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Roadside Vegetation Management Research – 2020 Report

ANNUAL REPORT

June 30, 2020

By Jeffrey C. Jodon, Elizabeth Egan, Joe Plummer, David A. Despot, and James C. Sellmer

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 Control Herbicides on Control of Exotic Shrub Honeysuckle-2nd Year, Evaluation of Brush Control Herbicides on Control of Autumn Olive *(Elaeagnus umbellata)*-First Year Results, Evaluation of Esplanade 200 SC Application on Tall Fescue, Kentucky Bluegrass, and Fine Fescue, Evaluation of Telar XP, Segment, and Assure II for Tall Fescue Control and Safety on Fine Fescues, Conversion of Existing Roadside Turf to a Low Growing Fine Fescue Groundcover Around Cable Guiderails-Second Year Results, Low Maintenance Turfgrass Species and Cultivar Comparison to Kentucky-31 Tall Fescue-Second Year, Evaluation of Flumioxazin + Pyroxasulfone Alone and Combinations to Other Total Vegetation Control Mixes for Season-Long Total Vegetation Control, Evaluation of Plainview SC, Esplanade Sure, and Commonly Used Tank Mixes for Total Vegetation Control.		
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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

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.

Trade Name	Active Ingredients	Formulation	Manufacturer
Assure II	quizalofop-Q	0.88 S	DuPont
CleanTraxx	penoxsulam + oxyfluorfen	0.83 + 3.93 S	Dow AgroSciences LLC
DMA 4 IVM	2,4-D	3.8 S	Dow AgroSciences LLC
Depth Charge	flumioxazin + 2,4-D	0.26 + 4 L	NuFarm Inc.
Escort XP	metsulfuron methyl	60 DF	Bayer Environmental Science
Esplanade 200 SC	indaziflam	1.67 SC	Bayer Environmental Science
Esplanade EZ	indazflam+diquat+glyphosate	0.089+0.89+20.46S	Bayer Environmental Science
Esplanade Sure	indazflam + rimsulfuron	24.3 + 16.7 WDG	Bayer Environmental Science
Freelexx	2,4-D choline	3.8 S	Dow AgroSciences LLC
Garlon 3A	triclopyr amine	3 S	Dow AgroSciences LLC
Krovar I DF	bromacil + diuron	40 + 40 DG	Bayer Environmental Science
MSM 60	metsulfuron methyl	60 DF	Alligare LLC
Method 240SL	aminocyclopyrachlor	2 SL	Bayer Environmental Science
Milestone VM	aminopyralid	2 S	Dow AgroSciences LLC
NuFarm Imazapic	imazapic	2 SL	NuFarm Inc.
Oust XP	sulfmeturon	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
Polaris	imazapyr	2 S	NuFarm Inc.
Razor Xtreme	glyphosate	5.83 S	NuFarm Inc.
Roundup Pro	glyphosate	4 S	Monsanto Company
Roundup Pro Concentrate	glyphosate	5 S	Monsanto Company
Segment	sethoxydim	1 S	BASF Corp.
Spyder Extra	sulfometuron + metsulfuron	56.25 + 15 DG	NuFarm Inc.
Telar XP	chlorsulfuron	75 DF	Bayer Environmental Science
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 CONTROL HERBICIDES ON CONTROL OF EXOTIC SHRUB HONEYSUCKLE-2ND 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. After the first growing season, RoundUp Pro at 128 oz/ac, DMA 4 IVM at 128 oz/ac, and Garlon 3A at 384 oz/ac provided a minimum of 99% injury of honeysuckle. By 366 DAT (days after treatment), the most effective treatments based on percent control of honeysuckle 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 showed 72.78 and 78.33 percent control of honeysuckle, respectively. The untreated check continued to show signs of damage with 22.89 percent control of honeysuckle. Further data collection will determine the long-term effectiveness of the herbicide treatments.

