Freelexx at 96 oz/ac + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac showed 83.33% canopy reduction and Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac showed 46.5% canopy reduction. One observation while evaluating percent canopy reduction was that herbicide mixes typically showed less canopy reduction compared to the individual herbicide applied alone. For example, herbicides applied alone like MSM 60 at 0.5 oz/ac resulted in 100% canopy reduction, Method 240SL at 16 oz/ac resulted in 97.22% canopy reduction, Freelexx at 96 oz/ac resulted in 59.5% canopy reduction and Garlon 3A at 64 oz/ac resulted in 70.5% canopy reduction. In comparing the mix Freelexx at 96 oz/ac + Garlon 3A 64 oz/ac + MSM 60 0.5 oz/a (46.5% canopy reduction) to the same herbicides and rates applied individually, those applied alone had greater canopy reduction. However, one exception to the trend of individual herbicides outperforming mixes was Freelexx at 96 oz/ac (59.5%reduction) was less than the mix Freelexx at 96 oz/ac + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac (83.33%).

CONCLUSIONS

By October 3, 2019, 14 DAT, percent injury of the herbicide treatments ranged from 4% to 99.7%. All of the herbicide treatments, except for MSM 60 (4% injury), had similar levels of injury as a result of herbicide treatments. While Garlon 3A at 64 oz/ac (99.7%) resulted in the highest rate of injury, by 234 days after treatment, MSM 60 at 0.5 oz/ac had the highest canopy reduction of autumn olive at 100% followed by Vanquish at 99.7%. The least effective treatment was Freelexx at 128 oz/ac with 71.11% canopy reduction. With the exception of MSM 60, all remaining treatments showed signs of resprouting from dormant buds or roots at 229 days after treatment. This trend continued while rating one year after treatment. MSM 60 at 0.5 oz/ac showed the highest percent canopy reduction at 100% and Method 240SL at 16 oz/ac showed 97.22 percent canopy reduction. Increasing the rate of Garlon 3A from 64 oz/ac to 128 oz/ac did not increase canopy reduction, however, increasing the rate of Garlon 3A to 384 oz/ac did increase canopy reduction. Similarly, increasing the rate of Freelexx from 96 oz/ac to 128 oz/ac did not increase canopy reduction. Herbicide mixes containing MSM 60 resulted in less canopy reduction of autumn olive than MSM 60 applied alone. Data analysis two years after treatment will determine whether the MSM 60 has long-term canopy reduction and if Method 240SL at 16 oz/ac can offer complete canopy reduction of autumn olive.

MANAGEMENT IMPLICATIONS

By 229 DAT and continuing one year after treatment MSM 60 showed 100% control, while the other herbicide treatments showed resprouts from dormant buds. Method 240SL at 16 oz/ac is a treatment to monitor to determine if the plants are completely controlled 2 years after treatment or if growth continues. Two years after treatment data collection and analysis will determine recommendations for autumn olive canopy reduction. MSM 60 or products containing metsulfuron-methyl and Method 240SL or products containing aminocyclopyrachlor should be used with caution. Previous work by the roadside project recommended rates of metsulfuron-methyl not to exceed 0.5 oz/ac to minimize damage to understory grass[7]. The Method 240SL label cautions that exceeding rates of 8 oz/ac may result in unacceptable injury to desirable turfgrasses, the addition of MSO adjuvant may increase the potential for turfgrass injury, and potential to injure desirable trees and plants when their root system extend into treated areas[8].

[7] Jon M Johnson et al 2014. Examining Potential Turf Phytotoxicity Caused by Escort XP, Krenite S and MAT 28. Roadside Vegetation Management Research – 2014 Report. pp 23-26.
[8] Bayer CropScience LP. Method 240SL label. http://www.cdms.net/ldat/ldCFU015.pdf Internet November 23, 2020

Table 1. Percent injury and canopy reduction of autumn olive (*Elaeagnus umbellata*). The experiment was visually rated for percent injury where 0 = no injury –100 = complete injury on October 3, 2019, 14 days after treatment (DAT), and percent canopy reduction where 0 = no canopy reduction –100 = complete canopy reduction on May 5, and September 22, 2020, 229 and 370 DAT, respectively. Treatments were applied September 19, 2019. All treatments included methylated seed oil at 1% v/v. Each value is the mean of ten replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/ac	% Injury 10/3/19 14 DAT	% Canopy Reduction 5/5/20 229 DAT	% Canopy Reduction 09/22/20 370 DAT
Untreated	--	6.5 a	11 a	9.67 a
Freelexx Method 240SL MSM 60	96 16 0.5	99.6 b	97.22 b	83.33 cd
Freelexx Garlon 3A MSM 60	96 64 0.5	96.8 b	82.8 b	46.5 b
Method 240SL	16	81.4 b	96.9 b	97.22 d
Garlon 3A	64	99.7 b	87.4 b	70.5 bcd
Garlon 3A	128	89.2 b	82.89 b	61.67 bc
Garlon 3A	384	97.3 b	91.3 b	71 bcd
Freelexx	96	99.2 b	91.7 b	59.5 bc
Freelexx	128	80.6 b	71.11 b	47.78 b
Vanquish	64	96.4 b	99.7 b	85.5 cd
MSM 60	0.5	4 a	100 b	100 d

EVALUATION OF FOLIAR APPLICATIONS TO SHRUB HONEYSUCKLE DURING FLOWERING FOR CANOPY REDUCTION

Herbicide trade and common names: Freelexx (*2,4-D choline*); Method 240SL (*aminocyclopyrachlor*); MSM 60 (*metsulfuron methyl*); Garlon 3A (*triclopyr amine*); Vanquish (*dicamba*); RoundUp Pro Concentrate (g*lysophate*); TerraVue (*aminopyralid + florpyrauxifen*); Vastlan (*triclopyr choline*)

Plant common and scientific names: Morrow's honeysuckle *(Lonicera morrowii*); Amur honeysuckle (*Lonicera maackii)*; and Tatarian honeysuckle *(Lonicera tatarica)*

ABSTRACT

Brush control along the roadsides of Pennsylvania is difficult, even with a strong and effective brush herbicide program in place. An experiment was established at the Penn State Horticulture Farm located at the Russell E. Larson Agricultural Research Center near Rock Springs, PA to evaluate the efficacy of brush herbicide applications during the flowering stage of exotic shrub honeysuckle. The herbicide treatments included Freelexx at 96 oz/ac tank mixed with MSM 60 at 0.5 oz/ac and Method 240SL at 16 oz/ac, Freelexx at 96 oz/ac tank mixed with MSM 60 at 0.5 oz/ac and Garlon 3A at 64 oz/ac, Freelexx at 96 oz/ac tank mixed with MSM 60 at 0.5 oz/ac and TerraVue at 2.85 oz/ac, Freelexx at 128 oz/ac and Garlon 3A at 64 oz/ac, Garlon 3A at 128 oz/ac, Vanquish at 64 oz/ac, RoundUp Pro Concentrate at 104 oz/ac, TerraVue at a rate of 2.85 oz/ac, Freelexx at 64 oz/ac tank mixed with TerraVue at 2.85 oz/ac and Vastlan at 64 oz/ac, Freelexx at 128 oz/ac, MSM 60 at 0.5 oz/ac and an untreated check. By 60 days after treatment, Freelexx alone at 128 oz/ac, Freelexx at 64 oz/ac tank mixed with TerraVue at 2.85 oz/ac and Vastlan at 64 oz/ac, and Freelexx at 96 oz/ac tank mixed with MSM 60 at 0.5 oz/ac and Method 240SL at 16 oz/ac provided a minimum of 99% injury to exotic shrub honeysuckle.

INTRODUCTION

The introduction and use of exotic shrub honeysuckle as an ornamental planting and the continuous spread of the plant's seed has made non-native honeysuckles extremely difficult to control in Pennsylvania. Native and non-native honeysuckle can be easily differentiated by the stem pith, native species have a solid pith and non-native species have a hollow pith. Like the native species, the exotic shrub honeysuckle species produces seeds which are viable for years. The seeds are readily distributed by foraging birds which has created an ongoing need for control of exotic shrub honeysuckle[9].

Each shrub was identified on May 26, 2020. Two characteristics that were used to identify the different varieties of exotic honeysuckle are the length of the flower peduncles compared to the leaf petioles and the flower color. At least seven different species of honeysuckle have been found in Pennsylvania. Among these seven species, the three most

[9] Jodon et. al. 2020. 2020 Evaluation of brush control herbicides on control of exotic shrub honeysuckle – 2nd year. Roadside Vegetation Management Research 2020 Report. pp 1-3.

common honeysuckle species include morrow's honeysuckle, amur honeysuckle, and tatarian honeysuckle[10]. Amur honeysuckle has a white to yellow flower with a shorter peduncle, morrow's honeysuckle has a creamy-white to yellow flower with a longer peduncle, and tatarian honeysuckle has a pink to white flower with a longer peduncle[11]. Within the experimental area, only two shrubs of the morrow's honeysuckle were identified, with the remaining identified as amur honeysuckle.

This experiment was designed to determine the efficacy of several herbicide treatments applied during the flowering period. A Missouri field crop study focusing on control of perennial broadleaf weeds showed that effective control can be achieved before and during flower bud initiation when food supplies are being transported down to the root system along with any penetrating herbicide[12]. Another study examining the effect of application timing on morrow's honeysuckle showed that control can be successful when the application coincides with a plant's flowering stage. The levels of total nonstructural carbohydrates (TNC) that are stored in the roots, fluctuate during different phenological stages of a plant, lowering the levels and nearly exhausting the plant during flowering[13]. This experiment was designed to utilize the low levels of TNC during flowering to allow for maximum efficacy of the herbicides.

MATERIALS AND METHODS

The experiment was established at the Penn State Horticulture Farm at the Russell E. Larson Agricultural Research Center as a complete randomized design with ten plants per treatment. Each honeysuckle was measured. To determine the canopy area of each plant, the average width was multiplied by its height then multiplied by 2 to capture the whole plant as a three-dimensional object (Appendix Table 3). A complete table can be found in the appendix at the end of this report. The herbicide application amounts were based on the calculated canopy area. The herbicide treatments are listed in order of appearance in Table 1 and included (2)Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac + Method 240SL at 16 oz/ac, (3)Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac + Garlon 3A at 64 oz/ac, (4)Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac + TerraVue at 2.85 oz/ac, (5)Freelexx at 128 oz/ac + Garlon 3A at 64 oz/ac, (6)Garlon 3A at 128 oz/ac, (7)Vanquish at 64 oz/ac, (8)RoundUp Pro Concentrate at 104 oz/ac, (9)TerraVue at 2.85 oz/ac, (10, 13) Freelexx at 64 oz/ac + TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac (an initial and alternate application), (11)Freelexx at 128 oz/ac, (12)MSM 60 at 0.5 oz/ac, and an untreated check. Methylated seed oil at 1% v/v was added to all herbicide treatments. The application was made at a carrier volume of 35 gallons per acre (GPA). All treatments were

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[10] Gover, Art, Johnson, Jon, and Kuhns, Larry. Noxious and Troublesome Roadside Weeds. Herbicide Applicator Training Modul 4. Penn State Vegetation Management

[11] Olson, Cassandra and Cholewa, Anita F. Table comparing nonnative shrubby Lonicera spp. A guide to Non-native Invasive Plants Inventoried in the North by Forest Inventory and Analysis. NRS Publications and Data. Viewed June 2020. https://www.nrs.fs.fed.us/pubs/34183

[12] DeFelica, Michael S. and Sims, Barry D. Control of perennial broadleaf weeds in Missouri field crops. Agricultural Guide. Published by the University Missouri-Columbia Extension Division. Department of Agronomy College of Agriculture. Viewed April 29, 2021

[13] Love, Jason P. and Anderson, James T. Seasonal Effects of Four Control Methods on the Invasive Morrow's Honeysuckle (Lonicera morrowii) and Initial Responses of Understory Plants in a Southwestern Pennsylvania Old Field. Restoration Ecology Research Article. The Journal of the Society of Ecological Restoration International. Viewed April 29, 2021

applied using a CO_2-powered backpack sprayer equipped with a 30 GunJet spray gun and one PPX 6 adjustable nozzle at 32 pounds per square inch (PSI). Treatments 2-10 were applied on June 4, 2020. The weather at the time of application was sunny to partly cloudy with wind speeds of 5-10 mph. Soil temperatures at the surface, 1-inch, 3-inch, and 6-inch depths were 72°F, 72°F, 73°F and 72°F, respectively. Due to a heavy rainstorm developing in the area approximately 20-30 minutes after treatment 10 was sprayed, the remaining treatments 11 and 12 were applied the following day on June 5, 2020. The weather at the time of application consisted of sunny skies, wind speeds of 5-10 mph, air temperature of 72° F, and 71% relative humidity. Soil moisture temperatures at the surface, 1-inch, 3-inch, and 6-inch depths were 72° F, 72°F, 73°F and 72° F, respectively. Finally, since a rainstorm developed shortly after the application of treatment 10 (Freelexx 64 oz/ac + Initial TerraVue 2.85 oz/ac + Vastlan 64 oz/ac), this treatment was re-applied to additional honeysuckle plants on June 8, 2020. In Appendix Table 3, plant A1 through A10 represents the honeysuckle treated. In Table 1, treatment 13 (Freelexx 64 oz/ac + Alternate TerraVue 2.85 oz/ac + Vastlan 64 oz/ac) identifies this additional treatment. The weather at the time of the second application consisted of sunny skies, wind speeds of 5-10 mph, air temperature of 72° F, and 43% relative humidity. Soil moisture temperatures at the surface, 1-inch, 3-inch, and 6-inch depths were 72° F, 72°F, 73° F, and 72° F, respectively, according to http://newa.cornell.edu. The nearest weather station was located at Rock Springs, PA.

Treatments were visually rated for percent injury 0 = no injury – 100 = complete injury on July 6, 2020, 30 days after treatment (DAT) and on August 6, 2020, 60 DAT, respectively. All data were subjected to analysis of variance, and when treatment effect F-tests were significant ($p \leq 0.05$), treatment means were compared using Tukey's HSD separation test.

RESULTS AND DISCUSSION

Initial percent injury of the herbicide treatments ranged from 26% to 98.2% by July 6, 2020, 32 DAT, while the untreated check showed 1.1% (Table 1). By 63 DAT, Freelexx at 128 oz/ac, Freelexx 64 oz/ac + Alternate TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac, and Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac + Method 240SL at 16 oz/ac showed an increase in injury with a minimum of 99%. Followed by Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac + Garlon 3A at 64 oz/ac with 97.5% injury, Freelexx at 128 oz/ac + Garlon 3A at 64 oz/ac with 95.5%, Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac + TerraVue at 2.85 oz/ac also 95%, and Garlon 3A at a rate of 128 oz/ac with 92.5% injury. The most effective treatment was Freelexx at a rate of 128 oz/ac with a percent injury rate of 99.3. In fact, all treatments containing Freelexx resulted in the greatest injury. Vanquish at 64 oz/ac, MSM 60 at 0.5 oz/ac, TerraVue at 2.85 oz/ac, and RoundUp Pro Concentrate at 104 oz/ac, produced a lower percent injury ranging from 72% to 40%. RoundUp Pro Concentrate at 104 oz/ac treatment resulted in the lowest percent injury at 40. The untreated check showed a 1 percent injury rate.

In comparing the Initial and Alternate TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx 64 oz/ac treatments, it appears the rainstorm reduced percent injury of honeysuckle to the Initial treatment by more than 30%. It appears that this mix was not rain-safe 30 minutes after application. Previous work by the roadside project (Jodon et.al. 2020) showed higher % injury to honeysuckle with RoundUp Pro at 128 oz/ac, which was an equivalent rate to the amount of glyphosate used in the current experiment. Apparently, the rainstorm may have affected the Freelexx 64 oz/ac + Initial TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac treatment but also the RoundUp Pro Concentrate treatment, thus, also potentially affecting the TerraVue treatment at 2.85 oz/ac as well. Garlon 3A at 128 oz/ac showed similar % injury to past work.

CONCLUSIONS

By August 6, 2020, 63 DAT, treatments with percent injury above 90 included Freelexx at 128 oz/ac, Freelexx at 64 oz/ac + Alternate TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac, Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac + Method 240SL at 16 oz/ac , Freelexx 96 oz/ac + MSM 60 at 0.5 oz/ac + Garlon 3A at 64 oz/ac+, Freelexx at 128 oz/ac + Garlon 3A at 64 oz/ac, Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac + TerraVue at 2.85 oz/ac , and Garlon 3A at 128 oz/ac. The remaining treatments: Vanquish at 64 oz/ac, Freelexx at 64 oz/ac + Initial TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac, MSM 60 at 0.5 oz/ac, TerraVue at 2.85 oz/ac, and RoundUp Pro Concentrate at 104 oz/ac, showed a lower percent injury and ranged from 72 to 40. Further data collection and analysis, one and two years after treatment, will determine canopy reduction and future recommendations.

Table 1. Percent injury of exotic shrub honeysuckle (*Lonicera morrowii* and *Lonicera maackii)*. The experiment was visually rated for percent injury on July 6, 2020, 32 DAT, and August 6, 2020, 63 DAT. Herbicides were applied on June 4 (treatments 1-10), 5 (treatment 11 & 12), and 8 (treatment 13), 2020. All treatments included methylated seed oil at 1% v/v. Each value is the mean of ten replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Treatment #	Treatment	Rate oz/ac	% Injury 7/6/20 32 DAT	% Injury 8/6/20 63 DAT
1	untreated	--	1.1 a	1 a
2	Freelexx MSM 60 Method 240 SL	96 0.5 16	94.9 def	99 d
3	Freelexx MSM 60 Garlon 3A	96 0.5 64	96 ef	97.5 d
4	Freelexx MSM 60 TerraVue	96 0.5 2.85	90.9 def	95 d
5	Freelexx Garlon 3A	128 64	94 def	95.5 d
6	Garlon 3A	128	83.5 def	92.5 d
7	Vanquish	64	67 cde	72 cd
8	RoundUp Pro Concentrate	104	26 ab	40 b
9	TerraVue	2.85	35.5 b	48 bc
10	Freelexx-Initial TerraVue Vastlan	64 2.85 64	43.5 bc	62 bc
11	Freelexx	128	97.5 f	99.3 d
12	MSM 60	0.5	66 cd	56.9 bc
13	Freelexx-Alternate TerraVue Vastlan	64 2.85 64	98.2 f	99 d

EVALUATION OF TERRAVUE APPLICATIONS TO AMUR HONEYSUCKLE FOR CANOPY REDUCTION

Herbicide trade and common names: TerraVue (*aminopyralid + florpyrauxifen*); Freelexx (*2, 4-D choline*); MSM 60 (*metsulfuron methyl*); Vastlan (*triclopyr choline*)

Plant common and scientific names: Morrow's honeysuckle *(Lonicera morrowii*); Amur honeysuckle (*Lonicera maackii)*; and Tatarian honeysuckle *(Lonicera tatarica)*

ABSTRACT

Control of exotic shrub honeysuckle along the roadsides of Pennsylvania has been an ongoing challenge. To expand the existing list of effective products available for use within brush herbicide programs, TerraVue was evaluated. Though it is not yet listed on the label's recommended plants-controlled list, there is interest from industry as to whether this product may be a valid option. An experiment was established at the Penn State Horticulture Farm located at the Russell E. Larson Agricultural Research Center near Rock Springs, PA to evaluate the efficacy of TerraVue tank mixed with Freelexx, MSM, and Vastlan. The herbicide treatments included TerraVue at 2.85 oz/ac, TerraVue at 2.85 oz/ac tank mixed with Freelexx at 96 oz/ac and MSM 60 at 0.5 oz/ac, TerraVue at 2.85 oz/ac tank mixed with Freelexx at 96 oz/ac and Vastlan at 64 oz/ac, and an untreated check.

By 23 days after treatment, TerraVue tank mixed with Freelexx and MSM 60 provided greater than 99% injury to exotic shrub honeysuckle. Following closely behind was TerraVue tank mixed with Freelexx and Vastlan with a minimum of 95% injury. Finally, TerraVue alone produced 67% injury compared to the untreated check.

INTRODUCTION

The two main methods for managing nonnative honeysuckle are mechanical through cutting back or prescribed burns, and chemical, most commonly with Glysophate. No biological controls are known that would target solely nonnative honeysuckle species[14]. According to the label, TerraVue is used to control only certain woody plants[15]. Finding new chemical tools that are effective and meet regulatory safety standards involves significant time and costs. This experiment was designed to determine the efficacy of TerraVue alone and in combination with two standard brush mixes on amur honeysuckle.

[14] http://www.docs.dcnr.pa.gov/cs/groups/public/documents/dcnr_010229.pdf Shrub Honeysuckles. Viewed May 20, 2021.

[15] https://www.agrian.com/pdfs/TerraVue_Label.pdf CORTEVA agriscience. TerraVue. Label. Viewed on May 20, 2021.

MATERIALS AND METHOD

The experiment was established at the Penn State Horticulture Farm at the Russell E. Larson Agricultural Research Center as a complete randomized design with ten plants per treatment. Each shrub was identified on September 4, 2020. Two characteristics that were used to identify the different varieties of exotic honeysuckle are the length of the flower peduncles compared to the leaf petioles and the flower color. Amur honeysuckle has a white to yellow flower with a shorter peduncle compared to the other common invasive honeysuckle shrubs.[16] Within the experimental area, only amur honeysuckle was identified.