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 until deemed invasive. Even though the native shrub honeysuckle species were higher in nutritional value than the exotics[1]. The exotic shrub honeysuckle species were further spread by birds feeding on the berries and depositing the seed, which remains viable for several years. One key identification characteristic used to separate native and non-native shrub honeysuckle species is that the native species pith is solid, whereas, the pith of non-native honeysuckle is hollow. 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 to determine the area of each plant. The herbicide application amounts were based on calculated canopy area. 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, September 11, 2018, and July 10, 2019; 30, 64, and 366 days after treatment (DAT), respectively (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. The least effective treatment was Garlon 3A at 64 oz/ac. The most effective treatment was RoundUp Pro at 128 oz/ac. In comparison, the untreated check increased to 29.44 percent injury at 64 DAT. Suggesting that the wet conditions during the summer of 2018 was also promoting foliar disease among the brush honeysuckle to a minor extent. To verify the presence of a leaf disease among the control plants a leaf sample was collected and submitted to the Penn State Plant Disease Clinic. The clinic identified that the sample contained Alternaria which can cause leaf spot on honeysuckle. By 366 DAT, the most effective treatments based on percent control of honeysuckle 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 showed 72.78 and 78.33 percent control of honeysuckle, respectively. The untreated check continued to show signs of damage with 22.89 percent control of honeysuckle.

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 were effective treatments one year after treatment. Increasing the rate of Garlon 3A will increase control of honeysuckle. DMA 4 IVM at 128 oz/ac was similarly effective as Garlon 3A at 64 oz/ac + DMA 4 IVM at 128 oz/ac. The addition of Garlon3A at 64 oz/ac to DMA 4 IVM at 128 oz/ac did not increase control of honeysuckle. Further data collection will determine the long-term effectiveness of the treatments to control the shrub honeysuckle and prevent resprouting.

MANGEMENT IMPLICATIONS

Herbicide treatments of 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 provided 95 percent or greater honeysuckle control one year after treatments were applied. Garlon 3A and DMA 4 IVM are grass safe broadleaf herbicides. The most effective treatment, RoundUp Pro at 128 oz/ac, showed 100 percent control. 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 control of honeysuckle (Lonicera spp.). The experiment was visually rated for percent injury on August 8, 2018, (30 days after treatment, DAT) and September 11, 2018, (64 DAT) and percent control on July 10, 2019 (366 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	% Control 7/10/19 366 DAT
Untreated	---	5.56 a	29.44 a	22.89 a
DMA 4 IVM	128	91.78 bc	99.78 b	95.22 b
RoundUp Pro	128	99.33 c	99.89 b	100 b
Garlon 3A	64	63.78 b	86.67 b	72.78 b
Garlon 3A	128	75.33 bc	93.67 b	78.33 b
Garlon 3A	384	97.33 c	99 b	95.56 b
Garlon 3A DMA 4 IVM	64 128	87 bc	98.78 b	95 b

EVALUATION OF BRUSH CONTROL HERBICIDES ON CONTROL OF AUTUMN OLIVE *(ELAEAGNUS UMBELLATA),* FIRST YEAR RESULTS

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

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

ABSTRACT

Autumn olive is identified as an invasive plant in Pennsylvania and has proven to be difficult to control through mowing and cutting activities without the use of brush control herbicides. An experiment was conducted at the Penn State Agronomy Farm located at the Russell E. Larson Agricultural Research Center near Rock Springs, PA to compare numerous brush herbicides for control of autumn olive. In a continuing effort to find effective brush control mixes, this experiment evaluated ten herbicide treatments including Freelexx at increasing rates of 96 oz/ac and 128 oz/ac, Freelexx at 96 oz/ac tank mixed with Method 240 SL 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 240 SL at 16 oz/ac, MSM 60 at 0.5 oz/ac, Garlon 3A at increasing rates of 64 oz/ac, 128 oz/ac, and 384 oz/ac, and Vanquish at 64 oz/ac. At 19 days after treatment, Freelexx at 96 oz/ac, Freelexx at 96 oz/ac tank mixed with Method 240 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 234 days after treatment, MSM 60 at 0.5 oz/ac had the best control of autumn olive at 100% while Vanquish resulted in 99.7% control.

INTRODUCTION

Autumn olive (*Elaeagnus umbellata*) is a problematic brush species on roadsides. Elaeagnus is a nitrogen fixing small tree or shrub species which aids its establishment and growth in poor soil conditions found along the roadside.[4] Plants can reach 11 feet in height and fruit prolifically with birds dispersing the seeds beyond the immediate area. After mowing or cutting autumn olive vigorously resprouts, spreading and crowding out desirable vegetation reducing visibility for motorists and impeding maintenance operations. All these characteristics have earned autumn olive the designation of an invasive plant species in Pennsylvania.[5]

The following experiment evaluated the effectiveness of Freelexx, Method 240 SL, MSM 60, Garlon 3A, Vanquish, a mix of Freelexx plus Method 240 and MSM 60, and a mix of Freelexx plus Garlon 3A and MSM 60 when applied to the entire autumn olive shrub.