Each honeysuckle was measured. To determine the canopy area of each plant, the average width was multiplied by its height then multiplied by 2 to capture the whole plant as a three-dimensional object (Appendix Table 4). A complete table can be found in the appendix at the end of this report. The herbicide application amounts were based on the calculated canopy area. The herbicide treatments TerraVue at 2.85 oz/ac, TerraVue at 2.85 oz/ac tank mixed with Freelexx at 64 oz/ac and MSM 60 at 0.5 oz/ac, TerraVue at 2.85 oz/ac tank mixed with Freelexx at 64 oz/ac and Vastlan at 64 oz/ac, and an untreated check. Induce, a non-ionic surfactant, at 0.25% v/v was added to all herbicide treatments. The application was made at a carrier volume of 35 gallons per acre (GPA). All treatments were applied using a CO_2-powered backpack sprayer equipped with a 30 GunJet spray gun and one PPX 6 adjustable nozzle at 32 pounds per square inch (PSI). Treatments were applied on September 9, 2020. The weather at the time of application was clear and sunny with wind speeds of 5-10 mph. Soil temperatures at the surface, 1-inch, 3-inch, and 6-inch depths were 71°F, 71°F, 70°F and 70°F, respectively, according to http://newa.cornell.edu. The nearest weather station was located at Rock Springs, PA.

Treatments were visually rated for percent injury 0 = no injury – 100 = complete injury on October 2, 2020, 23 days after treatment (DAT). All data were subjected to analysis of variance, and when treatment effect F-tests were significant ($p \leq 0.05$), treatment means were compared using Tukey's HSD separation test.

RESULTS AND DISCUSSION

By 23 DAT (Table 1), TerraVue at 2.85 oz/ac tank mixed with Freelexx at 64 oz/ac and MSM 60 at 0.5 oz/ac resulted with the highest injury rating of 99.6%. Similar results occurred with TerraVue at 2.85 oz/ac tank mixed with Freelexx at 64 oz/ac and Vastlan at 64 oz/ac resulting in an injury rate of 95.6%. Single treatment of TerraVue at 2.8 oz/ac produced a significantly lower injury rating of 67.4%. Due to the growing season coming to an end, a standard second injury rating was not conducted.

CONCLUSIONS

All treatments were effective in causing injury to the amur honeysuckle. TerraVue combined with Freelexx and MSM was most effective with an injury rate of 99.6%. These high results may be due to the different modes of action of the chemicals within the mix effectively

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[16] Egan, Elizabeth A. 2021. Evaluations to foliar applications to shrub honeysuckle during flowering for canopy reduction. Roadside Vegetation Management Research-2021.

disrupting the plant's growth processes. The Vastlan + TerraVue combination was also effective resulting in a 95.6% injury rating. TerraVue as a single treatment was less effective resulting in 67.4% injury. Data collection in year two will determine whether TerraVue alone and the TerraVue combinations have long-term control potential.

MANAGEMENT IMPLICATIONS

All herbicide treatments showed significant injury to amur honeysuckle except TerraVue alone producing the least amount of injury. A second-year follow-up rating after treatment will determine whether TerraVue and TerraVue combinations will be an effective recommendation for exotic shrub honeysuckle control.

Table 1. Percent injury of amur honeysuckle (*Lonicera maackii)*. The experiment was visually rated for percent injury on October 2, 2020, 32 DAT. Herbicides were applied on September 9, 2020. All treatments included Induce, a non-ionic surfactant at 0.25% v/v. Each value is the mean of ten replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Treatment #	Treatment	Rate oz/ac	% Injury 10/2/20 30 DAT
1	untreated	--	1a
2	TerraVue	2.85	67.4b
3	TerraVue Freelexx MSM 60	2.85 96 0.5	99.6c
4	TerraVue Vastlan Freelexx	2.85 64 64	95.6c

EVALUATION OF TELAR XP, SEGMENT II, AND ASSURE II FOR SUPPRESSION OF TALL FESCUE AROUND CABLE GUIDERAIL SYSTEMS IN GRASS MEDIANS

Herbicide trade and common names: Telar XP *(chlorsulfuron)*; Segment II *(sethoxydim)*; Assure II *(quizalofop-Q)*; Triplet L/O *(2,4-D, mecoprop, dicamba)*

Plant common and scientific names: tall fescue *(Schedonorus arundinacea)*; fine fescue *(Festuca spp.)*; Kentucky bluegrass *(Poa pratensis)*; creeping red fescue *(Festuca rubra)*; bentgrass *(Agrostis spp.)*; Canada thistle *(Cirsium arvense)*; crownvetch *(Coronilla varia)*; buckhorn plantain *(Plantago coronpus)*; broadleaf plantain *(Plantago major)*; birdsfoot trefoil *(Lotus corniculatus)*; poverty dropseed *(Sporobolus vaginiflorus)*; and foxtail *(Setaria spp.)*

ABSTRACT

Three herbicides were evaluated for tall fescue suppression. The purpose of this experiment was to selectively suppress tall fescue while allowing fine fescue to establish and grow along a roadside cable guiderail. The treatments included Telar XP at 2.6 oz/ac, Segment II at 24 oz/ac, Segment II at 32 oz/ac, Assure II at 8 oz/ac, Assure II at 14 oz/ac, and an untreated check. All herbicide treatments included methylated seed oil at 1% v/v. Treatments were applied on September 16, 2019. On September 17, 2019, an application of Triplet L/O at 64 oz/ac + Induce, a non-ionic surfactant, at 0.25%v/v was applied to all plots including the untreated check to control broadleaf weeds. All treatments were applied at 35 gallons per acre using a CO_2 powered backpack sprayer equipped with a 6-foot boom, four 8004 VS nozzles, at a pressure of 35 pounds per square inch (psi). The experiment was arranged as a randomized complete design with four replications on plots approximately 30-feet by 12-feet. Four, 1-meter square subplots were established to conduct visual cover ratings. By 367 DAT, Telar XP at 2.6 oz/ac reduced tall fescue cover by 60 percent, Segment II at 24 oz/ac reduced tall fescue cover by 60 percent, Segment II at 32 oz/ac reduced tall fescue cover by 71 percent, Assure II at 8 oz/ac reduced tall fescue cover by 55 percent, and Assure II at 14 oz/ac reduced tall fescue cover by 46 percent. The untreated check showed 43% reduction in tall fescue cover. Fine fescue cover increased and ranged between 55.73% and 68.81%.

INTRODUCTION

Cable guiderail systems have been installed throughout Pennsylvania as a safety device to minimize the severity of a crash by preventing a vehicle from reaching a more hazardous fixed object or terrain[17]. Vegetation management around cable guiderails may include mowing, plant growth regulator applications, and in certain situations bareground applications. Roadside medians may contain a mixture of grass species including K-31 tall fescue, Kentucky bluegrass, creeping red fescue, and bentgrass. The placement of cable guiderails in the median is often on sloped and easily eroded soils, so disturbing the vegetation may result in erosion[18]. Mowing

[17] Pennsylvania Department of Transportation. Roadside Safety Pocket Guide 2018 Edition. PUB 652 (5-18)
[18] Jodon, J.C. et al 2018 Evaluation of Seed Mixes and Seeding Methods for Overseeding Low Growing Turf Groundcover around Cable Guiderails. Roadside Vegetation Management Research – 2018 Report. pp 23-27

under the rail requires specialized equipment or large amounts of labor[19]. In an effort to use sustainable practices and methods to reduce maintenance around cable guiderails, the project evaluated three seeding methods, two seed mixes, and seeding timing (i.e. spring versus fall seeding) into established turf cover around cable guiderails with the intention to convert the ground cover around the guiderail to a permanent, sustainable low growing fine fescue groundcover. Two separate multi-year experiments showed mixed results in establishing fine fescue cover into existing roadside turf. The main factor was the species of the existing turfgrass cover prior to overseeding. Every site presents its own characteristics and challenges. Specific site conditions will determine the soil preparation, mowing frequencies or turf suppression, and seeding methods to achieve a fine fescue groundcover[20]. As a result of those past experiments, the question arose as to whether tall fescue could be suppressed while promoting fine fescue establishment and spread. Previous research by Dernoden, reported that a single application of chlorsulfuron controlled tall fescue[21]. Recent experiments conducted by the roadside project evaluated Telar XP, Segment, and Assure II for control of tall fescue and safety on fine fescue species. Our results showed that Telar XP reduced tall fescue cover but injured the fine fescue; however, Segment and Assure II reduced tall fescue and appeared to be safe to the fine fescue species present[22]. The purpose of this experiment was to evaluate Telar XP, Segment II, and Assure II for tall fescue suppression in a roadside setting where fine fescue species had been established under a cable guiderail.

METHODS AND MATERIALS

The site was situated on an area previously seeded to formula L (55% hard fescue, 35% creeping red fescue, and 10% annual ryegrass,), modified formula L (55% sheep fescue, 35% creeping red fescue, and 10% annual ryegrass,), or sheep fescue in 2017[23]. The experiment was established along a cable guiderail in the median of I-99 near the Shiloh Road exit State College, PA as a randomized complete design with four replications on plots approximately 30-feet by 12-feet. Four, 1-meter square subplots were established to conduct sampling. Each subplot was off-set from a post using a 1-foot by 1-foot jig. Subplots 1 and 4 were on the south side of the cable guiderail and subplots 2 and 3 were on the north side. The treatments included Telar XP at 2.6 oz/ac, Segment II at 24 oz/ac, Segment II at 32 oz/ac, Assure II at 8 oz/ac, Assure II at 14 oz/ac, and an untreated check. All herbicide treatments included methylated seed oil at 1% v/v. Treatments were applied on September 16, 2019. On September 17, 2019, an application of Triplet L/O at 64 oz/ac + Induce, a non-ionic surfactant, at 0.25%v/v was applied to all plots including the untreated check to control broadleaf weeds. All treatments were applied at 35 gallons per acre using a CO_2 powered backpack sprayer equipped with a 6-foot boom, four 8004 VS nozzles, at a pressure of 35 pounds per square inch (psi). The experiment was visually rated

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[19] Jodon, J.C. et al 2018 Evaluation of Seed Mixes and Seeding Methods for Overseeding Low Growing Turf Groundcover around Cable Guiderails. Roadside Vegetation Management Research – 2018 Report. pp 23-27
[20] Jodon, J.C. et al 2019 Conversion of Existing Turf to a Low Growing Fine Fescue Groundcover around Cable Guiderails. Roadside Vegetation Management Research – 2019 Report. pp 26-29
[21] Dernoden, P.H. Comparison of Three Herbicides for Selective Tall Fescue Control in Kentucky Bluegrass. Agronomy Journal 82:278-282 (1990)
[22] Jodon, J.C. et al 2020 Evaluation of Telar XP, Segment, and Assure II, for Tall Fescue Control and Safety on Fine Fescues. Roadside Vegetation Management Research – 2020 Report. pp 22-30
[23] Jodon, J.C. et al 2019 Evaluation of Seed Mixes and Seeding Methods for Overseeding Low Growing Turf Groundcover around Cable Guiderails. Roadside Vegetation Management Research – 2019 Report. pp 19-25

for percent tall fescue, fine fescue, Kentucky bluegrass, grass weed, and broadleaf weed cover on September 9, 2019, 0 days after treatment (DAT); June 11, 2020, 269 DAT; and September 17, 2020, 367 DAT. Percent tall fescue and broadleaf weed injury was visually rated on October 15, 2019, 25 DAT. Percent bareground cover was visually rated on September 9, 2019, 0 DAT and September 17, 2020, 367 DAT. All data were subjected to analysis of variance and when F-tests were significant ($p \leq 0.05$), treatment means were compared using Tukey's HSD separation test.

RESULTS AND DISCUSSION

The site was a mixed stand of tall fescue, fine fescue, Kentucky bluegrass, grass weeds, and broadleaf weeds. Fine fescues were the dominant species ranging from 34.81 to 43.88 percent cover across treatments at the commencement of the experiment (Table 1). Also, tall fescue cover ranged from 15.31 to 19.38 percent, Kentucky bluegrass cover ranged from 13.75 to 24.63 percent, broadleaf weed cover ranged from 1.01 to 14.25 percent, grass weed cover ranged from 0.25 to 3.25 percent, and bareground cover ranged from 15.56 to 21.25 percent. Percent injury to tall fescue and broadleaf weeds were rated 29 DAT (Table 2). Injury to tall fescue in treated plots ranged from 53.44 to 87 percent. Injury to broadleaf weeds ranged between 92.5 and 100 percent.

By June 11, 269 DAT, percent tall fescue cover of the treated plots ranged from 8.25 to 15.25 (Table 3). The untreated check showed 18.69 percent tall fescue cover. Average tall fescue cover for plots treated with Telar XP at 2.6 oz/ac was 10.06%, Segment II at 24 oz/ac was 10.13%, Assure II at 8 oz/ac was 13.88%, and Assure II at 14 oz/ac was 15.25%. Segment II at 32 oz/ac treatments showed 8.25% tall fescue cover, significantly less than the untreated check. Fine fescue cover of treated plots ranged from 33.69% to 43.19%. The untreated check showed 41.88% fine fescue cover. Percent Kentucky bluegrass cover of the treated plots ranged from 22.19 to 31.06. The untreated check showed 22.19% Kentucky bluegrass cover.

Percent tall fescue cover, rated on September 17, 2020, continued to decline (Table 4). By 367 DAT, percent tall fescue cover for plots treated with Segment II at 32 oz/ac was 4.41, Segment II at 24 oz/ac was 5.44, Telar XP at 2.6 oz/ac was 6.66, Assure II at 8 oz/ac was 8, and Assure II at 14 oz/ac was 10.38. The untreated check showed 10.94% tall fescue cover. In general, fine fescue cover increased and ranged between 55.73% and 68.81%. Kentucky bluegrass cover ranged from 11.5% to 16.63%. Bareground cover was reduced when compared to the initial bareground rating at 0 DAT, indicating the ability of desirable turf cover to fill in previous voids. Broadleaf weed cover ranged between 1.8 to 7.76 percent, statistically similar among treatments. No broadleaf weed herbicide were applied during the 2020 growing season. Weeds identified across the site included Canada thistle, crownvetch, buckhorn plantain, broadleaf plantain, birdsfoot trefoil, poverty dropseed, and foxtail.

Evaluation of tall fescue cover showed a reduction one year after herbicide treatments were applied (Table 5). Percent tall fescue reduction for herbicide treated plots ranged from 46 to 71. It should be noted that the untreated check showed 43 percent reduction of tall fescue cover. Possible explanations for the unexpected decline in tall fescue cover in the untreated plot include the subjective visually rating system utilized and possibly environmental conditions during the experiment. The treatment showing the highest reduction in tall fescue cover at 71% was Segment II at 32 oz/ac. Telar XP at 2.6 oz/ac and Segment II at 24 oz/ac reduced tall fescue cover by 60 percent. Assure II at 8 oz/ac and Assure II at 14 oz/ac reduced tall fescue cover by 55% and 46%, respectively.

Fine fescue cover showed an increase or expansion in cover one year after treatment (Table 6). Percent fine fescue expansion from herbicide treatments ranged from 34 to 94. The untreated check plots averaged 36% increase in fine fescue cover. Percent expansion of fine fescue cover for plots treated with Telar XP at 2.6 oz/ac was 49, Segment II at 24 oz.ac was 94, Segment II at 32 oz/ac was 77, Assure II at 8 oz/ac was 72, and Assure II at 14 oz/ac was 34.

CONCLUSIONS

Based on the results of this experiment, Segment II at 32 oz/ac was the most effective in suppressing or reducing tall fescue followed by Telar XP at 2.6 oz/ac and Segment II at 24 oz/ac. Conversely, Telar XP at 2.6 oz/ac and Segment II at 24 oz/ac appeared most effective in allowing fine fescues to expand with Segment II at 32 oz/ac being next most effective. In previous experiments Telar XP appeared to damage fine fescue so caution with Telar XP is warranted[24]. Although tall fescue was not completely suppressed with a single application of Telar XP, Segment II, or Assure II, this experiment demonstrated the competitiveness of fine fescues to expand cover and fill voids. As a result of the herbicide applications to selectively control or suppress tall fescue, fine fescue cover increased and resulted in less bareground within the plots. Follow up applications of Telar XP, Segment II, or Assure II may be necessary to completely suppress tall fescue.

MANAGEMENT IMPLICATIONS

None of the herbicide treatments completely controlled tall fescue by the final evaluation, one year after treatment. Caution should be exercised if utilizing this technique to selectively remove tall fescue. Roadsides inhabited by both tall fescue and fine fescue are well suited for a Segment II or Assure II application. Before applications are made to a roadside turf, the roadside specialist should determine the amount of fine fescue cover present. If adequate fine fescue cover exists, this technique may be successful and not cause soil erosion. Previous research demonstrated that Segment and Assure II reduced tall fescue cover and are safely applied to fine fescue. Telar XP reduced tall fescue cover, but showed injury to fine fescue, however, the fine fescue rebounded[25]. Data from the current experiment with Telar XP did not show a reduction in fine fescue cover as result of Telar XP applications. The Telar XP label recommends applications to sheep fescue not exceed 0.5 oz/ac. Additionally, Telar XP label recommend applications to Festuca species between 0.25 to 0.5 oz/ac[26]. Telar XP does have the added benefit of some broadleaf weed control, however, it may be injurious to fine fescue. For this reason, as well as label recommendations, we don’t recommend using Telar XP to selectively

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[24] Jodon, J.C. et al 2020 Evaluation of Telar XP, Segment, and Assure II, for Tall Fescue Control and Safety on Fine Fescues. Roadside Vegetation Management Research – 2020 Report. pp 22-30.
[25] Jodon, J.C. et al 2020 Evaluation of Telar XP, Segment, and Assure II, for Tall Fescue Control and Safety on Fine Fescues. Roadside Vegetation Management Research – 2020 Report. pp 22-30.
[26] Bayer. Telar XP Label.

remove tall fescue from fine fescue. The Assure II label cautions against tank mixing with broadleaf weed herbicides as some grass control may be reduced in certain situations[27]. The label recommends split applications of Assure II and broadleaf weed herbicides: apply a broadleaf weed herbicide at least 24 hours after applying Assure II. Alternatively, Assure II can be applied seven days after a broadleaf weed control application. The Assure II label recommends applying the following adjuvants: crop oil concentrates at 1% v/v or non-ionic surfactants at 0.25% v/v. The Segment II label recommends not tank mixing other pesticides, fertilizers, or other additives, except those listed on the label, due to reduced grass control, physical incompatibilities, and crop injury[28]. Also, according to label recommendations apply Segment II with either crop oil concentrates (COC) or methylated/modified seed oils (MSO). Non-ionic surfactants are not recommended because weed control may not be satisfactory. COC The recommended rate for COC is 2 pints per acre and for MSO is 1.5 pints per acre. As always, read and follow all label directions. Based on the results of past experiments and the current experiment, Segment II at 32 oz/ac (or equivalent rates of Segment) resulted in the highest reduction in tall fescue cover and would be recommended by the project for use.

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[27] Corteva agriscience. DuPont Assure II Label.
[28] BASF. Segment II Label.

Table 1. Percent tall fescue, fine fescue, Kentucky bluegrass, broadleaf weed, grass weed, and bareground cover. Initial percent tall fescue, fine fescue, Kentucky bluegrass, broadleaf weed, grass weed, and bareground cover was visually rated on September 9, 2019, 0 days after treatment (DAT). Herbicide treatments were applied on September 16, 2019. All herbicide treatments contained methylated seed oil at 1% v/v. Triplet L/O at 64 oz/ac + Induce, a non-ionic surfactant, at 0.25%v/v was applied on September 17, 2019. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/acre	% Tall fescue cover 9/9/19 0 DAT	% Fine fescue cover 9/9/19 0 DAT	% Kentucky bluegrass cover 9/9/19 0 DAT	% Broadleaf weed cover 9/9/19 0 DAT	% Grass weed cover 9/9/19 0 DAT	% Bareground cover 9/9/19 0 DAT
Untreated	--	19.06	36.06	21	2	3.25	17.5
Telar XP	2.6	16.5	37.31	18.69	5.31	1.31	21.25
Segment II	24	16.69	35.38	18	11.25	0.75	18.19
Segment II	32	15.31	34.81	14.31	14.25	2.44	16.94
Assure II	8	17.81	39.25	24.63	1.25	0.25	15.56
Assure II	14	19.38	43.88	13.75	1.01	0.56	18.81
		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Table 2. Percent tall fescue and broadleaf weed injury. Percent tall fescue and broadleaf weed injury was visually rated on October 15, 2019, 29 days after treatment (DAT). Treatments were applied on September 16, 2019. All herbicide treatments contained methylated seed oil at 1% v/v. Triplet L/O at 64 oz/ac + Induce, a non-ionic surfactant, at 0.25%v/v was applied on September 17, 2019. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/acre	% Tall fescue injury 10/15/19 29 DAT	% Broadleaf weed injury 10/15/19 29 DAT
Untreated	--	16.69 a	96.25
Telar XP	2.6	76.81 c	99.63
Segment II	24	87 c	94.25
Segment II	32	77.75 c	92.5
Assure II	8	53.44 b	96.56
Assure II	14	74.63 c	100
			n.s

Table 3. Percent tall fescue, fine fescue, Kentucky bluegrass, broadleaf weed, and grass weed cover. Plots were visually rated for percent tall fescue, fine fescue, Kentucky bluegrass, broadleaf weed, and grass weed cover on June 11, 2020, 269 days after treatment (DAT). Treatments were applied on September 16, 2019. All herbicide treatments contained methylated seed oil at 1% v/v. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/acre	% Tall fescue cover 6/11/20 269 DAT	% Fine fescue cover 6/11/20 269 DAT	% Kentucky bluegrass cover 6/11/20 269 DAT	% Broadleaf weed cover 6/11/20 269 DAT	% Grass weed cover 6/11/20 269 DAT
Untreated	--	18.69 b	41.88	22.19	0.82	0.06
Telar XP	2.6	10.06 ab	39.19	22.63	1.42	0.36
Segment II	24	10.13 ab	43.19	22.25	7.34	0.09
Segment II	32	8.25 a	37.5	27.06	7.89	0.06
Assure II	8	13.88 ab	33.69	31.06	1.98	0.13
Assure II	14	15.25 b	36.19	24.31	2.22	0.47
			n.s.	n.s.	n.s.	n.s.

Table 4. Percent tall fescue, fine fescue, Kentucky bluegrass, broadleaf weed, grass weed, and bareground cover. Plots were visually rated for percent tall fescue, fine fescue, Kentucky bluegrass, broadleaf weed, grass weed, and bareground cover on September 17, 2020, 367 days after treatment (DAT). Treatments were applied on September 16, 2019. All herbicide treatments contained methylated seed oil at 1% v/v. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/acre	% Tall fescue cover 9/17/20 367 DAT	% Fine fescue cover 9/17/20 367 DAT	% Kentucky bluegrass cover 9/17/20 367 DAT	% Broadleaf weed cover 9/17/20 367 DAT	% Grass weed cover 9/17/20 367 DAT	% Bareground cover 9/17/20 367 DAT
Untreated	--	10.94	59.24	16.63	1.91	0.72	9.94
Telar XP	2.6	6.66	55.73	17.81	5.37	0.31	13.94
Segment II	24	5.44	68.81	11.5	5.72	0.3	8.25
Segment II	32	4.41	61.92	14.63	7.76	0.33	11.56
Assure II	8	8	67.58	16.56	1.8	0.03	5.94
Assure II	14	10.38	59.45	13.96	5.09	0.13	13.36
		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Table 5. Percent change and reduction of tall fescue cover. Plots were visually rated for percent tall fescue cover on September 9, 2019, 0 days after treatment (DAT) and September 17, 2020, 367 DAT. Treatments were applied on September 16, 2019. All herbicide treatments contained methylated seed oil at 1% v/v. Percent change in tall fescue cover is the comparison of tall fescue at 0 DAT and 367 DAT. Percent reduction tall fescue cover was calculated using the formula [(tall fescue cover 0 DAT- tall fescue cover 367 DAT / tall fescue cover 0 DAT) x 100]. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/acre	% Tall fescue cover 9/9/19 0 DAT	% Tall fescue cover 9/17/20 367 DAT	% Change tall fescue cover	% Reduction tall fescue cover
Untreated	--	19.06	10.94	-8	43
Telar XP	2.6	16.5	6.66	-10	60
Segment II	24	16.69	5.44	-12	60
Segment II	32	15.31	4.41	-11	71
Assure II	8	17.81	8	-10	55
Assure II	14	19.38	10.38	-9	46
		n.s.	n.s.		

Table 6. Percent change and expansion of fine fescue cover. Plots were visually rated for percent fine fescue cover on September 9, 2019, 0 days after treatment (DAT) and September 17, 2020, 367 DAT. Treatments were applied on September 16, 2019. All herbicide treatments contained methylated seed oil at 1% v/v. Percent change in fine fescue cover is the comparison of fine fescue at 0 DAT and 367 DAT. Percent expansion fine fescue cover was calculated using the formula [(fine fescue cover 367 DAT- fine fescue cover 0 DAT / fine fescue cover 0 DAT) x 100]. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/acre	% Fine fescue cover 9/9/19 0 DAT	% Fine fescue cover 9/17/20 367 DAT	% Change fine fescue cover	% Expansion fine fescue cover
Untreated	--	36.06	59.24	+ 13	36
Telar XP	2.6	37.31	55.73	+18	49
Segment II	24	35.38	68.81	+33	94
Segment II	32	34.81	61.92	+27	77
Assure II	8	39.25	67.58	+28	72
Assure II	14	43.88	59.45	+15	34
		n.s.	n.s.		

EFFICACY OF COMMONLY USED PREEMERGENCE AND POSTEMERGENCE HERBICIDES FOR CONTROL OF JAPANESE STILTGRASS

Herbicide trade and common names: Plateau *(imazapic)*; Pendulum Aquacap *(pendimethalin)*; Esplanade Sure *(indaziflam + rimsulfuron)*; ProClipse 65 WDG *(prodiamine)*; Oust XP *(sulfometuron methyl)*; Acclaim Extra *(fenoxaprop p-ethyl)*; Assure II *(Quizalofop p-ethyl)*; Segment II *(sethoxydim)*; Facet L *(quinclorac)*; RoundUp Pro Concentrate *(glyphosate)*

Plant common and scientific names: Japanese stiltgrass *(Microstegium vimineum)*

ABSTRACT

An experiment was established at the Penn State Horticulture Research Farm, Russell E Larson Agricultural Center in Rock Springs, PA to evaluate the control or reduction of Japanese stiltgrass using preemergence and postemergence herbicides. Preemergence treatments included Plateau at 6 oz/ac, Pendulum Aquacap at 67.4 oz/ac, Esplanade Sure at 3 and 4.5 oz/ac, ProClipse at 16 oz/ac, and Oust XP at 0.5 oz/ac. The post emergence treatments included multiple rates of Acclaim Extra at 16, 20, and 39 oz/ac, Assure II at 8, 12, and 16 oz/ac, Segment II at 16, 24, and 40 oz/ac, Facet L at 64 oz/ac, and an untreated check. Preemergence applications of Pendulum Aquacap 67.4 oz/ac, ProClipse 16 oz/ac, and Esplanade Sure 3 oz/ac resulted in 2%, 4.69%, and 7% Japanese stiltgrass cover, respectively at 164 DAT. By 77 DAT, the postemergence herbicide treatments ranged from 0 to 7.63% Japanese stiltgrass cover. Depending on rate, Acclaim Extra treatments resulted in 0.75% or less cover, Assure II treatments resulted in 0.59% or less cover, and Segment II treatments resulted in less than 3%. Finally, Facet L resulted in 7.63% cover and RoundUp Pro resulted in 1.03% cover.

INTRODUCTION

Japanese stiltgrass, *Microstegium vimineum*, is an annual warm season grass capable of growing in shaded areas with large patches invading roadsides as well as adjacent forest understories. Introduced into the United States in 1919 near Knoxville, Tennessee[29], Japanese stiltgrass is native to Asia. *M. vimineum* can grow up to 3 feet in height, leaves are elongate and lance shape, 1-3 inches long, with an off center silvery midvein. The stems are thin, wiry and supported by stilt-like prop roots. A three branched flower spike develops in late summer producing up to 1,000 seeds per plant. Additionally, the seeds can remain viable in the soil up to 5 years. Japanese stiltgrass can be found in most habitats with moist soil, including forests, especially along logging roads, abandoned farm fields, and roadsides.[30] The purpose of this experiment was to evaluate the efficacy of preemergence herbicides in preventing Japanese stiltgrass seed from germinating and postemergence herbicides for reducing Japanese stiltgrass cover.

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[29] Fairbrothers, D.E.Gray, J.R. 1972. Microstegium vimineum (Trin.) A Camus (Gramineae) in the United States. Bulletin of the Torrey Botanical Club. 99: 97-100

[30] Templeton, S., A. Gover, D. Jackson, and S. Wurzbacher. 2020. Japanese stiltgrass. Penn State Extension. https://extension.psu.edu/japanese-stiltgrass

MATERIALS AND METHODS

An experiment was established at the Penn State Horticulture Research Farm, Russell E Larson Agricultural Center in Rock Springs PA. The experiment was arranged as a randomized complete design with four replications. One particular preemergence treatment, Segment II at 24 oz/ac, utilized only 3 replications because while walking between rep 3 and 4 the majority of the mix was discharged in an adjacent area. Due to the application error, only reps 1, 2, and 3, were included during analysis of this treatment. Preemergence treatments included Plateau at 6 oz/ac, Pendulum Aquacap at 67.4 oz/ac, Esplanade Sure at 3 and 4.5 oz/ac, ProClipse at 16 oz/ac, and Oust XP at 0.5 oz/ac. The postemergence treatments included multiple rates of Acclaim Extra at 16, 20, and 39 oz/ac, Assure II at 8, 12, and 16 oz/ac, Segment II at 16, 24, and 40 oz/ac, Facet L at 64 oz/ac, RoundUp Pro Concentrate at 64 oz/ac, and an untreated check. Methylated seed oil, MSO was added to all treatments at 1% v/v. Plots were 10 by 6 feet in size. The plots were laid out October 4, 2019, then visually rated for percent Japanese stiltgrass cover, to estimate Japanese stiltgrass cover during the 2020 growing season. Treatments were pre-measured, mixed, and preemergence herbicides were applied April 4, 2020. Postemergence herbicides were applied June 30, 2020. All applications were made using a CO_2 powered backpack sprayer equipped with a six-foot boom and four 8004 VS nozzles at 35 pounds per square inch (PSI) and delivered at 35 gallons per acre (GPA). After application of the preemergence treatments, rain events occurred on April 8, 9, 13, &14, 2020; with 0.54", 0.24", 0.29", & 0.59" respectively according to http://newa.cornell.edu. The nearest weather is located in Rock Springs, PA.

Percent Japanese stiltgrass cover was visually rated on May 14 (preemergence only), June 29, July 28, August 27, and September 15, 2020. Percent injury was visually rated for the postemergence treatment on July 14, 2020. All data were subjected to analysis of variance and when treatment F-tests were significant ($p \geq 0.05$), treatment means were compared using Tukey's HSD separation test.

RESULTS AND DISCUSSION

Preemergence Herbicides

Initial percent Japanese stiltgrass cover was visually rated on October 4, 2019, and ranged from 48.75 to 57.5, with no significant difference between plots (Table 1). By 40 days after treatment, DAT, the untreated plots averaged 5.53% cover while the herbicide treated plots ranged from 0.08% to 3.15% Japanese stiltgrass cover. By June 29, 2020, 86 DAT and out to 164 DAT Pendulum Aquacap at 67.4 oz/ac remained the most effective at reducing Japanese stiltgrass emergence followed by ProClipse 65 WDG at 16 oz/ac and Esplanade Sure at 3 oz/ac. Esplanade Sure at 4.5 oz/ac was the third most effective through 86 DAT but by 115 DAT it fell numerically behind ProClipse 65 WDG, Plateau at 6 oz/ac appeared effective through 40 DAT and then Japanese stiltgrass became more obvious in the treated plots than in the control plots by 86 DAT with 19% compared to 13.75% cover, respectively. Similarly, Oust XP at 0.5 oz/ac was effective at 40 DAT, but quickly the Japanese stiltgrass cover grew to 22.5% at 86 DAT and ended at 48.75% by 164 DAT.

Previous work by Judge et.al., showed plots treated with prodiamine at 0.8 kg ai/ha (approximately 18 oz/ac) demonstrated 1% Japanese stiltgrass cover at 56 DAT which differs from our findings[31]. Plots treated with Plateau showed poor results, which contradicts previous work by the project in 2003[32]. The 2003 work reported Plateau with 1% total cover about 5 MAT (months after treatment), whereas the current experiment Plateau rating was 35% stiltgrass cover about 5 MAT. An observation during the present experiment revealed that a one of the four treatment reps of Plateau had water moving through the plots after rain events. This alone was not the cause for the higher percent stiltgrass cover but may have reduced effectiveness of the treatment in in the plot. Esplanade Sure at 4.5 oz/ac had higher stiltgrass cover than the lower rate of 3 oz/ac. In evaluating plots treated with Esplanade Sure at 4.5 oz/ac two of the four showed signs that water had actively moved through the plots after rain events. This may have reduced the effectiveness of Esplanade Sure at 4.5 oz/ac, as well.

Postemergence Herbicides

Initial Japanese stiltgrass cover on October 4, 2019, ranged between 42.5-62.5% (Table 2). The percent stiltgrass cover the day before postemergence herbicides were applied on June 29, 2020, ranged from 6.25% to 22.5%.

July 14, 2020, 14 DAT Japanese stiltgrass injury ranged from 0% in the untreated plots to 100% in plots treated with RoundUp Pro at 64 oz/ac. The lowest percent injury from herbicide treatments was Facet L at 58.75%.

By 28 DAT, stiltgrass cover in plots treated with Segment II at 24 & 40 oz/ac, Acclaim Extra at 39 oz/ac, and RoundUp Pro at 64 oz/ac was 0%. Similarly, the rates of Japanese stiltgrass cover were found to be below 1% for Assure II 12 and 16 oz/ac at 0.03%; Assure II 8 oz/ac was 0.09%; Acclaim Extra 20 oz/ac at 0.5%; Acclaim Extra 16 oz/ac at 0.25%; and Segment II 16 oz/ac at 0.38%. Facet L was the only treatment with a cover rating greater than 1%. By 58 DAT, all herbicide treatments remained under 1% Japanese stiltgrass cover except Facet L which was over 6%. On September 15, 77 DAT, percent Japanese stiltgrass break through began to show with cover for the untreated check was 25.75% which was still less than the year before. Facet L reported the highest percent cover at 7.63% with Segment II 16 oz/ac showing 2.9% and RoundUp Pro at 1.03%. All other treatments at the end of the growing season were showing Japanese stiltgrass coverage under 1%. Of those treatments only Acclaim Extra at 39 oz/ac recorded no Japanese stiltgrass followed by Acclaim Extra at 16 oz/ac and Assure II 16 oz/ac with under 0.1% cover by Japanese stiltgrass. The results from this experiment were similar to those reported by Judge et al 2005.

In order to provide a perspective of the reduction in Japanese stiltgrass from prior to treatment, the percent reduction (Table 3) was calculated by the following formula: [((Japanese stiltgrass cover 0 DAT- Japanese stiltgrass cover 77 DAT) / Japanese stiltgrass cover 0 DAT) x 100]. Acclaim Extra at 39 oz/ac resulted in 100% reduction in Japanese stiltgrass cover. The treatments that reduced cover by 99% included Acclaim Extra at 16 oz/ac, Assure II at 8 oz/ac & 16 oz/ac, and Segment II at 40 oz/ac. Acclaim Extra at 20 oz/ac and Assure II at 12 oz/ac resulted in 97% cover reduction, Segment II at 24 oz/ac 96%, RoundUp Pro at 64 oz/ac 94%,

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[31] Judge, CA, Neal J, Derr J, 2005. Preemergence and Postemergence Control of Japanese Stiltgrass (*Microstegium vimineum*). Weed Technology 19:183-189.
[32] Gover, A.E. et al 2003. A Comparison of Pre- and Postemergence Herbicide Applications for Control of Japanese Stiltgrass. Roadside Vegetation Management Research - Seventeenth Year Report. pp 23-28

Segment II at 16 oz/ac 85%, and Facet L 32%. The untreated plots increased Japanese stiltgrass cover by 87% by the end of the experiment.

CONCLUSIONS

Pendulum Aquacap at 67.4 oz/ac was the most effective preemergence herbicide evaluated during this experiment. With the exception of Facet L, all postemergence herbicides reduced stiltgrass cover to less than 3%. Acclaim Extra at 39 oz/ac was the only postemergence treatment to completely control Japanese stiltgrass through the last rating. Japanese stiltgrass is known to continue to germinate from seed throughout the growing season and this was observed in most of the other postemergence treatment plots to varying degrees in this experiment. In seeking more than one control option among postemergence products, further experiments should continue to evaluate the various rates of products like Assure II, and Segment II. Also, alternative rates of Pendulum Aquacap and ProClipse should be further evaluated to determine efficacy. Plateau and Oust XP should continue to be evaluated possibly at higher rates to determine preemergence efficacy and duration of control. Additionally, mixes containing combinations of postemergence and preemergence herbicides could be evaluated for season long control of Japanese stiltgrass.

MANAGEMENT IMPLICATIONS

Several preemergence and postemergence products are available to prevent Japanese stiltgrass seed from germinating or reduce established stands along the roadside. Pendulum Aquacap and ProClipse offer reliable preemergence control of Japanese stiltgrass. In areas where a nonselective application can be used to reduce Japanese stiltgrass, RoundUp Pro or any glyphosate containing products would be an option. If a postemergence herbicide is warranted for Japanese stiltgrass reduction consider Assure II, Segment II, or Acclaim Extra. Acclaim Extra is safe to apply to several grasses including Kentucky bluegrass, tall fescue and the fine fescues[33]. According to the herbicide label, Segment II should not be applied to desirable tall fescue and when applied to fine fescue rates are not to exceed 16 oz/ac[34]. Assure II has no label restrictions, but experience with Assure II would caution use to tall fescue groundcover. In previous work the project has reported that Assure II at 8 oz/ac can reduce tall fescue cover by 55%. The roadside specialist should exercise caution when considering Segment II or Assure II especially if an objective is to maintain desirable grass groundcover. Acclaim Extra at 39 oz/ac was the most effective post treatment, however it is not on the state herbicide list.

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[33] Bayer CropScience LP. Acclaim Extra label. http://www.cdms.net/ldat/ld0DF003.pdf
[34] BASF Corporation. Segment II label. http://www.cdms.net/ldat/ldDSK005.pdf

Table 1. Percent Japanese stiltgrass *(Microstegium vimineum)* cover. The experiment was visually rated for initial cover October 4, 2019. Preemergence herbicide treatments were applied April 4, 2020. Percent Japanese stiltgrass cover was visually rated May 14, June 29, July 28, August 28, & September 15, 2020 (40, 86, 115, 145, & 164 days after treatment, DAT, respectively). Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/acre	% Japanese stiltgrass cover 10/4/19	% Japanese stiltgrass cover 5/14/20 40 DAT	% Japanese stiltgrass cover 6/29/20 86 DAT	% Japanese stiltgrass cover 7/28/20 115 DAT	% Japanese stiltgrass cover 8/27/20 145 DAT	% Japanese stiltgrass cover 9/15/20 164 DAT
Untreated	--	51.25	5.53	13.75 ab	14.25 ab	17.5 ab	25.75 ab
Plateau	6	50	1.58	19 ab	25 b	28.75 ab	35.25 ab
Pendulum Aquacap	67.4	52.5	0.11	0.31 a	0.28 a	1.09 a	2 a
Esplanade Sure	3	53.75	0.08	1.8 ab	1.9 a	2.28 a	7 a
Esplanade Sure	4.5	57.5	0.21	5.06 ab	7.88 ab	14.38 ab	21.13 ab
ProClipse 65 WDG	16	52.5	3.15	7 ab	5.25 ab	5.19 a	4.69 a
Oust XP	0.5	48.75	0.36	22.5 ab	23.75 b	40 b	48.75 b
		n.s.	n.s.				

Table 2. Percent Japanese stiltgrass *(Microstegium vimineum)* cover. The experiment was visually rated for initial cover October 4, 2019. Postemergence herbicide treatments were applied June 30, 2020. All treatments included a non-ionic surfactant (i.e., Induce) at 0.25% v/v. Percent Japanese stiltgrass injury was visually rated on July 14, 2020. Percent Japanese stiltgrass cover was visually rated June 29, July 28, August 28, & September 15, 2020 (0, 28, 58, & 77 days after treatment, DAT, respectively). Each value is the mean of four replications, except Segment II at 24 oz/ac which is the mean of three replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/acre	% Japanese stiltgrass cover 10/4/19	% Japanese stiltgrass cover 06/29/20 0 DAT	% Japanese stiltgrass injury 7/14/20 14 DAT	% Japanese stiltgrass cover 7/28/20 28 DAT	% Japanese stiltgrass cover 8/27/20 58 DAT	% Japanese stiltgrass cover 9/15/20 77 DAT
Untreated	--	51.25	13.75 ab	0 a	14.25 b	17.5 b	25.75 b
Acclaim Extra	16	45	6.25 ab	72.5 bc	0.25 a	0.13 a	0.05 a
Acclaim Extra	20	42.5	21.25 ab	71.25 bc	0.5 a	0.81 a	0.75 a
Acclaim Extra	39	55	15 ab	77.5 bc	0 a	0 a	0 a
Assure II	8	52.5	16.25 ab	77.5 bc	0.09 a	0.13 a	0.21 a
Assure II	12	62.5	22.5 ab	82.5 bc	0.03 a	0.06 a	0.59 a
Assure II	16	62.5	27.5 b	87.5 bc	0.03 a	0.03 a	0.09 a
Segment II	16	50	18.75 ab	85 bc	0.38 a	0.5 a	2.9 a
Segment II*	24	47.5	13.33 ab	86.67 bc	0 a	0 a	0.45 a
Segment II	40	43.75	15 ab	75 bc	0 a	0 a	0.15 a
Facet L	64	46.25	11.25 ab	58.75 b	7.88 ab	6.63 ab	7.63 a
RoundUp Pro Concentrate	64	45	17.5 ab	100 c	0 a	0.18 a	1.03 a
		n.s.					

* = mean of three replications

Table 3. Percent reduction of Japanese stiltgrass *(Microstegium vimineum)* cover. Postemergence herbicide treatments were applied June 30, 2020. All treatments included a non-ionic surfactant (i.e., Induce) at 0.25% v/v. Percent Japanese stiltgrass injury was visually rated on July 14, 2020. Percent Japanese stiltgrass cover was visually rated June 29 & September 15, 2020 (0 & 77 days after treatment, DAT, respectively). The % reduction Japanese stiltgrass was calculated using the formula [((Japanese stiltgrass cover 0 DAT- Japanese stiltgrass cover 77 DAT) / Japanese stiltgrass cover 0 DAT) x 100]. Each value is the mean of four replications, except Segment II at 24 oz/ac which is the mean of three replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/acre	% Japanese stiltgrass cover 06/29/20 0 DAT	% Japanese stiltgrass cover 9/15/20 77 DAT	% Reduction Japanese stiltgrass
Untreated	--	13.75 ab	25.75 b	+ 87
Acclaim Extra	16	6.25 ab	0.05 a	99
Acclaim Extra	20	21.25 ab	0.75 a	97
Acclaim Extra	39	15 ab	0 a	100
Assure II	8	16.25 ab	0.21 a	99
Assure II	12	22.5 ab	0.59 a	97
Assure II	16	27.5 b	0.09 a	99
Segment II	16	18.75 ab	2.9 a	85
Segment II*	24	13.33 ab	0.45 a	96
Segment II	40	15 ab	0.15 a	99
Facet L	64	11.25 ab	7.63 a	32
RoundUp Pro Concentrate	64	17.5 ab	1.03 a	94

* = mean of three replications
+ = increase

LOW MAINTENANCE TURFGRASS SPECIES AND CULTIVAR COMPARISON TO KENTUCKY-31 TALL FESCUE – THIRD YEAR

Herbicide trade and common names: RoundUp Pro *(glyphosate)*; Triplet L/O *(2,4-D, mecoprop, dicamba)*

Plant common and scientific names: tall fescue *(Schedonorus arundinaceum,* synonym *Festuca arundinacea);* creeping red fescue *(Festuca rubra)*; Chewing's fescue *(Festuca rubra spp. commutata)*; annual ryegrass *(Lolium multiflorum)*; hard fescue *(Festuca trachyphylla)*; sheep fescue *(Festuca ovina)*; buffalograss *(Buchloe dactyloides)*

ABSTRACT

Low maintenance turfgrass species are used along roadsides to provide dense vegetation which helps to control erosion and limit weed invasion. Historically, 'Kentucky-31' also known as 'K-31' tall fescue has been the standard for infields, medians, and roadsides where sight lines are protected, and broadleaf weeds and brush are discouraged. However, regional and national environmental agencies and advocacy groups are claiming that 'K-31' is invading into pasture lands and detrimental to cattle feeding operations due to its endophyte symbiotic relationship. The characteristics of 'K-31' tall fescue that make it desirable as a roadside right-of-way ground cover includes its dependability, adaptability over a wide range of soils, persistence, drought tolerance, and that endophytic relationship that inhibits and dissuades deer from feeding along the roadside becoming a hazard to vehicular traffic. Over the years the question has arisen as to whether 'K-31' is still the best choice? Nine species and cultivars were evaluated against 'K-31' tall fescue as effective groundcover replacements along Pennsylvania roadsides including: species sheep fescue and two cultivars ('Quatro' and 'Marco Polo'); four turf-type tall fescue cultivars ('Arid 3', 'No-Net', 'Technique', and 'Patagonia'); a forage tall fescue ('Fawn'); and a buffalograss variety ('Bowie'). By the end of the first growing season, 'K-31' remained one of the strongest performers in all characteristics except turfgrass color. No significant difference was found between the 'K-31' and the turf-type tall fescue cultivars tested. All sheep fescue entries and buffalograss were slow to establish and provided less than 50% overall plot cover at the end of the first growing season. During the second growing season, all entries continued to grow and develop except for 'Bowie' buffalograss which showed diminished overall test plot cover. By the end of the third growing season, 'Bowie' buffalograss was only 9.75% of the test plot while the remaining entries covered greater than 75% of their plots. Of the remaining entries the sheep fescue entries 'Marco Polo', the species, and 'Quatro' covered 75.25%, 78%, and 78%, respectively. Among the turf-type tall fescue entries 'No-Net' was the weakest at 89% cover followed by 'Technique' at 89.75%, 'Arid 3' at 90%, and 'Patagonia' at 93.5%. The forage type tall fescues of 'K-31' and 'Fawn' produced the greatest cover at 95.25% and 95.75%, respectively. 'K-31' and 'Fawn' along with 'Arid 3', 'No-Net', 'Technique', 'Patagonia', and the sheep fescue species and cultivars 'Quatro' and 'Marco Polo' showed good establishment characteristics by developing from seed and growing into mature sod. Each of the new turf-type tall fescues, 'Arid 3', 'No-Net', 'Technique', and 'Patagonia', and the sheep fescue species and cultivars 'Quatro' and 'Marco Polo' merit consideration as a replacement for 'K-31' if 'K-31' is ultimately determined to be problematic or invasive. 'Fawn' stands out as a suitable replacement

in that it is an endophyte-free tall fescue as are the species sheep fescue and cultivars 'Marco Polo' or 'Quatro'.

INTRODUCTION

A 'Kentucky-31' tall fescue ecotype was found growing on a steep mountain pasture at the farm of William Suiter in Menifee county, Kentucky which caught the attention of Dr. E.N. Fergus of the University of Kentucky in 1931. It is believed this pasture existed before 1890. Dr. Fergus obtained seed for trials. After extensive evaluations, 'KY-31' was released as a cultivar in 1943. The advantages of 'KY-31' included dependability and adaptability to grow on a wide range of soils. After the release of 'KY-31', it was rapidly and widely adopted for use as a forage and turf cover crop in pastures and along roadsides[35]. 'KY-31' was shortened and now known as 'K-31' tall fescue. Additional benefits of 'K-31' tall fescue is its ability to tolerate traffic and low mowing heights. Roadside soils are often compacted, consisting of non-uniform soil profiles containing coarse aggregates, limited organic matter, and covered with a shallow veneer of topsoil. A groundcover of low maintenance turfgrass helps to control erosion, provides competition against weed invasions, allows for mowing, and tolerates selective broadleaf herbicide applications. Selecting and establishing turfgrass species that survive and thrive in harsh roadside environments is an important component of roadside vegetation management. 'K-31' tall fescue has been widely used as a roadside cover crop from Pennsylvania and Maryland[36] to Illinois[37] and Nebraska[38]. PennDOT specifications utilize several different seeding mixes in new construction and revitalization projects. Two common formulations are Formula D consisting of 60% 'K-31' tall fescue, 30% creeping red fescue or Chewing's fescue, and 10% annual ryegrass by weight, respectively for most medians and Formula L consisting of 55% hard fescue, 35% creeping red fescue, and 10% annual ryegrass for use in difficult to mow areas and under cable guiderails. This experiment was initiated for several reasons: 1) in response to some federal and state agencies call for replacement of 'K-31' due to claims that it is invasive, although to date it has not shown up on invasive species lists; 2) recently 'K-31' seed has been in limited supply due to poor yield among seed producers in the western U.S. and lower than normal seed production acreage; and 3) while evaluating the potential of using a low maintenance and low growing grass seed mix (i.e., Formula L and sheep fescue)[39,40] the question arose whether there are other turfgrass species and newer cultivars that would be more suitable in the roadside environment? In considering the above reasons, questions arose on whether there were turf-type tall fescue cultivars with a finer texture, reduced vertical growth, and higher tiller densities that would be more suitable and competitive than 'K-31' tall fescue? This experiment was designed to compare the effectiveness of forage tall fescue, sheep fescue, turf-type tall fescue, and buffalograss for use as low maintenance turfgrass groundcovers along a roadside in

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[35] Fribourg, H. A., D. B. Hannaway, and C. P. West (ed.) 2009. Tall Fescue for the Twenty-first Century. Agron. Monog. 53. ASA, CSSA, SSSA. Madison, WI. 540 pp. (http://forages.oregonstate.edu/tallfescuemonograph).
[36] https://www.roads.maryland.gov/OPR_Research/MD-16-SHA-UMCES-6-3_Turfgrass_Report.pdf
[37] https://natseed.com/illinois-tollway-seed-mixtures.htm#26
[38] https://dot.nebraska.gov/media/4016/veg-manual.pdf
[39] Johnson, J.M. et al 2017. Investigating Grass Species Seeding Rates and Fertilizer Plus Broadleaf Herbicide Application for Groundcover Establishment in Roadside Applications – Third Year. Roadside Vegetation Management Research – 2017 Report. pp 45-50.
[40] Jodon, J.C. et al 2018. Evaluation of Seed Mixes and Seeding Method for Reseeding Low Grow Turf Groundcover Around Cable Guiderails. Roadside Vegetation Management Research – 2018 Report. pp 23-27.

central Pennsylvania. In selecting sheep fescue entries for this trial, we learned there is some confusion on the genetics of some sheep fescue cultivars. Sheep fescue has 28 chromosomes. 'Quatro' sheep fescue has been classified as a true sheep fescue and confirmed based on laser flow cytometry by Huff and Palazzo (1998)[41]. This experiment utilized 'Quatro', 'Marco Polo' and a species sheep fescue which are all listed as sheep fescue *Festuca ovina* on the seed tag. However, a review of fine fescues (Braun et al. 2020) stated that 'Marco Polo' may be better classified as hard fescue[42]. This determination about 'Marco Polo' does not impact the outcome of the experiment, but further clarifies the differences between the entries for those interested in further analyzing these cultivars.

MATERIALS AND METHODS

Turfgrass Plot Establishment

The experiment was established within the right of way on SR 0322 westbound near the Flat Rock/East Mountain Road exit west of Port Matilda, Pennsylvania. The following turfgrasses were evaluated: three forms of sheep fescue including the species and two cultivars 'Quatro', and 'Marco Polo'; four turf-type tall fescues 'Arid 3', 'No-Net', 'Technique', and 'Patagonia'; two forage tall fescues 'K-31' and 'Fawn'; and 'Bowie' buffalograss. Plots were 10-feet by 6-feet in size and arranged in a randomized complete block design with four replications. All plots were sprayed on April 26, 2018, with RoundUp Pro at 64 ounces per acre (oz/ac) in a carrier volume of 50 gallons per acre (GPA) with a pressure of 36 psi (pounds per square inch) using a CO_2 powered backpack sprayer with a six-foot boom equipped with four 8004VS nozzles. The plots were retreated with RoundUp Pro at 64 oz/ac on May 21, 2018, to eliminate vegetation not controlled by the first application. The soil was cultivated with a disc harrow, pulled by a Kubota L2500 tractor and hand seeded on June 6, 2018. All plots were seeded at a rate of 54 pounds per acre (lbs./ac), equaling 5.8 ounces of seed per plot. Soil temperatures at the surface, 1-inch, 3-inch, and 6-inch depths, were 64° F, 63° F, 62° F, 62° F, respectively. On June 7, 2018, the experimental area was fertilized, according to the soil test report with a complete fertilizer, 10-6-4 at a rate of 1 lb. N/1000 ft^2, followed by the installation of East Coast ECS-1 erosion control straw blankets. The experimental site was treated with Triplet L/O at 64 oz/ac on August 7, 2018, to control broadleaf weeds. A second application of Triplet L/O at 64 oz/ac was applied August 1, 2019. The first mowing of the site occurred October 16, 2018, with a Kubota zero turn rotary mower set to a 5-inch height of cut. The second mowing occurred August 14, 2019. No broadleaf herbicide applications or mowing operations were performed to the experimental site during the 2020 growing season.

Turfgrass Evaluation Parameters

Turfgrass color was visually rated July 10, 2018, 34 days after seeding (DAS) and May 6, 2019, 334 DAS on a scale 1-10 (1=light green-10=dark green) and reflected the inherent genetic color of the entry, not yellowing or browning due to mowing, drought stress, disease, etc. Spring green up was rated on May 6, 2019, 334 DAS. Spring green-up, the transition from winter dormancy to active spring growth, was visually rated on a scale 1-10 (1=straw brown-10=dark

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[41] Huff and Palazzo 1998. Fine Fescue Species Determination by Laser Flow Cytometry. Crop Science 38:445-450 (1998)

[42] Braun et al 2020. Fine fescue: A review of the species, their improvement, production, establishment, and management. Crop Science 2020: 60:1142-1187

green). Seedling vigor was evaluated July 10 and August 6, 2018, 34 and 61 DAS. Seedling vigor was a visual estimate of percent groundcover and plant height during the early stages of seedling establishment and was rated on a scale 1-10 (1=least vigorous seedling growth-10=most vigorous seedling growth). Percent turfgrass density was rated on September 5, 2018, July 2, 2019, and September 5, 2019, 91, 391, and 456 DAS. Turfgrass density was a visual estimate of the number of plants or tillers per square foot based on three permanent subplots within each plot. Turf density was evaluated on a scale from 1-10, (1=minimum plants or tillers/ft^2-10=maximum plants or tillers/ft^2). The plots were rated for percent turfgrass cover on September 5, 2018, July 2, October 8, 2019, June 10, and October 14, 2020, which corresponds to 91, 391, 489, 735, and 861 DAS. Percent turfgrass cover was a visual estimate of the percent of species or cultivar seeded. Percent weed cover was rated on September 5, 2018, July 2, October 8, 2019, June 10, and October 14, 2020, which corresponds to 91, 391, 489, 735, and 861 DAS. Percent weed cover included broadleaf weeds, grass weeds, and grass species not originally seeded within the plot. Turfgrass height and seedhead height were measured on June 6, 2019, 364 DAS. The heights were measured using a yard stick at three permanent subplots per plot, to estimate the average turfgrass and seedhead height. All data were subjected to analysis of variance, and when treatment effect F-tests were significant ($p \leq 0.05$) treatment means were compared using Tukey's HSD separation test.

RESULTS AND DISCUSSION

Turfgrass Color

By 34 DAS, turfgrass color ranged from 6.5 to 9 (Table 1). Buffalograss produced the lowest rating of 6.5, while three turf-type tall fescues, 'Arid-3', 'No-Net', and 'Technique', were the highest turfgrass at 9. There was no significant difference in turfgrass color between the sheep fescue and the tall fescue entries, however, 'Bowie' buffalograss had an overall obvious lighter green color and was rated much lower than the other entries. By 334 DAS, turfgrass color ranged from 1 to 9.75 with buffalograss at 1 and all sheep fescue entries ('Quatro', 'Marco Polo' and the species) at 9.75. In comparison the National Turfgrass Evaluation Program (NTEP) fine fescue trials in 2014 in Connecticut and New Jersey using a 9 point color scale rated 'Quatro' at 7.3 and equivalent of an 8.1 on a 10 point scale in Connecticut and in New Jersey 9 (10 adjusted for 1-10 scale)[43]. Among the turf-type tall fescues 334 DAS 'Arid 3', 'No-Net', and Technique were rated at 9 while 'Patagonia' was rated at 9.25. Similar results were found at the 1996 and 2006 NTEP tall fescue trials with 'Patagonia' rated at 7.7 (8.6 adjusted 1-10 scale)[44] and 'Arid 3' averaged 7.2 (8 adjusted 1-10 scale) across five sites in Maryland, Ohio, New York and New Jersey[45]. Our rating results are generally consistent with these national trials conducted away from the roadside environment. Spring green-up, the transition from winter dormancy to active spring growth was visually rated 334 DAS and ranged from 2.25 to 10 (Table 1). Buffalograss showed the lowest spring green up with a rating of 2.25 due to the fact that it is a warm season grass requiring higher temperatures to transition to active spring growth. A month later on June 5, buffalograss showed effective green up. Spring green up for all of the tall fescue entries was rated a 10 and all of the sheep fescue entries was 9.25.

[43] https://ntep.org/data/ff14/ff14_20-14f/ff14_20-14f.pdf
[44] https://ntep.org/data/tf06/tf06_12-10f/tf06_12-10f.pdf
[45] https://ntep.org/data/tf96/tf96_01-14f/tf96_01-14f.pdf

Seedling Vigor

Seedling vigor ranged from 1.5 to 7.3 at 34 DAS (Table 1). 'Bowie' buffalograss was the least vigorous at 1.5 and 'K-31' tall fescue was the most vigorous with a rating of 7.3. By 61 DAS 'Marco Polo' sheep fescue was statically less vigorous among the entries with a rating of 3.3 and 'K-31' continued to rate the highest at 8.5. All entries increased in vigor except the sheep fescue entries. Among the sheep fescue entries 'Quatro' remained the same while 'Marco Polo' and the species declined after the 34 DAS rating. Fine fescues in general and sheep fescue in particular are slow to establish[46]. The best time to seed turfgrass in central Pennsylvania is late summer to early fall[47]. However, cool-season grasses can be seeded in Pennsylvania during the spring no later than April 1 for southeastern PA, May 20 for high altitude and northern PA counties, and May 7 for all other PA areas[48]. Early spring to mid-spring seedlings of cool-season turfgrasses may yield an acceptable turfgrass cover prior to mid-summer stress, but because of cool soil temperatures, early development of the new turf is usually slower than that observed with late-summer seedings according to Emeritus Professor of Turfgrass Turgeon[49]. The June seeding time for this experiment may have been a factor in the lower seedling vigor ratings found at 61 DAS. Previous National Turfgrass Evaluation Program trials conducted at Penn State between 1993-1996, showed seedling vigor for 'Quatro' sheep fescue at 3.3 (scale 1-9) with plots rated shortly after seeding (9/24/93)[50]. This experiment showed seedling vigor 4.8 (scale 1-10) at 34 DAT. One reality in operational seeding on large scale road projects is that seeding outside of the recommended time windows for reduced stress will occur to close out a reconstruction project contract or to prevent erosion. This action may stress the new seedlings and require longer time to develop. This may result in more maintenance to prevent weed invasion.

Turfgrass Density

The experiment was visually rated for turfgrass density at three permanent 1-foot^2 subplots with each plot (Table 2). On September 5, 2018, 91 DAS, turfgrass density ranged from 2.5 for buffalograss to 8.5 for 'K-31'. Slightly beyond one year after seeding (391 DAS), turfgrass density ranged from 2.33 to 8.42. 'Bowie' buffalograss was the lowest and 'Fawn' a forage tall fescue was the highest rated. By 456 days after seeding, 'Bowie' buffalograss continued as the lowest rated at 2 while all other entries were statistically similar based on turfgrass density and ranged from 5.92 to 7.75. 'Patagonia' rated the highest at 7.75. All tall fescue entries produced density ratings over 7.33. The three sheep fescue entries ranged from 5.92 to 6.67. Previous NTEP trials, scale 1-9, for summer density rated 'Patagonia' on at 6.7 (7.4 adjusted 1-10 scale) in Indiana and Kentucky[51], 'Arid 3' 6.95 (7.7 adjusted 1-10 scale) in Delaware and Kentucky[52], 'K-31' a 4.0 (4.4 adjusted 1-10 scale) in Indiana and 'Technique' at 6.6 (7.3 adjusted 1-10 scale) in Indiana[53]. 'K-31'density results were not similar to past NTEP trials, which may be the result of different mowing practices. The experiment was only mowed

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[46] http://www.roads.maryland.gov/OPR_Research/MD-16-SHA-UMCES-6- 3_Turfgrass_Report.pdf

[47] Turfgrass Establishment. https://extension.psu.edu/turfgrass-establishment

[48] Turfgrass Establishment. https://extension.psu.edu/turfgrass-establishment

[49] Turgeon, A.J. Turfgrass Management Third Edition. Regents Prentice Hall, 1991.

[50] Performance of Fine Fescue Cultivars and Selections (1993-1996) https://plantscience.psu.edu/research/centers/turf/extension/factsheets/1993-96-fine-fescue-report.pdf

[51] https://ntep.org/data/tf06/tf06_12-10f/tf06_12-10f.pdf

[52] https://ntep.org/data/tf96/tf96_01-14f/tf96_01-14f.pdf

[53] https://ntep.org/data/tf12/tf12_18-13f/tf12_18-13f.pdf

two times at a 5-inch height to simulate a typical mowing practices used to maintain highways. The NTEP trials were mowed more frequently and at a lower height which may have induced more tillering in the newer turf- type tall fescues compared to ‘K-31’. The height of cut at the Indiana site was 2.6-3-inches. Previous fine fescue NTEP trials at University Park, PA, rated ‘Quatro’ at 6.6 (7.3 adjusted 1-10 scale)[54].

Turfgrass Cover

Percent turfgrass cover by 91 DAS (Table 3), ranged from 29.25 (‘Quatro’) to 82.5 (‘K-31’). All entries, except buffalograss, increased percent turfgrass cover between 91 and 391 DAS. About a year after seeding, 391 DAS, cover ranged from 26.25% for buffalograss to 95% for ‘K-31’. By 489 DAS, the last evaluation of the 2019 season, percent cover for all tall fescue and sheep fescue entries were significantly higher than ‘Bowie’ buffalograss. ‘Patagonia’, ‘Technique’, ‘Fawn’, and ‘K-31’ produced over 90 percent turfgrass cover. ‘No-Net’ and ‘Arid 3’ turf-type tall fescues produced over 85 percent cover. The sheep fescues, ‘Marco Polo’, the species, and ‘Quatro’ produced a cover rating of over 75 percent.

Throughout the third growing season, percent cover was rated on June 10, and October 14, 2020 (735 and 861 DAS), respectively. On June 10, 2020, cover ranged from 6% for buffalograss to 85% for ‘Fawn’ tall fescue. The species sheep fescue cover was 62.5% with ‘Quatro’ and ‘Marco Polo’ at 66.25%. While ‘Technique produced cover of 72.5%, ‘Arid 3’ 73.25%, ‘No-Net’ 75%, ‘Patagonia’ 80%, and ‘K-31’ 81.25%. By October 14, 2020, 861 DAS, the last rating day for the experiment, percent cover for ‘Bowie’ buffalograss was 9.75 with ‘Marco Polo’ 75.25, species sheep fescue 78, ‘Quatro’ 78, ‘No-Net’ 89, ‘Technique’ 89.75, ‘Arid 3’ 90, ‘Patagonia’ 93.5, ‘K-31’ tall fescue 95.25 and ‘Fawn’ at 95.75.

By comparison, previous NTEP trials in Indiana, New Jersey, Kentucky and Delaware ‘Arid 3’ averaged 73.6% for fall living ground cover and ‘K-31’ averaged 61.3%[55]. NTEP trials in Indiana, Kentucky, and Tennessee showed ‘Patagonia’ averaged 88.8% fall living groundcover and ‘K-31’ averaged 81.1%[56]. Additionally, NTEP trials in North Carolina and Tennessee showed ‘Technique’ averaged 88.8% fall living groundcover and ‘K-31’ averaged 93.3%[57]. The 1996 and 2006 NTEP trials showed the percent ‘K-31’ groundcover to be much less than the results of this experiment. However, the 2012 NTEP trial reported similar percent ‘K-31’ groundcover compared to the results of this experiment. Differences in ‘K-31’ cover between the NTEP trials and this experiment may be the result of differing maintenance practices including mowing height and frequency, fertilization, and weed control as well as the diversity of locations in the United States.

Percent Weed Cover

Weed cover ratings represent the percent cover by any broadleaf or grass species present in plots other than the seeded turfgrass cultivar or species (Table 4). On August 7, 2018, 62

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[54] Performance of Fine Fescue Cultivars and Selections (1993-1996) https://plantscience.psu.edu/research/centers/turf/extension/factsheets/1993-96-fine-fescue-report.pdf

[55] https://ntep.org/data/tf96/tf96_01-14f/tf96_01-14f.pdf
[56] https://ntep.org/data/tf06/tf06_12-10f/tf06_12-10f.pdf
[57] https://ntep.org/data/tf12/tf12_18-13f/tf12_18-13f.pdf

DAS, Triplet L/O at 64 oz/ac with Induce at 0.25% volume to volume basis, was applied to all plots to control broadleaf weeds. By 91 DAS, percent weed cover ranged between 3.25-10.75. ‘Marco Polo’ sheep fescue had the highest weed cover at 10.75%, followed by ‘Bowie’ buffalograss at 10.25%, ‘Quatro’ at 8.75%, ‘Arid 3’ at 8.5%,’No-Net’ at 7%, the species sheep fescue at 6.75%, ‘Fawn’ at 5.5%, ‘Patagonia’ at 4.75%, ‘K-31’ at 4.5%, and ‘Technique’ at 3.25%. There was no significant difference in weed cover among all entries.

During the second growing season on July 2, 2019, all plots showed under 15 percent weed cover except buffalograss where weed cover was 46.25 percent. It was apparent by one year after seeding, buffalograss could not compete in this environment in central Pennsylvania. Cool season grasses such as tall fescue, Kentucky bluegrass, creeping red fescue, and orchardgrass and annual grass weeds like foxtail began to outcompete buffalograss seeded plots. On August 1, 2019, an application of Triplet L/O at 64 oz/ac plus Induce at 0.25% v/v was applied to all plots to control broadleaf weeds. By 489 DAS, weed cover in tall fescue plots was below 2%, the sheep fescue plots ranged from 17.88 to 21%, and buffalograss was over 60%.

By the beginning of the third growing season, weed cover ranged between 0.63% (Arid 3) to 71.75% (buffalograss) about two years after seeding. Weed cover was statistically similar among entries except buffalograss which was statistically higher. No broadleaf weed treatments were applied during 2020. October 14, 2020, 861 DAS, weed cover was highest in the buffalograss plots at 79%, followed by species sheep fescue at 17.5%,‘Marco Polo’ at 16.35%, ‘Quatro’ at 14.75%, ‘No-Net’ at 3.5%, ‘Arid 3’ and ‘Technique’ at 1.38%, ‘K-31’ at 1%, ‘Patagonia’ at 0.75%, and ‘Fawn’ supported the fewest weeds at 0.5% cover.

The existing roadside turfgrass species adjacent to the plots was predominantly ‘K-31’tall fescue mixed with creeping red fescue and occasionally Kentucky bluegrass which may have influenced weed cover. During evaluations it was easy to determine ‘K-31’ tall fescue as a weed in sheep fescue and buffalograss plots based on plant characteristics. In the turf-type tall fescue plots, ‘K-31’ could be detected as a weed by the color and height. ‘K-31’ tall fescue is taller and light green in color. The turf-type tall fescues are shorter and have a deeper dark green color. Throughout the third growing season it was easy to determine if ‘K-31’ was present in turf-type tall fescue, sheep fescue, and buffalograss entries because the plots were not mowed. ‘K-31’ was never a problematic or invasive weed but it was found in some of those plots.

Turfgrass Height

Buffalograss had the shortest with an average height of 3.38 inches and was statistically similar to ‘Marco Polo’ at 364 DAS (Table 5). In contrast, ‘Fawn’ was the tallest with an average height of 11.33 inches. All of the turf-type tall fescues, ‘Arid 3’, ‘No-Net’, ‘Patagonia’, and ‘Technique’ were shorter in height than ‘K-31’. Additionally, the sheep fescues were statistically similar in height and shorter than ‘K-31’ in both stem and seedhead height. Buffalograss was the shortest at 5.33 inches in seedhead height and ‘Fawn’ was the tallest at 30.83 inches. ‘K-31’ tall fescue was statistically similar but numerically shorter than ‘Fawn’ tall fescue. Seedhead height was similar amongst the turf-type tall fescues and shorter than ‘K-31’ tall fescue. The three sheep fescue entries, ‘Patagonia’ and ‘Technique’ were within a preferred height for maintenance and sight line safety in general and may be useful around cable guiderail systems.

CONCLUSIONS

‘Fawn’ tall fescues performed equal to ‘K-31’ tall fescue. ‘Arid 3’, ‘No-Net’, ‘Technique’, and ‘Patagonia’ consistently performed similar or superior to ‘K-31’ based on turfgrass density, turfgrass cover, turfgrass height and seedhead height. Quatro’, ‘Marco Polo’ and species sheep fescue were similar to ‘K-31’ based on turfgrass density, turfgrass cover. ‘Quatro’, ‘Marco Polo’ and the species sheep fescue were significantly shorter than ‘K-31’ tall fescue in turfgrass height and seedhead height. Buffalograss declined over time and was not a competitive groundcover in central Pennsylvania.

MANAGEMENT IMPLICATIONS

After the establishment phase of this experiment and through the second and third growing season the turf-type tall fescues demonstrated that they can be an effective roadside turfgrass groundcover. Considering that the sheep fescues are slow to establish, their performance was acceptable during the first growing season and continued through the second and third growing season providing effective groundcover along a roadside site. ‘K-31’ and ‘Fawn’ tall fescue, ‘Arid 3’, ‘No-Net’, ‘Technique’, and ‘Patagonia’ turf-type tall fescue, and ‘Quatro’, ‘Marco Polo’, and the species sheep fescue performed at acceptable levels and should be considered for use as a roadside groundcover. ‘Fawn’ tall fescue performed as well as ‘K-31’ tall fescue and has the added benefit of not containing endophytes. ‘Arid 3’, ‘No-Net’, ‘Technique’, and ‘Patagonia’ turf-type tall fescue performed similar to ‘K-31’ tall fescue and could be used as a substitution for ‘K-31’ tall fescue in seed mixes. This research was conducted in small plots along a single roadside. To blindly adopt these without consideration of the location and varied soil and environmental conditions of the site would be ill advised; however, as alternative to ‘K-31’due to limited availability ‘Patagonia’, ‘Arid 3’ or ‘Technique’ are reasonable selections for further deployment in larger plantings. Additionally, if a decision to drop the use of ‘K-31’ due to its endophyte relationship, ‘Fawn’ tall fescue is an endophyte-free substitute.

Table 1. Turfgrass Color, Seedling Vigor, Spring Green-Up. The experiment was visually rated for turfgrass genetic color on July 10, 2018, 34 days after seeding (DAS), and May 6, 2019, 334 DAS, on a scale from 1-10 (1=light green-10=dark green). Seedling vigor was rated on July 10 and August 6, 2018, 34 and 61 DAS, respectively, on a scale from 1-10 (1=least vigorous seedling growth-10=most vigorous seedling growth). Spring green up, the transition from winter dormancy to active spring growth, was visually rated on May 6, 2019, 334 DAS, on a scale from 1-10 (1=straw brown-10=dark green). The soil within the experimental plots was cultivated with a disc harrow and seeded on June 6, 2018. The plots were fertilized, and erosion control straw blankets installed on June 7, 2018. The site was treated with Triplet L/O at 64 oz/ac on August 7, 2018, to control broadleaf weeds. The first mowing occurred October 16, 2018, with a Kubota zero turn rotary mower set to a 5-inch height of cut. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Turfgrass	Variety	Turfgrass Color 7/10/18 34 DAS	Seedling Vigor 7/10/18 34 DAS	Seedling Vigor 8/6/18 61 DAS	Spring Green-Up 5/6/19 334 DAS	Turfgrass Color 5/6/19 334 DAS
Sheep fescue	Quatro	8.5 b	4.8 ab	4.8 ab	9.25 b	9.75 d
Sheep fescue		8.8 b	5.3 b	4.5 ab	9.25 b	9.75 d
Sheep fescue	Marco Polo	8.3 b	3.8 ab	3.3 a	9.5 b	9.75 d
Tall fescue	K-31	8.3 b	7.3 b	8.5 b	10 b	8.25 bc
Tall fescue turf-type	Arid 3	9 b	6 b	7 ab	10 b	9 bcd
Tall fescue turf-type	No-Net	9 b	6.3 b	7 ab	10 b	9 bcd
Tall fescue	Fawn	8.3 b	6.8 b	8.3 b	10 b	8 b
Tall fescue turf-type	Technique	9 b	6.3 b	8 b	10 b	9 bcd
Tall fescue turf-type	Patagonia	8.8 b	6.3 b	8 b	10 b	9.25 cd
Buffalograss	Bowie	6.5 a	1.5 a	4.3 ab	2.25 a	1 a

Table 2. Turfgrass Density. The experiment was visually rated for turfgrass density, on a scale from 1-10 (1=minimum turfgrass plants or tillers/ft^2-10=maximum turfgrass plants or tillers/ft^2), on September 5, 2018; July 2 and September 5, 2019; 91, 391, 419, and 456 days after seeding (DAS), respectively. Turf density is a visual estimate of the number of turfgrass plants or tillers per $foot^2$ from three permanent subplots per plot. The soil within the experimental plots was cultivated with a disc harrow and seeded on June 6, 2018. The plots were fertilized, and erosion control straw blankets installed on June 7, 2018. The site was treated with Triplet L/O at 64 oz/ac, including a non-ionic surfactant (Induce) at 0.25% v/v on August 7, 2018, and August 1, 2019, to control broadleaf weeds. The first mowing of the site occurred October 16, 2018, with a Kubota zero turn rotary mower set to a 5-inch height of cut. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Turfgrass	Variety	Turf Density 9/5/18 91 DAS	Turf Density 7/2/19 391 DAS	Turf Density 9/5/19 456 DAS
Sheep fescue	Quatro	2.8 a	6.75 bc	6.67 b
Sheep fescue		3.3 ab	5.83 b	6.5 b
Sheep fescue	Marco Polo	3 a	6.33 bc	5.92 b
Tall fescue	K-31	8.5 c	7.67 bc	7.58 b
Tall fescue turf-type	Arid 3	6.5 c	7 bc	7.5 b
Tall fescue turf-type	No-Net	5.8 bc	6.25 bc	7.33 b
Tall fescue	Fawn	7.5 c	8.42 c	7.33 b
Tall fescue turf-type	Technique	7.8 c	7.17 bc	7.42 b
Tall fescue turf-type	Patagonia	6.5 c	7.25 bc	7.75 b
Buffalograss	Bowie	2.5 a	2.33 a	2 a

Table 3. Turfgrass Cover. The experiment was visually rated for percent turfgrass cover on September 5, 2018; July 2, October 8, 2019; June 10, and October 14, 2020; 91, 391, 419, 489, 735, and 861 days after seeding (DAS), respectively. Percent turfgrass cover is a visual estimate of the percent cover by desirable (seeded) turfgrass species or cultivar per plot. The soil within the experimental plots was cultivated with a disc harrow and seeded on June 6, 2018. The plots were fertilized, and erosion control straw blankets installed on June 7, 2018. The site was treated with Triplet L/O at 64 oz/ac, including a non-ionic surfactant (Induce) at 0.25% v/v on August 7, 2018, and August 1, 2019, to control broadleaf weeds. On October 16, 2018, and August 14, 2019, all plots were mowed with a Kubota zero turn rotary mower set to a 5-inch height of cut. No broadleaf herbicide applications or mowing operations occurred during 2020. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Turfgrass	Variety	% Turfgrass Cover 9/5/18 91 DAS	% Turfgrass Cover 7/2/19 391 DAS	% Turfgrass Cover 10/8/19 489 DAS	% Turfgrass Cover 6/10/20 735 DAS	% Turfgrass Cover 10/14/20 861 DAS
Sheep fescue	Quatro	29.25 a	72.5 b	78.75 b	66.25 b	78 b
Sheep fescue		36.25 abcd	70 b	75 b	62.5 b	78 b
Sheep fescue	Marco Polo	30.25 ab	66.25 b	75 b	66.25 b	75.25 b
Tall fescue	K-31	82.5 e	90 b	93.75 b	81.25 b	95.25 b
Tall fescue turf-type	Arid 3	62.5 abcde	85 b	88.75 b	73.25 b	90 b
Tall fescue turf-type	No-Net	68.75 bcde	83.75 b	85 b	75 b	89 b
Tall fescue	Fawn	73.75 de	95 b	92.5 b	85 b	95.75 b
Tall fescue turf-type	Technique	68.75 bcde	87.5 b	90.75 b	72.5 b	89.75 b
Tall fescue turf-type	Patagonia	71.25 cde	87.5 b	90.75 b	80 b	93.5 b
Buffalograss	Bowie	32.5 abc	26.25 a	14.75 a	6 a	9.75 a

Table 4. Weed Cover. The experiment was visually rated for percent weed cover on September 5, 2018; July 2, October 8, 2019; June 10, and October 14, 2020; 91, 391, 419, 489, 735, and 861 days after seeding (DAS), respectively. The soil within the plots was cultivated with a disc harrow and seeded on June 6, 2018. Plots were fertilized, and erosion control straw blankets installed on June 7, 2018. The site was treated with Triplet L/O at 64 oz/ac, including a non-ionic surfactant (Induce) at 0.25% v/v on August 7, 2018, and August 1, 2019, to control broadleaf weeds. On October 16, 2018, and August 14, 2019, all plots were mowed with a Kubota zero turn rotary mower set to a 5-inch height of cut. No broadleaf herbicide applications or mowing operations occurred during 2020. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Turfgrass	Variety	% Weed Cover 9/5/18 91 DAS	% Weed Cover 7/2/19 391 DAS	% Weed Cover 10/8/19 489 DAS	% Weed Cover 6/10/20 735 DAS	% Weed Cover 10/14/20 861 DAS
Sheep fescue	Quatro	8.75	8.88 a	17.88 a	18.15 a	14.75 a
Sheep fescue		6.75	12.75 a	18.25 a	20.13 a	17.5 a
Sheep fescue	Marco Polo	10.75	14.38 a	21 a	22 a	16.25 a
Tall fescue	K-31	4.5	0.38 a	0 a	1.19 a	1 a
Tall fescue turf-type	Arid 3	8.5	0.56 a	0.75 a	0.63 a	1.38 a
Tall fescue turf-type	No-Net	7	2.25 a	1.5 a	5.4 a	3.5 a
Tall fescue	Fawn	5.5	2.53 a	0 a	1.31 a	0.5 a
Tall fescue turf-type	Technique	3.25	0.56 a	1.5 a	2.13 a	1.38 a
Tall fescue turf-type	Patagonia	4.75	0.31 a	0 a	0.88 a	0.75 a
Buffalograss	Bowie	10.25	46.25 b	61.75 b	71.75 b	79 b
		n.s.				

Table 5. Turfgrass height and seedhead height. The experiment was measured for turf height and seedheads height on June 5, 2019; 364 days after seeding (DAS). Turfgrass and seedheads height were measured from each of the three permanent subplots per plot. The soil within the experimental plots was cultivated with a disc harrow and seeded on June 6, 2018. The plots were fertilized, and erosion control straw blankets installed on June 7, 2018. On August 7, 2018, all plots were treated with Triplet L/O at 64 oz/ac, including a non-ionic surfactant (Induce) at 0.25% v/v. All plots were mowed to 5-inch height on October 16, 2018. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Turfgrass	Variety	Turfgrass Height (Inches) 6/5/19 364 DAS	Seedheads Height (Inches) 6/5/19 364 DAS
Sheep fescue	Quatro	6.25 bc	15.08 b
Sheep fescue		7.42 bc	21.42 cd
Sheep fescue	Marco Polo	4.5 ab	16.5 bc
Tall fescue	K-31	10.67 ef	28.67 e
Tall fescue turf-type	Arid 3	9.42 def	23.25 d
Tall fescue turf-type	No-Net	8.5 cde	22 d
Tall fescue	Fawn	11.33 f	30.83 e
Tall fescue turf-type	Technique	8.75 de	18.67 bcd
Tall fescue turf-type	Patagonia	8.33 cde	21.83 d
Buffalograss	Bowie	3.38 a	5.33 a

EVALUATION OF NATIVE GRASS AND POLLINATOR SEED MIXES AND SEEDING METHODS FOR CONVERSION AND ESTABLISHMENT ALONG ROADSIDES

Herbicide trade and common names: Accord XRT II (*glyphosate*)

Plant common and scientific names: hard fescue mixture (*Festuca longifolia*); creeping red fescue (*Fescue rubra*); little bluestem (*Andropogon scoparius*); Canada wildrye (*Elymus canadensis*); Virginia wildrye (*Elymus virginicus*); Indiangrass (*Sorghastrum nutans*); oats (*Avena sativa*);black-eyed susans (*Rudbeckia hirta*); New England aster (*Symphyotrichum novae-angeliae*); ox-eye sunflower (*Heliopsis helianthoides*); big bluestem (*Andropogon gerardii*); switchgrass (*Panicum virgatum*); sheep fescue (*Festuca ovina L.*); creeping red fescue (*Festuca rubra*); chewing's fescue (*Festuca rubra subsp. commutata*)

ABSTRACT

Utilizing native grass species for sites along the roadsides of Pennsylvania has gained momentum and is being promoted as a viable option for future revegetation programs. Soil stability, germination rate and speed of cover, vehicular safe site distance conditions, and ease of maintenance are all very important factors roadside managers consider when selecting seed mixes. A demonstration area was established where two native seed mixes, Formula N and modified Formula N, were seeded at a pure live seed (PLS) rate and at PennDOT's standard bulk rate. Once established, half the site will be subjected to standard maintenance practices while the other half will not in order to determine whether the seed mixes can tolerate and thrive under present roadside maintenance practices. By 97 DAS (days after seeding), at the two different seeding rates, Formula N produced the highest plant count with an average ranging from 0.06 to 4.13 plants per counted subplot of 4 sq. ft. and modified Formula N produced a lower average count range of 0.06 to 0.38 plants. Oats seed as a quick cover at a rate of 30 lbs./ac, produced a plant count average of from 2.88 to 5.38. Finally, the broadleaf weeds and grass weeds at the two different seeding rates for both seed mixes resulted in an average of 3.19 to 16.88 plants per 4 sq. ft. The sites will be evaluated throughout the coming years to provide a more comprehensive evaluation of the success of the two formulas and their associated seeding rates. Furthermore, it will be determined whether or not the areas will benefit from establishing initial maintenance program to better assist the establishment of the native seed mixes.

INTRODUCTION

PennDOT seed mixes used to provide groundcover are typically selected based on their adaptability to site conditions and ease of future maintenance[58]. With a growing call to assist with the establishment and regeneration of native species by the commonwealth of Pennsylvania, while maintaining soil stability and safe site distance along the roadside, we evaluated alternative grass species within a previously created PennDOT native seed mix (PennDOT Formula N). Formula N created in 2009 included native warm-season grasses (WSG) and was designed as an alternative to the PennDOT Formula C seed mix used for rocky, shallow soil, difficult to mow

[58] Johnson et. Al. 2009. Native Seed Mix Establishment Implementation. Roadside Vegetation Management Research-2009 Report. pp. 50.

areas and containing crownvetch. Crownvetch has been classified as a “situational invasive” by the PA DCNR[59].

The established Formula N (Table 1) seed mix consists of little bluestem and Indiangrass, which once established adapt well to poor soil conditions, provide sufficient groundcover, and prevent erosion. These two grasses are tall bunch type grass species with a very deep root system[60]. The hard and creeping red fescue species that germinate within 2-3 weeks of seeding provide early cover thus reducing weed pressure and erosion caused by heavy spring precipitation. The oats and wildrye also provide early cover and erosion protection. To support native wildlife food resources, the black-eyed Susan, oxeye sunflower and New England aster are nectar sources to foraging bees, butterflies, and insects, and seeds for birds. However, slow establishment was the main drawback with Formula N due to the WSG component, which generally requires three to four seasons to provide satisfactory groundcover and increased opportunity for erosion and increased weed pressure[61]. This slow establishment may be partially due to seed dormancy constraints which may require natural stratification through a winter freeze thaw cycle to germinate and variation in the level of dormancy within seed lots[62].

The goal behind development of a modified Formula N (Table 2) was to enhance the WSG component of the seed mix to better adapt to heat, drought, variable pH levels, low fertility, and salt buildup (Johnson et al., 2014) while developing a better stand of WSG. To do this the Canada and Virginia wildrye, black-eyed Susan, oxeye sunflower, and New England aster were replaced with big bluestem, switchgrass. In addition, the CSG component was enhanced with addition of sheep and chewing’s red fescue to provide better gap coverage for several seasons allowing the WSG time to establish and thus reducing weed pressure and possible soil erosion. The modified Formula N seed mix components were chosen based on grass type, site conditions, and concerns around standard broadleaf weed management procedures applied during seedling establishment and in future maintenance. Seeds were selected based on availability and applicability to the site.

In this experiment, Formula N and modified Formula N were seeded at two different rates to compare PennDOT’s standard bulk rate versus a pure live seed (PLS) rate. Comparison between these two seeding rates were the result of discussions within PennDOT on the economics and potential overall success of plant establishment on newly seeded sites with native seed mixes.

To evaluate maintenance practices the seed plots were subdivided to determine the effect of standard maintenance practices versus no maintenance on establishment of the two seed mixes. This paper represents first year observations of the seeding process.

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[59] Johnson et. Al. 2014. Evaluation of Native Seed Mixes For Roadside Application – Year Three. Roadside Vegetation Management Research-2014 Report. pp. 27-28.
[60] Delong, C. and M. Brittingham. 2007. Warm-Season Grasses and Wildlife. Penn State Extension. https://extension.psu.edu/warm-season-grasses-and-wildlife. Viewed April 15, 2020.
[61] Johnson et. Al. 2009. Native Seed Mix Establishment Implementation. Roadside Vegetation Management Research-2009 Report. pp. 50.
[62] Establishing Native Grasses, Conservation Reserve Program Job Sheet CP2, March 2011. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_017880.pdf Viewed May 5, 2021

MATERIALS AND METHODS

A demonstration site was established along Park Avenue on the back slope under the interchange of I-99 and SR 322. The site had a slight slope with poor soil conditions. There were several cool-season grass species onsite including fine fescue, tall fescue, Kentucky bluegrass, and reed canary grass, along with several broadleaf weed species. Four replicate plots of 60' x 160' were created and arranged in a randomized block design. Each replicate plot was split into four treatment plots of 30' x 40' and arranged in a complete randomized block design. Each treatment plot was then split into subplots that were 30' x 20' to compare maintenance vs. non-maintenance. To measure the first-year performance, plants were counted within four sub plots that were 2 x 2' in size and were arranged on a diagonal line running along the center of each treatment replication. On June 1, 2020, all plots were sprayed with Accord XRT II at 64 oz/ac in a carrier volume of 50 gallons per acre (GPA) with a pressure of 35 pounds per square inch (PSI) using a CO_2 powered backpack sprayer with a six-foot boom equipped with four 8004VS nozzles to eliminate vegetation. A surfactant, CWC90, was added to all treatments at 0.25% v/v. The weather at the time of application consisted of sunny skies, wind speeds of 5-10 mph, air temperature of 74° F, and 20% relative humidity. Soil temperatures at the surface, at the surface, 1-inch, and 3-inch depths, were 71° F, 71°F and 71° F, respectively. Following this application, on June 22 and 23, 2020, the soil was cultivated with a disc harrow, pulled by a Kubota L2500 tractor. Seeds were purchased from native seed nurseries and stored the seed until planting. Seeds were weighed and bagged for each plot separately. To assure accuracy in seeding rates and seed purity, seeding rates were calculated for each species using pure live seed (PLS), standardizing the overall seeding rate among the mix at 430 PLS seeds per square meter[63]. All plots were seeded with the different seed mixes at their specified rate and a quick cover of oats were seeded at 30 lbs./acre. Plots were fertilized with 10-6-4 at 1 lb. N per 1000 sq. ft. and covered with erosion control straw blankets on June 25, 2020. Eight plots were broadcast seeded, four with a PennDOT standard rate per acre and four with a rate based on PLS per acre. Formula N was seeded at PennDOT's bulk rate of 105.1 lbs./acre and at the PLS rate of 4.91 lbs./acre. Modified Formula N was seeded at PennDOT's bulk rate of 40 lbs./acre and at the PLS rate of 50.4lbs./acre. Local rain events occurred on June 27, July 1, and 3, 2020, measuring 0.52", 0.01", and 0.09", respectively, according to http://newa.cornell.edu. The nearest weather station was located at Rock Springs, PA. All data were subjected to analysis of variance, and when treatment effect F-tests were significant ($p \leq 0.05$), treatment means were compared using Tukey's HSD separation test.

RESULTS AND DISCUSSION

The experimental site was seeded after the typical spring seeding window and the growing season did not include a significant amount of precipitation immediately after seeding. The 2020 growing season can be generally categorized as a drought season with little precipitation. The dry conditions likely inhibited seed germination and represents what may

[63] Meissen, Justin; Williams, Dave; and Jackson, Laura (2017) "Cost-Effective Native Seed Mix Design and First-Year Management," Farm Progress Reports: Vol. 2016 : Iss. 1 , Article 62. DOI: https://doi.org/10.31274/farmprogressreports-180814-1632 Available at: https://lib.dr.iastate.edu/farmprogressreports/vol2016/iss1/62. Viewed May 5, 2021

happen in roadside plantings where supplemental irrigation is not available or financially justified. All treatments showed germination of broadleaf weeds, grass weeds, and oats.

At the end of the growing season, 97 DAS (days after seeding), Formula N at the two different seeding rates produced the highest plant count average range from 0.06 to 4.13 plants based on four 4 square foot subsampling units (Table 3). Black-eyed Susan was the greatest component with a plant count average range of 0.06 to 0.19 at the lower seeding rate and a plant count average range of 3.38 to 4.13 at the higher seed rate. The grass species at the lower seeding rate ranged from 0 to 0.06 for Indiangrass, followed by 0.13 to 0.19 for the fine fescues. Grass species at the lower seeding rate that had a plant count of 0 were little bluestem, Canada wildrye, and Virginia wildrye. The grass species at the higher seeding rate ranged from 0 to 0.19 for Indiangrass, followed by 0.25 to 0.88 for the little bluestem, and finally 0.44 to 1.88 for the fine fescues. Grass species at the higher seeding rate that had a plant count of 0 were Canada wildrye and Virginia wildrye. The broadleaf weeds and grass weeds at the two different seeding rates produced a plant count ranging from 3.19 to 14.16. There was no significant difference among the Formula N plots at both seeding rates for both broadleaf weeds and grass weeds. Among the modified Formula N there was no significant difference in broadleaf weeds germinated; however, there was a distinct trend with the PLS seeding rate showing more weeds than the bulk weight plots. There was a significant difference between plots for grass weed species and a tendency for more grass weeds appearing in the PLS plots compared to the bulk weight plots. The importance of this will likely be seen as the plots fully establish and will help to determine which maintenance program addresses the weeds development. Oats were seeded at a rate of 30 lbs./ac. and produced a plant count range from 2.94 to 5.38.

Within the modified Formula N seed mix cover in general had an average range from 0.06 to 0.38 at the two different seeding rates (Table 4). The grass species at the lower seeding rate ranged from 0 to 0.06 for switchgrass, followed by 0.13 to 0.31 for the fine fescues. Grass species at the lower seeding rate that had a plant count 0 were little bluestem, big bluestem, and Indiangrass. The grass species at the higher seeding rate ranged from 0.19 to 0.25 for big bluestem, followed by 0.19 to 0.31 for the switchgrass, and finally 0.31 to 0.38 for the little bluestem. Grass species at the higher seeding rate that had a plant count 0.0% were Indiangrass and fine fescue. The broadleaf weed and grass weeds at the two different seeding rates ranged from 5.94 to 16.88 plants per 4 sq. ft. Oats were seeded at a rate of 30 lbs./ac. and produced a plant count range from 2.88 to 5.19. All plant counts were based on a 4 sq. ft. sample plot.

The standard bulk weight seeding method used by PennDOT showed an overall greater number of seedlings germinating than the PLS seeding method proposed by the vendor. This was in part due to the nearly eight-fold increase in seed applied. The question remains as the site continues to fill in will the excess seed be a benefit to establishment or a hinderance due to competition and an unintended cost compared to the pure live seed seeding rate. With time as the plots develop there should be a clearer difference in the effect of seeding rate among the two seed mixes.

As observed broadleaf weeds were becoming a competitive inhibitor by the end of the first growing season. In the coming season maintenance treatments will be applied to reduce weed pressure in the plots and should provide a better understanding of effect of standard maintenance and no maintenance on seed population survival and development. One concern with standard broadleaf weed management strategies is the possible loss of the pollinator friendly components of the seed mix.

CONCLUSIONS

First year results for all species within both seed mixes showed very poor emergence, all showing less than 2 percent cover. The oats, which were intended to provide immediate cover for soil stability, showed a very low germination rate as well. We attribute this low germination to the limited precipitation experienced in the area over the last year. As a result of this, a high rate of weed species were observed in some plots. The late season establishment, low precipitation, and the lack of a first-year maintenance program to manage weeds is a reasonable expectation for roadside sites where limited horticultural support would be provided after seeding. Although the first-year rating had poor results, dormant seed will continue to germinate during the upcoming growing seasons and provide more significant cover. Initiation of a maintenance program going into the second growing should provide further information on how the seeding rates and mixes respond to standard PennDOT maintenance practices for weed control.

Table 1: Formula N: Species included in Formula N seed mix at PennDOT's rate of 105.1 lbs./acre and at a PLS rate of 4.91 lbs./acre.

Common name	**Scientific name**	**PennDOT Rate lbs./ac**	**430 PLS/m2 Rate lbs./ac**
Hard fescue	*Festuca longifolia*	43.56	2.03
Creeping red fescue	*Fescue rubra*	21.78	1.02
Little bluestem	*Schizachyrium scoparius*	5.81	0.27
Indiangrass	*Sorghastrum nutans*	4.36	0.02
Canada wildrye	*Elymus canadensis*	8.71	0.41
Virginia wildrye	*Elymus virginicus*	2	0.09
Black-eyed susan	*Rudbeckia hirta*	7.26	0.34
New England Aster	*Symphyotrichum novae-angeliae*	4.36	0.2
Ox-eye Sunflower	*Heliopsis helianthoides*	7.26	0.34
Total		**105.1**	**4.91**

Table 2: Modified Formula N: Species included in Modified Formula N seed mix at Penn State Roadside Project recommended rate of 40 lbs./acre and at a PLS rate of 5.04 lbs./acre.

Common name	**Scientific name**	**Rate lbs.PLS/ac**	**430 PLS/m2 Rate lbs./ac**
Big bluestem	*Andropogon gerardii*	6	0.76
Little bluestem	*Schizachyrium scoparius*	6	0.76
Indiangrass	*Sorghastrum nutans*	6	0.76
Switchgrass	*Panicum virgatum*	2	0.25
Hard fescue	*Festuca longifolia*	5	0.63
Sheep fescue	*Festuca ovina L.*	5	0.63
Creeping red fescue	*Festuca rubra*	5	0.63
Chewing's fescue	*Festuca rubra subsp. commutata*	5	0.63
Total		**40**	**5.04**

Table 3: Formula N: Plant counts were conducted using four permanent sub plot samples per plot that were 2 x 2' in size. All plots were sprayed with Accord XRT II at 64 oz/ac on June 1, 2020. The soil was cultivated with a disc harrow on June 22 and 23, 2020. All plots were broadcast seeded with the specified seed mix shown below and oats at a rate of 30 lbs./acre, fertilized with 10-6-4 at 1 lb. N per 1000 sq. ft., and covered with erosion control straw blankets on June 25, 2020. Four plots were seeded with Formula N at PennDOT's rate of 105.1 lbs./acre and at a PLS rate of 4.91 lbs./acre. Each value is a mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Seed Mix	Seed Rate lbs./ac	Fine fescue Count 9/20	Little Bluestem Count 9/20	Indiangrass Count 9/20	Canada Wildrye Count 9/20	Virginia wildrye Count 9/20	Black-eyed susans Count 9/20	New England aster Count 9/20	Ox-eye Sunflower Count 9/20	Broadleaf Weeds Count 9/20	Grass Weeds Count 9/20	Oats Count 9/20
Formula N- Maint.	105.10	0.44	0.25ab	0.19	0	0	3.38	0	0	7.06	3.38	5.38
Formula N- Maint.	4.91	0.19	0a	0.06	0	0	0.19	0	0	12	3.50	5.88
Formula N- No maint.	105.10	1.88	0.88b	0	0	0	4.13	0	0	14.16	3.81	2.94
Formula N- No maint.	4.91	0.13	0a	0	0	0	0.06	0	0	5.88	3.19	5.38
		n.s.		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Table 4: Modified Formula N: Plant counts were conducted using four permanent sub plot samples per plot that were 2 x 2' in size. All plots were sprayed with Accord XRT II at 64 oz/ac on June 1, 2020. The soil was cultivated with a disc harrow on June 22 and 23, 2020. All plots were broadcast seeded with the specified seed mix shown below and 30 lbs./acre, fertilized with 10-6-4 at 1 lb. N per 1000 sq. ft., and covered with erosion control straw blankets on June 25, 2020. Four plots were seeded with Modified Formula N at a rate of 40 lbs./acre and at a PLS rate of 5.04 lbs./acre. Each value is a mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Seed Mix	Seed Rate lbs./ac	Fine fescue Count 9/20	Big bluestem Count 9/20	Little bluestem Count 9/20	Indiangrass Count 9/20	Switchgrass Count 9/20	Broadleaf Weeds Count 9/20	Grass Weed Count 9/20	Oat Count 9/20
Modified Formula N- Maint.	40.00	0	0.19	0.38	0	0.19	5.94	1.81a	5.19
Modified Formula N- Maint.	5.04	0.13	0	0	0	0.06	7.25	5.81b	4.13
Modified Formula N- No maint.	40.00	0	0.25	0.31	0	0.31	14.81	2.81ab	3.88
Modified Formula N- No maint.	5.04	0.31	0	0	0	0	16.88	4.19ab	2.88
		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.		n.s.

COMPARISON OF FALL VS. SPRING APPLICATION OF COMMONLY USED TANK MIXES TO ACHIEVE SEASON LONG TOTAL VEGETATIVE CONTROL

Herbicide trade and common names: RoundUp Pro Concentrate *(glyphosate)*; Plainview SC *(indaziflam+ aminocyclopyrachlor + imazapyr)*; Method 240SL *(aminocyclopyrachlor)*; Milestone VM *(aminopyralid)*; Esplanade 200 SC *(indaziflam)*; Arsenal Powerline *(imazapyr)*; Plateau *(imazapic)*; Piper *(flumioxazin + pyroxasulfone)*; Payload SC *(flumioxazin)*; Spyder Extra *(sulfometuron + metsulfuron)*

Common and scientific names of most common: wild carrot *(Daucus carota)*; white health aster *(Aster pilosus)*; birdsfoot trefoil *(Lotus corniculatus)*; devils beggartick *(Bidens frondosa)*; common golden rod spp. *(Solidago spp.)*; white sweet clover *(Melilotus alba)*; American burnweed *(Erechtites hieraciifolius)*; witchgrass *(Panicum capillare)*; pineapple-weed *(Matricaria matricaroides)*; tufted lovegrass *(Eragrostis pectinacea)*; foxtail *(Setaria spp.)*; common ragweed *(Ambrosia artemissifolia)*; switchgrass *(Panicum virgatum)*; barnyardgrass *(Echinochloa crus-galli)*; yarrow *(Achillea millefollium)*; kochia *(Kochia scoparia)*

ABSTRACT

Bareground weed control is an essential program within roadside vegetation management which calls for the use of bareground total vegetation control herbicide tank mixes. This experiment evaluated the effects of timing on applications applied in the fall compared to spring applied. Treatments included RoundUp Pro at 64 oz/ac; Plainview SC at 32 oz/ac + RoundUp Pro at 64 oz/ac; Plainview SC at 48 oz/ac + RoundUp Pro at 64 oz/ac; Plainview SC at 64 oz/ac + RoundUp Pro at 64 oz/ac; Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac +Arsenal Powerline at 8 oz/ac + Plateau at 8 oz/ac + RoundUp Pro at 64 oz/ac; Milestone VM at 7oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro at 64 oz/ac; Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac +Arsenal Powerline at 8 oz/ac + RoundUp Pro at 64 oz/ac; Piper at 10 oz/ac + Payload at 3oz/ac + Spyder Extra at 4 oz/ac + RoundUp Pro at 64 oz/ac and an untreated check. By the end of both experiments, plots treated with Plainview SC at 64 oz/ac + RoundUp Pro at 64 oz/ac showed the lowest percent total vegetative cover. The spring application appeared most effective with 0.13% total cover compared to the fall treatment which resulted in 16.38% total cover.

INTRODUCTION

Bareground weed control programs provide season-long weed control along roadsides to allow for proper surface water movement from the roadway, ease of maintenance activities, increased sight distance, and aesthetics[64]. A bareground herbicide mix consists of a broad-spectrum residual, a pre-emergent, and a post emergent that a roadside specialist will choose based on effectiveness, site of action, current label restrictions, cost, and availability[65].

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[64] Jodon, J.C. et al 2020. Evaluation of Plainview SC, Esplanade Sure, Commonly Used Tank Mixes for Total Vegetation Control. Roadside Vegetation Management Research – 2020 Report. pp 58.
[65] Jodon, J.C. et al 2019. Comparison of Plainview SC and Commonly Used Tank Mixes for Season-Long Bareground Control. Roadside Vegetation Management Research – 2019 Report. pp 38-39.

A recently published report on bareground research in Colorado found that fall applied herbicides were effective and lasted throughout the growing season[66]. Herbicide mixes containing aminocyclopyrachlor, a post emergence herbicide with soil residual activity which controls annual and perennial broadleaf weeds, and indaziflam, a preemergence herbicide which controls annual grasses and broadleaf weeds, were among the most effective in Colorado for fall application. Both relatively new products are marketed for their prolonged residual control. These results raise several questions: 1) Would a fall bareground application be more efficient and effective in Pennsylvania versus a traditional spring application? 2) Would this approach benefit PennDOT in better utilization of resources? 3) Would the environment in Pennsylvania of wetter and cooler springs affect the long-term soil persistence of the herbicides? Soil persistence depends on several factors, such as herbicide properties, soil conditions, climatic conditions, and application timing[67]. In our experience an effective bareground herbicide mix for a season long control relies on four to six months of persistence in the soil[68]. To address the above questions and to evaluate the effectiveness of fall versus spring applied bareground mixes along Pennsylvania roadsides, this paper describes a similar experiment using similar bareground mixes in combination with RoundUp Pro[69,70.71]. This experiment was designed to evaluate season long environmental conditions and herbicide half-life on effective management of vegetation. Plainview SC at 64 oz/ac + RoundUp Pro at 64 oz/ac was the best at reducing total vegetative cover compared to the untreated checks at the end of both fall and spring growing seasons, however, more significantly less cover at the end of the spring growing season.

MATERIALS AND METHODS

Two experiments were established along I-99 north bound approximately 2 miles north of the Port Matilda, Pennsylvania as randomized complete designs with four treatment replications. The guiderail site offered a diverse variety of weed species for this experiment. Treatments included RoundUp Pro at 64 oz/ac; Plainview SC at 32 oz/ac + RoundUp Pro at 64 oz/ac; Plainview SC at 48 oz/ac + RoundUp Pro at 64 oz/ac; Plainview SC at 64 oz/ac + RoundUp Pro at 64 oz/ac; Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac +Arsenal Powerline at 8 oz/ac + Plateau at 8 oz/ac + RoundUp Pro at 64 oz/ac; Milestone VM at 7oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro at 64 oz/ac; Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac +Arsenal Powerline at 8 oz/ac + RoundUp Pro at 64 oz/ac; Piper at 10 oz/ac + Payload at 3oz/ac + Spyder Extra at 4 oz/ac + RoundUp Pro at 64 oz/ac and an untreated check. Induce, a nonionic surfactant, was added to all treatments at 0.25% v/v.

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[66] Sebastian, Derek J., Clark, Shannon L., Nissen, Scott J., and Lauer, Dwight K. Total vegetation control: a comprehensive summary of herbicides, application timings, and resistance management options. Weed Technology, 34(2) : 155-163 https:// doi.org/10/1017/wet.2019.94

[67] Jodon, J.C. et al 2019. Comparison of Plainview SC and Commonly Used Tank Mixes for Season-Long Bareground Control. Roadside Vegetation Management Research – 2019 Report. pp 38-39.

[68] Gover, A.E. (1997) Non-selective Weed Control in Non-crop Areas. University Park, PA. : The Pennsylvania State University, Department of Horticulture. 20 p

[69] Furmidge CGL, Osgerby JM (1967) Persistence of herbicides in soil. J Sci Food Agric 18:269–273

[70] Gover AE (1997) Non-selective Weed Control in Non-crop Areas. University Park, PA: The Pennsylvania State University,Department ofHorticulture. 20 p

[71] Jodon, J.C. et al 2020. Evaluation of Plainview SC, Esplanade Sure, Commonly Used Tank Mixes for Total Vegetation Control. Roadside Vegetation Management Research – 2020 Report. pp 58.

Plots were 20-feet by 4-feet in size. Treatments were pre-measured and mixed with fall treatments applied on October 25, 2019, and spring treatments applied on May 21, 2020. Applications were made with a CO_2 powered backpack sprayer equipped with one OC-04 nozzle spraying a four-foot pattern. The treatments were applied at 35 pounds per square inch (PSI) at a rate of 50 gallons per acre (GPA).

Fall Treatment

The weather at the time of application on October 25, 2019, consisted of overcast skies, wind speeds of 5-10 mph, 56% relative humidity, and air temperatures of 54° F. Soil temperatures were 56° F, 55° F, 54° F, and 53° F at 0, 1, 3, and 6- inch depths, respectively. Local rain events occurred on October 27, 31, November 23, and 24, 2019, measuring 1.65", 1.51", .49", and .31" respectively, according to httpp://newa.cornell.edu. The nearest weather station was located at Rock Springs, PA. Annual weeds were killed by frost prior to the fall application.

Treatments were visually rated for percent total vegetative cover on October 24, 2019, May 20, June 24, July 21, and August 20, 2020; 0, 208, 248, 270, and 300 DAT. Treatments were visually rated for percent total grass and broadleaf weed cover on June 24, July 21, and August 20, 2020; 248, 270, and 300 DAT.

Spring Treatment

The weather at the time of application on May 21, 2020, consisted of partly cloudy skies, wind speeds of 5-10 mph, 66% relative humidity, and air temperatures of 75° F. Soil temperatures were 64° F, 64° F, 62° F, and 58° F at 0, 1, 3, and 6- inch depths, respectively. Local rain events occurred on May 22, 28, June 3, 4, and 10, 2020 measuring 0.30", 0.77", 0.61", 1.11", and 1.21" respectively.

Treatments were visually rated for percent total vegetative cover on October 24, 2019, May 20, June 24, July 21, and August 20, 2020, 0, 34, 61, and 91 DAT. Treatments were visually rated for percent total grass and broadleaf weed cover on June 24, July 21, and August 20, 2020, 34, 61, and 91 DAT. A killing frost occurred on September 19, 20, and 21, 2020 ending the growing season for this site.

All data were subjected to analysis of variance, and when treatment effect F-tests were significant ($p \leq 0.05$), treatment means were compared using Tukey's HSD separation test.

RESULTS AND DISCUSSION

Overall Efficacy

In general, spring treatments were more effective in controlling total vegetation along the roadside during the summer growing season than fall treatments (Table 1 and 3). Our results differ from those of the Colorado experiment where the fall application outperformed the same treatments applied in the spring in three of the five sites[72]. One consideration for differences in

[72] Sebastian, Derek J., Clark, Shannon L., Nissen, Scott J., and Lauer, Dwight K. Total vegetation control: a comprehensive summary of herbicides, application timings, and resistance management options. Weed Technology, 34(2) : p 155 https:// doi.org/10/1017/wet.2019.94

results would be the Colorado experiment was established in field soils which differ greatly from those of typical roadside shoulder soils in Pennsylvania. Roadside shoulders are particularly rocky containing a minimum of organic matter whereas a field soil would provide more favorable mineral and organic matter soil conditions. The Colorado Front Range region sites were gravelly alluvium to alluvium, well-drained soils with levels of organic matter ranging from 1.5% to 2%. Soils of that region are sandy, fine-loamy, and mixed by Sebastian et al 2019.

Environmentally the experimental sites also differ in precipitation amount and timing within a year cycle. In general, Colorado has very dry spring and summer seasons which may have led to the spring treatments not being activated as effectively as the fall treatments. In Colorado, the mean annual precipitation based on the 30-year average during the fall and winter months ranged from 361 mm to 3,380 mm at the different sites used in the experiment by Sebastian et al 2019. A wet fall and snow covered, and cold winter may have aided products like Method 240SL in maintaining its activity through the growing season. The half-life of Method 240SL ranges from 114 to 433 days depending on the environmental conditions of the site. While the spring applied treatments may not have been adequately activated. In Pennsylvania, precipitation based on a 30-year average during the fall and spring have been comparable ranging from 255 mm to 258 mm in the fall and 276 mm to 283 mm in the spring which would have been adequate to assure activation in both seasons and the winters are in general as cold which is helpful in maintaining the residual activity through the winter and into the spring[73]. However, the soil types and ability for leaching vary between the Colorado and Pennsylvania test sites and continue to be a possible reason for the differences in overall treatment effectiveness between seasons.

Fall Treatment

Prior to the establishment of the experiment, the percent total vegetative cover rating among the plots were not significantly different (Table 1). By the spring of 2020 (208 DAT, May 20) there was no significant difference in total cover; however, all herbicide treatments produced total cover ratings of less the 12% whereas the untreated control plot had 14.75% cover early in the growing season. Among the treatments there were obvious numerical differences in percent total cover with the Plainview SC at 64 oz/ac + RoundUp Pro at 64oz/ac averaging less than 1% total cover, followed by the tank mix of Method 240SL at 16 oz/acre + Esplanade 200 SC at 6 oz/acre +Arsenal Powerline at 8 oz/acre + Plateau at 8 oz/acre + RoundUp Pro at 64 oz/acre with 1.44 percent cover.

By 248 DAT, vegetative break through was obvious among all treatments. For the products used in this experiment, the half-life ranges varied with indaziflam averaging more than 150 days; aminocyclopyrachlor ranging from 114 to 433 days based on soil type; imazapyr ranging from 25 to 142 days based on soil type and environmental conditions, aminopyralid ranging from 6 to 74 days under field conditions; imazapic averaging 120 days; flumioxazin ranging from 11 to 17 days, pyroxasulfone ranging from 16 to 26 days, sulfometuron ranging from 14 to 75 days depending on climate and soil characteristics, and metsulfuron ranging from 30 to 42 days depending on soil pH, temperature, and moisture[74]. Products with a short half-life

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[73] 2021. State and Regional Analysis, Monthly/Seasonal Climate Summary Tables. Northeast Regional Climate Center. (2021, April 2) https://www.nrcc.cornell.edu/

[74] Herbicide Handbook Weed Science Society of America Tenth Edition, 2014.

created an opportunity for regrowth or germination by this time in early summer because of degradation of their active ingredients. For plots treated with Milestone, Piper, Payload, and Spyder there is a trend in the percent broadleaf weed cover (Table 2) that remained or increased from June to August that was most likely due to the rapid degradation rate of aminopyralid, flumioxazin, pyroxasulfone, and sulfometuron and the lower temperature requirements of metsulfuron particularly with Spyder.

Throughout the rest of the growing season until the last rating at 300 DAT, the Plainview SC at 64 oz/ac + RoundUp Pro at 64 oz/ac remained the most effective treatment with an average rating under 17% total vegetative cover. In general, the expectation of clean bareground guide rails during the most active travel season does not make this set of treatments acceptable for protecting sight lines for traffic safety as a fall treatment.

Spring Treatment

Percent total vegetative cover among the plots showed no statistical difference, ranging from 9.5 to 19.25 (Table 3), prior to application. By June 24, 34 DAT, all herbicide treatments except RoundUp Pro at 64 oz/ac alone, showed a percent cover under 2%, and was significantly different from the untreated check with 42.5% cover. Among the herbicide treatments, Plainview SC at 64 oz/ac + RoundUp Pro at 64 oz/ac showed 0.05% total cover followed by Piper at 10 oz/ac + Payload at 3oz/ac + Spyder Extra at 4 oz/ac + RoundUp Pro at 64 oz/ac with 0.09%; Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac +Arsenal Powerline at 8 oz/ac + Plateau at 8 oz/ac + RoundUp Pro at 64 oz/ac with 0.11%; Plainview SC at 48 oz/ac + RoundUp Pro at 64 oz/ac with 0.15%; Plainview SC at 32 oz/ac + RoundUp Pro at 64 oz/ac with 0.55%; Milestone VM at 7oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro at 64 oz/ac with 1.09%; Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac +Arsenal Powerline at 8 oz/ac + RoundUp Pro at 64 oz/ac with 1.88%; and finally RoundUp Pro at 64 oz/ac with 4.5% total cover.

By July 21, 61 DAT, there was a slight increase in vegetative break through and regrowth among most herbicide treatments averaging 7% cover or less. Among the treatments the tank mix of Plainview SC at 64 oz/ac + RoundUp Pro at 64 oz/ac produced the same rating of 0.05% total cover followed by Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac +Arsenal Powerline at 8 oz/ac + Plateau at 8 oz/ac + RoundUp Pro at 64 oz/ac at 0.1%; Piper at 10 oz/ac + Payload at 3oz/ac + Spyder Extra at 4 oz/ac + RoundUp Pro at 64 oz/acre was close behind with 0.11%; Plainview SC at 48 oz/ac + RoundUp Pro at 64 oz/ac with 0.14% total cover; Plainview SC at 32 oz/ac + RoundUp Pro at 64 oz/ac with 0.71%; Milestone VM at 7oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro at 64 oz/ac with 1.21%; Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac +Arsenal Powerline at 8 oz/ac + RoundUp Pro at 64 oz/ac with 1.63%; and RoundUp Pro at 64 oz/ac with 7% total cover.

By the end of the growing season on August 20, 91 DAT, the most effective treatment was Plainview SC at 64 oz/ac + RoundUp Pro at 64 oz/ac with 0.13% total vegetative cover. Method 240SL at 16 oz/ac plus Esplanade 200 SC at 6 oz/ac plus Arsenal Powerline at 8 oz/ac and Plateau at 8 oz/ac plus Roundup Pro at 64 oz/ac and Piper at 10 oz/ac + Payload at 3oz/ac + Spyder Extra at 4 oz/ac + RoundUp Pro at 64 oz/ac with 0.25% total cover. Also, falling under less than 1% total cover was Plainview SC at 46 oz/ac + RoundUp Pro at 64 oz/ac with 0.46% total vegetative cover.

Among the herbicide tank mixes a numerical but not statistically different level of grass control was observed between the Method 240SL at 16 oz/acre + Esplanade 200 SC at 6 oz/acre +Arsenal Powerline at 8 oz/acre + Roundup Pro at 64 oz/acre treatment and the Method 240SL at 16 oz/acre + Esplanade 200 SC at 6 oz/acre +Arsenal Powerline at 8 oz/acre + Plateau at 8 oz/acre + Roundup Pro at 64 oz/acre treatment (Table 4). The difference between these two herbicide tank mixes was found to occur between 34 and 91 DAT. Grasses were found to germinate readily within the plots treated with the mix that did not contain Plateau. A common concern voiced by roadside vegetation managers has been the reemergence of yellow foxtail in treated areas. Plateau is known as an effective tool in grass control in bareground programs and the lack of it in a bareground tank mix may be one reason for poor yellow foxtail control during the growing season.

Plainview SC at 64 oz/ac + RoundUp Pro at 64 oz/ac showed the lowest percent total vegetative cover with a rating of 0.13% compared to the untreated checks at the end of both fall and spring growing seasons, however, significantly lower at the end of the spring growing season. The spring treatment of Method 240SL at 16 oz/ac plus Esplanade 200 SC at 6 oz/ac plus Arsenal Powerline at 8 oz/ac and Plateau at 8 oz/ac plus Roundup Pro at 64 oz/ac showed better control with a rating of 0.25% total cover compared to the fall treatment of the same tank mix with a rating of 23.25% total cover. The spring treatment of Plainview SC at 48 oz/ac + Roundup Pro at 64 oz/ac rated at 0.46% total cover compared to the fall treatment of Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac +Arsenal Powerline at 8 oz/ac + Roundup Pro at 64 oz/ac showing a rating of 25% total cover. Overall, all the spring applied treatments showed less total vegetative cover than that of the fall applied treatments.

Weed Population Differences

In general, the weeds found along the roadside were similar in the fall and spring. Common weed species identified in the untreated check plots on August 20, 2020, included: wild carrot, white health aster, birdsfoot trefoil, devil's beggartick, common goldenrod spp., white sweetclover, American burnweed, witchgrass, tufted lovegrass, foxtail, common ragweed, barnyard grass, and yarrow. Weed species identified in the fall applied herbicide mix plots included: wild carrot, common ragweed, pineapple-weed, tufted lovegrass, witchgrass, foxtail, and barnyard grass. Most notably among this group of weeds was the presence of Kochia in small amounts with it being identified in at least one plot for all the herbicide treatments. In examining the number of plots containing kochia more plots were found among the spring applied treatments than the same fall applied treatments. Kochia showed a low presence in the spring untreated check plots, however by 91 DAT on August 20th, there was a substantial amount of germination throughout all the spring treatment plots. Treatment plots that included the herbicide tank mixes of Plainview SC at 32 oz/ac + RoundUp Pro at 64 oz/ac, Plainview SC at 48 oz/ac + RoundUp Pro at 64 oz/ac, and Plainview SC at 64 oz/ac + RoundUp Pro at 64 oz/ac showed to have more vegetative cover of Kochia compared to the untreated check plots. Plainview SC, even at the different rates, showed to be less effective than expected at providing control for Kochia due to some known resistance Kochia's genetic population has to imazapyr, aminocyclopyrachlor, and glysophate. In contrast to those results, the herbicide tank mix of

Piper at 10 oz/ac + Payload at 3 oz/ac + Spyder Extra at 4 oz/ac + RoundUp Pro at 64 oz/ac showed a more effective control of vegetation cover of Kochia.

CONCLUSIONS

All spring applied treatments showed better control of vegetative cover than the same fall applied treatments. In both the fall and spring applied treatments, Plainview SC at 64 oz/ac + RoundUp Pro at 64 oz/ac was the most effective. Plainview SC at 64 oz/ac + RoundUp Pro at 64 oz/ac when applied in the fall rated at 23% vegetation cover compared 0.01% in the spring.

MANAGEMENT IMPLICATIONS

None of the herbicide treatments applied in the fall and spring provided complete season long total vegetative control; however, the spring applied treatments were more effective that than the fall treatments. Due to the unfavorable environmental influences and conditions that the fall season presents, based on our results we would not recommend incorporating fall applications into the herbicide rotation program if trying to achieve total vegetative control for bareground sites. The spring applied treatment of Plainview SC at 64 oz/ac and RoundUp Pro at 64 oz/ac was the most effective at 0.13% total vegetative cover by the end of the growing season. Among the other spring applied herbicide mixes, the following produced the best control with less than 1% total vegetative cover being found: Plainview SC at 48 oz/ac + RoundUp Pro at 64 oz/ac; Plainview SC at 64 oz/ac + RoundUp Pro at 64 oz/ac; Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac +Arsenal Powerline at 8 oz/ac + Plateau at 8 oz/ac + RoundUp Pro at 64 oz/ac; and Piper at 10 oz/ac + Payload at 3oz/ac + Spyder Extra at 4 oz/ac + RoundUp Pro at 64 oz/ac.

When applying products containing imazapyr, such as Plainview and Arsenal Powerline, caution must be taken as nearby trees can occasionally be affected by root uptake through movement into the topsoil[75,76]. With root systems sometimes extending into the treated area, caution must also be taken when using products containing aminocyclopyrachlor, such as Method 240SL, to avoid potential root uptake and damage to non-target trees and plants[77].

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[75] Bayer CropScience LP. Plainview SC. Internet March 19, 2021

[76] BASF The Chemical Company. Arsenal Powerline. Internet March 19, 2021

[77] Byer CropScience LP. Method 240 SL. Internet March 19, 2021

Table 1: Fall Total Cover. Effectiveness of Fall applied herbicide treatments based on percent total vegetative cover. The site was visually rated on October 24, 2019, May 20, June 24, July 21, and August 20, 2020, 0, 208, 248, 270, and 300 days after treatment (DAT). Treatments were applied in the Fall, on September 25, 2019. A surfactant, Induce, was added to all treatments at 0.25% v/v. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/acres	% Total Cover 10/24/19 0 DAT	% Total Cover 05/20/20 208 DAT	% Total Cover 06/24/20 248 DAT	% Total Cover 07/21/20 270 DAT	% Total Cover 08/20/20 300 DAT
Untreated	---	27.5	14.75	42.5c	33.25	40
Roundup Pro	64	23.75	10.5	27.5bc	33.25	38.75
Plainview SC Roundup Pro	32 64	25	4.13	16.25abc	23.75	32.5
Plainview SC Roundup Pro	48 64	31.25	8.25	23.75abc	27.5	35
Plainview SC Roundup Pro	64 64	21.25	0.9	8.25a	8.78	16.38
Method 240 SL Esplanade 200 SC Arsenal Powerline Plateau Roundup Pro	16 6 8 8 64	21.25	1.44	11.5ab	11.37	23.25
Milestone VM Esplanade 200 SC Arsenal Powerline Roundup Pro	7 6 8 64	31.25	5.5	17.5abc	23.25	27.5
Method 240 SL Esplanade 200 SC Arsenal Powerline Roundup Pro	16 6 8 64	23.75	7.5	23.75abc	18.75	25
Piper Payload Spyder Extra Roundup Pro	10 3 4 64	30	11.62	40abc	23	27.5
		n.s.	n.s.		n.s.	n.s.

Table 2: Fall Grass and Broadleaf Weed Cover. Effectiveness of fall applied herbicide treatments based on percent grass and broadleaf weed cover. The site was visually rated on October 24, 2019, June 24, July 21, and August 20, 2020, 0, 248, 270, and 300 days after treatment (DAT). Treatments were applied in the Fall, on October 25, 2019. A surfactant, Induce, was added to all treatments at 0.25% v/v. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Fall Treatment	Product	Rates oz/acres	% Grass 06/24/20 248 DAT	% Grass 07/21/20 270 DAT	% Grass 08/20/20 300 DAT	% Broadleaf Weed Cover 06/24/20 248 DAT	% Broadleaf Weed Cover 07/21/20 270 DAT	% Broadleaf Weed Cover 08/20/20 300 DAT
1	Untreated	---	21.5	13.25	22.5	21bc	20bc	17.5ab
2	Roundup Pro	64	17.25	12.75	15.75	22.75c	20.5c	23b
3	Plainview SC Roundup Pro	32 64	10.5	15.75	23.75	11.75abc	8abc	8.75ab
4	Plainview SC Roundup Pro	48 64	12	16.75	24.75	9abc	10.75abc	10.25ab
5	Plainview SC Roundup Pro	64 64	6.25	7.03	13.81	2a	1.75a	2.56a
10	Method 240 SL Esplanade 200 SC Arsenal Powerline Plateau Roundup Pro	16 6 8 8 64	6.75	7.88	16.75	4.75ab	3.5a	6.5ab
12	Milestone VM Esplanade 200 SC Arsenal Powerline Roundup Pro	7 6 8 64	10.5	16.75	20	7abc	6.5abc	7.5ab
14	Method 240 SL Esplanade 200 SC Arsenal Powerline Roundup Pro	16 6 8 64	11.13	14.5	18.25	5.75	4.25ab	6.75ab
16	Piper Payload Spyder Extra Roundup Pro	10 3 4 64	18.5	11.25	11.25	12.13abc	11.75abc	16.25ab
			n.s	n.s.	n.s.			

Table 3: Spring Total Cover. Effectiveness of Spring applied herbicide treatments based on percent total vegetative cover. The site was visually rated on May 20, June 24, July 21, and August 20, 2020, 0, 34, 61, and 91 days after treatment (DAT). Treatments were applied in the Spring, on May 21, 2020. A surfactant, Induce, was added to all treatments at .25% v/v. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/acres	% Total Cover 05/20/20 0 DAT	% Total Cover 06/24/20 34 DAT	% Total Cover 07/21/20 61 DAT	% Total Cover 08/20/20 91 DAT
Untreated	---	14.75	42.5 b	33.25 b	40 b
Roundup Pro	64	10	4.5 a	7 a	16.25 a
Plainview SC Roundup Pro	32 64	12	0.55 a	0.71 a	1.75 a
Plainview SC Roundup Pro	48 64	12.25	0.15 a	0.14 a	0.46 a
Plainview SC Roundup Pro	64 64	19	0.05 a	0.05 a	0.13 a
Method 240 SL Esplanade 200 SC Arsenal Powerline Plateau Roundup Pro	16 6 8 8 64	19.25	0.11 a	0.1 a	0.25 a
Milestone VM Esplanade 200 SC Arsenal Powerline Roundup Pro	7 6 8 64	14	1.09 a	1.21 a	1.96 a
Method 240 SL Esplanade 200 SC Arsenal Powerline Roundup Pro	16 6 8 64	13	1.88 a	1.63 a	3.63 a
Piper Payload Spyder Extra Roundup Pro	10 3 4 64	9.5	0.09 a	0.11 a	0.25 a
		n.s.			

Table 4: Spring Grass and Broadleaf Weed Cover. Effectiveness of Spring applied herbicide treatments based on percent grass and broadleaf weed cover. The site was visually rated on June 24, July 21, and August 20, 2020, 34, 61, and 91 days after treatment (DAT). Treatments were applied in the Spring, on May 21, 2020. A surfactant, Induce, was added to all treatments at 0.25% v/v. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rates oz/acres	% Grass 06/24/20 34 DAT	% Grass 07/21/20 61 DAT	% Grass 08/20/20 91 DAT	% Broadleaf Weed Cover 06/24/20 34 DAT	% Broadleaf Weed Cover 07/21/20 61 DAT	% Broadleaf Weed Cover 08/20/20 91 DAT
Untreated	---	21.5b	13.25 b	22.5 b	21 b	20 b	17.5 b
Roundup Pro	64	1.69 a	1.38 a	3	2.81 a	5.63 a	13.25 b
Plainview SC Roundup Pro	32 64	0.31 a	0.55 a	1	0.24 a	0.17 a	0.75 a
Plainview SC Roundup Pro	48 64	0.1 a	0.05	0.16 a	0.05 a	0.09 a	0.31 a
Plainview SC Roundup Pro	64 64	0.03 a	0.03 a	0.04 a	0.03 a	0.03 a	0.09 a
Method 240 SL Esplanade 200 SC Arsenal Powerline Plateau Roundup Pro	16 6 8 8 64	0.05 a	0.013 a	0.05 a	0.06 a	0.09 a	0.2 a
Milestone VM Esplanade 200 SC Arsenal Powerline Roundup Pro	7 6 8 64	0.44 a	0.275 a	0.51 a	0.65 a	0.94 a	1.45 a
Method 240 SL Esplanade 200 SC Arsenal Powerline Roundup Pro	16 6 8 64	0.81 a	0.94 a	1.69 a	1.06 a	0.69 a	1.94 a
Piper Payload Spyder Extra Roundup Pro	10 3 4 64	0.09 a	0.08 a	0.14 a	0	0.04 a	0.11 a

APPENDIX

Appendix Table 1. Canopy area of honeysuckle (*Lonicera spp.*) and dose amount per plant. The experiment evaluated 7 treatments, with 9 plants per treatment.

Stem	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in)	Area (ft.sq.)	Dose (ml.)
1	4	72	72	72	48	48	209
2	5	60	48	54	40	30	130
3	7	48	48	48	30	20	87
4	2	54	60	57	32	25	110
5	1	42	44	43	36	22	93
6	6	54	48	51	40	28	123
7	3	24	28	26	24	9	38
8	5	36	36	36	26	13	56
9	3	41	40	40.5	28	16	68
10	7	88	84	86	70	84	363
11	1	40	30	35	48	23	101
12	2	55	67	61	48	41	177
13	4	65	55	60	53	44	192
14	6	66	55	60.5	56	47	204
15	6	64	70	67	52	48	210
16	2	68	72	70	84	82	355
17	5	38	36	37	72	37	161
18	7	107	84	95.5	96	127	553
19	1	80	84	82	96	109	475
20	3	77	80	78.5	80	87	379
21	4	56	72	64	96	85	371
22	5	108	110	109	70	106	460
23	2	52	29	40.5	36	20	88
24	7	38	31	34.5	30	14	62
25	6	72	84	78	60	65	282
26	3	72	40	56	48	37	162
27	4	60	60	60	48	40	174
28	1	68	43	55.5	60	46	201
29	6	62	84	73	50	51	220
30	7	57	50	53.5	63	47	203
31	4	72	75	73.5	48	49	213
32	1	110	100	105	80	117	507
33	5	89	94	91.5	66	84	364
34	2	86	50	68	56	53	230
35	3	75	41	58	60	48	210

Appendix Table 1 (continued). Canopy area of honeysuckle (*Lonicera spp.*) and dose amount per plant. The experiment evaluated 7 treatments, with 9 plants per treatment.

Stem	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in)	Area (ft.sq.)	Dose (ml.)
36	4	55	42	48.5	51	34	149
37	7	62	52	57	62	49	213
38	1	50	46	48	52	35	151
39	5	63	62	62.5	58	50	219
40	3	62	80	71	64	63	274
41	6	70	74	72	56	56	243
42	2	53	55	54	50	38	163
43	3	51	51	51	36	26	111
44	6	38	41	39.5	31	17	74
45	1	58	67	62.5	49	43	185
46	5	55	41	48	62	41	180
47	7	72	76	74	66	68	295
48	2	40	33	36.5	51	26	112
49	4	52	66	59	48	39	171
50	7	40	26	33	38	17	76
51	3	94	118	106	80	118	512
52	4	126	106	116	84	135	588
53	5	52	63	57.5	46	37	160
54	2	70	60	65	54	49	212
55	1	90	47	68.5	73	69	302
56	6	49	75	62	66	57	247
57	7	52	37	44.5	54	33	145
58	4	56	55	55.5	36	28	121
59	3	52	69	60.5	65	55	237
60	1	45	56	50.5	46	32	140
61	2	88	47	67.5	62	58	253
62	5	88	80	84	68	79	345
63	6	56	68	62	60	52	224

Appendix Table 2. Canopy area of autumn olive (*Elaeagnus umbellata*) and dose amount per plant. The experiment evaluated 11 treatments, with 10 plants per treatment.

Plant	Treat-ment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft.sq.)	Dose (ml.)
1	8	60	48	54	96	72	219
2	9	60	60	60	96	80	243
3	2	48	48	48	84	56	170
4	1	24	36	30	84	35	106
5	6	24	24	24	60	20	61
6	3	18	18	18	72	18	55
7	7	72	72	72	72	72	219
8	10	84	96	90	72	90	274
9	11	48	36	42	60	35	106
10	4	108	60	84	84	98	298
11	5	60	60	60	72	60	182
12	7	60	36	48	48	32	97
13	4	60	48	54	72	54	164
14	5	48	24	36	60	30	91
15	11	48	48	48	78	52	158
16	6	30	24	27	60	23	68
17	1	36	42	39	60	33	99
18	8	36	60	48	84	56	170
19	3	72	96	84	90	105	319
20	2	84	42	63	60	53	160
21	10	60	54	57	72	57	173
22	9	60	60	60	84	70	213
23	8	48	60	54	72	54	164
24	2	24	24	24	72	24	73
25	11	36	72	54	84	63	192
26	10	30	48	39	84	46	138
27	4	84	96	90	96	120	365
28	9	60	108	84	138	161	490
29	3	72	60	66	72	66	201
30	5	48	60	54	78	59	178

Appendix Table 2 (continued). Canopy area of autumn olive (*Elaeagnus umbellata*) and dose amount per plant. The experiment evaluated 11 treatments, with 10 plants per treatment.

Plant	Treat-ment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft.sq.)	Dose (ml.)
31	6	72	96	84	78	91	277
32	1	24	24	24	96	32	97
33	7	78	104	91	111	140	427
34	7	48	96	72	108	108	328
35	9	36	40	38	38	20	61
36	8	58	36	47	48	31	95
37	5	48	60	54	54	41	123
38	10	40	72	56	80	62	189
39	1	48	96	72	108	108	328
40	6	128	108	118	90	148	449
41	4	48	32	40	60	33	101
42	2	60	60	60	110	92	279
43	11	40	28	34	56	26	80
44	3	30	30	30	40	17	51
45	6	80	72	76	72	76	231
46	11	24	36	30	60	25	76
47	3	40	58	49	77	52	159
48	9	69	36	52.5	65	47	144
49	4	56	36	46	54	35	105
50	10	41	52	46.5	64	41	126
51	5	20	36	28	50	19	59
52	7	48	72	60	44	37	112
53	8	48	50	49	80	54	166
54	1	32	42	37	55	28	86
55	2	48	36	42	96	56	170
56	11	48	42	45	107	67	203
57	2	57	40	48.5	70	47	143
58	9	72	48	60	80	67	203
59	7	75	90	82.5	147	168	512
60	3	60	40	50	86	60	182

Appendix Table 2 (continued). Canopy area of autumn olive (*Elaeagnus umbellata*) and dose amount per plant. The experiment evaluated 11 treatments, with 10 plants per treatment.

Plant	Treat-ment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft.sq.)	Dosage (ml.)
61	10	24	24	24	72	24	73
62	5	30	48	39	72	39	119
63	6	48	48	48	102	68	207
64	1	70	82	76	108	114	347
65	8	48	72	60	74	62	188
66	4	42	36	39	77	42	127
67	6	24	24	24	72	24	73
68	4	36	48	42	60	35	106
69	10	36	48	42	70	41	124
70	2	60	61	60.5	90	76	230
71	11	43	46	44.5	74	46	139
72	1	24	32	28	69	27	82
73	5	30	32	31	49	21	64
74	7	48	48	48	74	49	150
75	8	39	58	48.5	72	49	147
76	3	66	72	69	104	100	303
77	9	40	40	40	67	37	113
78	9	64	47	55.5	64	49	150
79	4	64	36	50	78	54	165
80	5	32	20	26	56	20	61
81	7	32	42	37	52	27	81
82	10	30	36	33	51	23	71
83	1	35	52	43.5	48	29	88
84	11	24	24	24	84	28	85
85	2	46	48	47	48	31	95

Appendix Table 2 (continued). Canopy area of autumn olive (*Elaeagnus umbellata*) and dose amount per plant. The experiment evaluated 11 treatments, with 10 plants per treatment.

Plant	Treat-ment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft.sq.)	Dosage (ml.)
86	8	52	72	62	64	55	168
87	6	42	26	34	39	18	56
88	3	36	30	33	48	22	67
89	2	43	53	48	100	67	203
90	6	112	60	86	100	119	363
91	3	106	78	92	90	115	350
92	11	20	55	37.5	30	16	48
93	4	46	48	47	55	36	109
94	10	40	44	42	44	26	78
95	9	40	48	44	78	48	145
96	8	55	48	51.5	134	96	291
97	7	90	84	87	137	166	503
98	1	56	74	65	77	70	211
99	5	87	90	88.5	78	96	292
100	3	26	30	28	63	25	75
101	1	30	36	33	68	31	95
102	2	83	56	69.5	62	60	182
103	11	56	36	46	50	32	97
104	4	36	54	45	56	35	106
105	5	32	42	37	49	25	77
106	6	54	40	47	53	35	105
107	7	64	42	53	66	49	148
108	10	24	24	24	48	16	49
109	9	92	102	97	74	100	303
110	8	72	54	63	77	67	205

Appendix Table 3. Canopy area of each plant and species. A total of thirteen treatments were evaluated. Each plant is an individual treatment, and each treatment was replicated 10 times. Plant A1 through A10 represents the specimens treated with Alternate TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac on June 8.

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft. sq.)	Dosage (ml.)	Plant ID
1	10	70	48	59	76	62	189	L. maackii
2	5	62	50	56	79	61	187	L. maackii
3	8	48	56	52	72	52	158	L. maackii
4	12	68	72	70	92	89	272	L. maackii
5	11	114	85	99.5	92	127	387	L. maackii
6	7	89	65	77	78	83	254	L. maackii
7	3	72	48	60	86	72	218	L. maackii
8	2	108	77	92.5	84	108	328	L. maackii
9	4	60	75	67.5	82	77	234	L. maackii
10	9	62	48	55	84	64	195	L. maackii
11	6	120	84	102	90	128	388	L. maackii
12	1	90	80	85	89	105	320	L. maackii
13	6	38	44	41	65	37	113	L. maackii
14	4	60	55	57.5	67	54	163	L. maackii
15	9	34	60	47	56	37	111	L. maackii
16	8	55	30	42.5	75	44	135	L. maackii
17	7	43	70	56.5	67	53	160	L. maackii
18	12	148	120	134	96	179	543	L. morrowii
19	3	106	84	95	96	127	385	L. maackii
20	10	84	80	82	88	100	305	L. maackii
21	11	80	40	60	82	68	208	L. maackii
22	5	100	72	86	96	115	349	L. maackii
23	1	108	72	90	114	143	433	L. maackii
24	2	65	94	79.5	72	80	242	L. maackii
25	4	67	40	53.5	100	74	226	L. maackii
26	6	84	64	74	92	95	288	L. maackii
27	2	36	30	33	70	32	98	L. maackii
28	11	53	72	62.5	90	78	238	L. maackii
29	1	69	48	58.5	100	81	247	L. maackii
30	7	72	45	58.5	97	79	240	L. maackii
31	3	42	48	45	77	48	146	L. maackii
32	5	64	52	58	66	53	162	L. maackii
33	10	96	80	88	94	115	349	L. morrowii

Appendix Table 3 (continued). Canopy area of each plant and species. A total of thirteen treatments were evaluated. Each plant is an individual treatment, and each treatment was replicated 10 times.

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft. sq.)	Dosage (ml.)	Plant ID
34	8	72	60	66	65	60	181	L. maackii
35	12	70	70	70	84	82	248	L. maackii
36	9	66	48	57	55	44	132	L. maackii
37	12	120	104	112	104	162	492	L. maackii
38	2	45	57	51	62	44	134	L. maackii
39	3	68	44	56	55	43	130	L. maackii
40	10	59	48	53.5	87	65	197	L. maackii
41	8	48	48	48	90	60	182	L. maackii
42	9	54	72	63	90	79	239	L. maackii
43	1	44	48	46	71	45	138	L. maackii
44	6	40	32	36	79	40	120	L. maackii
45	5	48	33	40.5	82	46	140	L. maackii
46	7	96	72	84	86	100	305	L. maackii
47	4	80	60	70	84	82	248	L. maackii
48	11	64	40	52	58	42	127	L. maackii
49	8	32	22	27	36	14	41	L. maackii
50	2	30	27	28.5	56	22	67	L. maackii
51	7	66	80	73	80	81	247	L. maackii
52	1	101	70	85.5	85	101	307	L. maackii
53	10	60	46	53	52	38	116	L. maackii
54	3	76	57	66.5	92	85	258	L. maackii
55	9	84	54	69	88	84	256	L. maackii
56	12	80	86	83	98	113	344	L. maackii
57	4	39	27	33	70	32	98	L. maackii
58	6	55	34	44.5	60	37	113	L. maackii
59	11	66	60	63	63	55	168	L. maackii
60	5	46	39	42.5	61	36	110	L. maackii
61	10	50	55	52.5	70	51	155	L. maackii
62	12	35	20	27.5	27	10	31	L. maackii
63	8	34	27	30.5	22	9	28	L. maackii
64	6	58	41	49.5	70	48	146	L. maackii
65	7	54	58	56	88	68	208	L. maackii
66	2	25	27	26	22	8	24	L. maackii
67	5	84	55	69.5	66	64	194	L. maackii
68	4	41	34	37.5	70	36	111	L. maackii

Appendix Table 3 (continued). Canopy area of each plant and species. A total of thirteen treatments were evaluated. Each plant is an individual treatment, and each treatment was replicated 10 times.

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft. sq.)	Dosage (ml.)	Plant ID
69	9	45	60	52.5	75	55	166	L. maackii
70	1	32	22	27	34	13	39	L. maackii
71	3	36	36	36	56	28	85	L. maackii
72	11	54	52	53	80	59	179	L. maackii
73	9	75	101	88	104	127	387	L. maackii
74	1	63	56	59.5	70	58	176	L. maackii
75	11	84	65	74.5	85	88	267	L. maackii
76	3	53	40	46.5	65	42	128	L. maackii
77	8	50	35	42.5	82	48	147	L. maackii
78	6	52	38	45	82	51	156	L. maackii
79	5	60	43	51.5	58	41	126	L. maackii
80	10	63	58	60.5	73	61	187	L. maackii
81	7	51	59	55	87	66	202	L. maackii
82	4	101	45	73	113	115	348	L. maackii
83	12	63	47	55	65	50	151	L. maackii
84	2	76	60	68	76	72	218	L. maackii
85	3	57	50	53.5	80	59	181	L. maackii
86	4	54	60	57	74	59	178	L. maackii
87	7	72	92	82	75	85	260	L. maackii
88	9	64	42	53	70	52	157	L. maackii
89	6	48	60	54	90	68	205	L. maackii
90	1	80	65	72.5	87	88	266	L. maackii
91	8	33	46	39.5	80	44	133	L. maackii
92	5	56	40	48	65	43	132	L. maackii
93	10	48	60	54	58	44	132	L. maackii
94	2	64	30	47	76	50	151	L. maackii
95	12	60	54	57	76	60	183	L. maackii
96	11	44	36	40	54	30	91	L. maackii
97	4	49	55	52	65	47	143	L. maackii
98	1	44	57	50.5	77	54	164	L. maackii
99	6	44	37	40.5	70	39	120	L. maackii
100	12	66	53	59.5	80	66	201	L. maackii
101	7	49	44	46.5	67	43	132	L. maackii
102	2	25	24	24.5	69	23	71	L. maackii
103	10	84	77	80.5	94	105	320	L. maackii

Appendix Table 3 (continued). Canopy area of each plant and species. A total of thirteen treatments were evaluated. Each plant is an individual treatment, and each treatment was replicated 10 times. Plant A1 through A10 represents the specimens treated with Alternate TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac on June 8.

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft. sq.)	Dosage (ml.)	Plant ID
104	8	84	52	68	70	66	201	L. maackii
105	3	35	38	36.5	74	38	114	L. maackii
106	9	48	72	60	90	75	228	L. maackii
107	11	60	65	62.5	78	68	206	L. maackii
108	5	50	48	49	75	51	155	L. maackii
109	6	108	74	91	92	116	354	L. maackii
110	9	80	71	75.5	103	108	328	L. maackii
111	1	60	84	72	90	90	274	L. maackii
112	4	34	55	44.5	70	43	132	L. maackii
113	8	42	72	57	84	67	202	L. maackii
114	2	60	80	70	100	97	296	L. maackii
115	12	36	42	39	52	28	86	L. maackii
116	10	36	68	52	84	61	184	L. maackii
117	11	46	64	55	86	66	200	L. maackii
118	5	42	44	43	68	41	124	L. maackii
119	7	36	24	30	46	19	58	L. maackii
120	3	56	40	48	59	39	120	L. maackii
A1	10	130	65	97.5	125	169	515	L. maackii
A2	10	46	72	59	70	57	174	L. maackii
A3	10	60	45	52.5	72	53	160	L. maackii
A4	10	16	38	27	46	17	52	L. maackii
A5	10	84	45	64.5	66	59	180	L. maackii
A6	10	67	80	73.5	87	89	270	L. maackii
A7	10	48	72	60	68	57	172	L. maackii
A8	10	27	36	31.5	62	27	82	L. maackii
A9	10	100	90	95	140	185	562	L. maackii
A10	10	72	48	60	80	67	203	L. maackii

Appendix Table 4. Canopy area of each plant and species. A total of four treatments were evaluated. Each plant is an individual treatment, and each treatment was replicated 10 times.

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft. sq.)	Dosage (ml.)	Plant ID
1	1	74	72	73	124	126	382	L. maackii
2	2	83	98	90.5	130	163	497	L. maackii
3	4	51	71	61	71	60	183	L. maackii
4	3	71	73	72	94	94	286	L. maackii
5	4	48	73	60.5	95	80	243	L. maackii
6	1	89	65	77	118	126	384	L. maackii
7	2	78	62	70	94	91	278	L. maackii
8	3	89	70	79.5	98	108	329	L. maackii
9	3	73	56	64.5	83	74	226	L. maackii
10	4	52	58	55	66	50	153	L. maackii
11	1	47	46	46.5	71	46	139	L. maackii
12	2	116	114	115	121	193	588	L. maackii
13	4	164	114	139	143	276	840	L. maackii
14	1	95	130	112.5	160	250	760	L. maackii
15	2	85	81	83	89	103	312	L. maackii
16	3	91	106	98.5	105	144	437	L. maackii
17	2	47	55	51	95	67	205	L. maackii
18	4	58	98	78	89	96	293	L. maackii
19	3	68	38	53	83	61	186	L. maackii
20	1	57	71	64	95	84	257	L. maackii
21	2	35	70	52.5	114	83	253	L. maackii
22	3	78	40	59	88	72	219	L. maackii
23	4	54	43	48.5	71	48	145	L. maackii
24	1	75	49	62	109	94	285	L. maackii
25	1	73	50	61.5	62	53	161	L. maackii
26	2	27	94	60.5	110	92	281	L. maackii
27	4	73	93	83	121	139	424	L. maackii
28	3	121	73	97	98	132	402	L. maackii
29	1	131	55	93	93	120	365	L. maackii
30	4	68	99	83.5	104	121	367	L. maackii
31	3	55	47	51	85	60	183	L. maackii
32	2	56	62	59	76	62	189	L. maackii
33	3	67	65	66	109	100	304	L. maackii
34	1	54	73	63.5	98	86	263	L. maackii

Appendix Table 4 (continued). Canopy area of each plant and species. A total of four treatments were evaluated. Each plant is an individual treatment, and each treatment was replicated 10 times.

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft. sq.)	Dosage (ml.)	Plant ID
35	2	94	67	80.5	90	101	306	L. maackii
36	4	62	58	60	81	68	205	L. maackii
37	4	75	80	77.5	72	78	236	L. maackii
38	1	52	70	61	86	73	222	L. maackii
39	2	47	49	48	60	40	122	L. maackii
40	3	89	61	75	88	92	279	L. maackii