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[4] Dave Despot et al 2018. Comparison of Aminocyclopyrachlor, aminopyralid, and two formulations of triclopyr for control of autumn olive *(Elaeagnus umbellate)* using low volume foliar treatments. Roadside Vegetation Management Research – 2018 Report. pp 1.

[5] http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/dcnr_010230.pdf Invasive Plants in Pennsylvania Russian and Autumn Olive Viewed April 20, 2020.

MATERIALS AND METHODS

The experiment was established at the Penn State Agronomy Farm at the Russell E. Larson Agricultural Research Center. The herbicide treatments included Freelexx at 96 oz/ac and 128 oz/ac; Freelexx at 96 oz/ac + Method 240 SL 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 240 SL 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. 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. The application was made at a carrier volume of 35 gallons per acre (GPA). The experiment was established as a complete randomized design with eleven plants per treatment. Individual shrubs were measured, the average width was multiplied by the height which was then multiplied by 2 in order to capture the whole plant as a three-dimensional object, to determine the canopy area of each plant (Table 1). The herbicide application amounts were based on calculated canopy area. Treatments were applied using a CO_2-powered sprayer equipped with a handgun and one PPX 6 nozzle at 35 psi. The autumn olive was treated on September 14, 2019.

Treatments were visually rated for percent injury where 0 = no injury–100 = complete injury on October 3, 2019, 19 days after treatment (DAT) and for percent control where 0 = no control–100 = complete control on May 5, 2020, 234 DAT, respectively. 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

MSM 60 at 0.5 oz/ac appeared to produce less injury (4%) than the injury found on untreated plants (6.5%). These ratings were not significantly different (Table 2). Single treatments of Freelexx at 128 oz/ac, Garlon 3A at 128 oz/ac and Method 240 SL at 16 oz/ac resulted in injury ratings of 80.6%, 81.4%, and 89.2%, respectively. Vanquish at a rate of 64 oz/ac; Freelexx at 96 oz/ac tank mixed with Garlon 3A at 64 oz/ac and MSM 60 at 0.5 oz/ac; and Garlon 3A at 384 oz/ac showed similar injury ratings of 96.4%, 96.8%, and 97.3%, respectively. Freelexx at 96 oz/ac; Freelexx at 96 oz/ac tank mixed with Method 240 SL at 16 oz/ac and MSM 60 at 0.5 oz/ac resulted in the some of the highest injury at 99.2% and 99.6%, respectively. While Garlon 3A at 64 oz/ac appeared to be the most effective at 99.7% injury at 19 DAT, it produced a lower percent control than Method 240 SL at 234 DAT. In previous trials, Garlon produced slightly greater injury compared to Method 240SL. Similarly, second year results for Garlon 3A at 128 oz/ac resulted in less than 50% control.[1] The carrier rate used for all treatments in the previous experiment[1] was 15 gallons /acre, a low volume application, and may not have produced adequate coverage when applied. To assure adequate coverage the carrier rate in this experiment was increased to the more common rate of 35 gallons/acre. While there is a difference between the Garlon 3A carrier volumes between this experiment and previous trials, the early stage injury results were similar. Due to frost damage, a standard one month after treatment injury rating was not conducted.

By 234 DAT, MSM 60 at 0.5 oz/ac resulted in 100% control followed by Vanquish (64 oz/ac) at 99.7% and Method 240 SL (16 oz/ac) at 96.9%. Freelexx at 96 oz/ac showed greater control (91.7%) than Freelexx at 128 oz/ac (71.11). Percent control of Freelexx at 96 oz/ac tank mixed with Method 240 SL 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, and Garlon 3A at increasing rates of 64 oz/ac, 128 oz/ac, and 384 oz/ac., ranged from 82.89% - 91.3%. There was only a slight increase in control with increasing concentrations of Garlon 3A.

CONCLUSIONS

By October 3, 2019, 19 DAT, percent injury of the herbicide treatments ranged from 4% to 99.7%. Most of the herbicides tested, except for MSM 60, had similar levels of injury. 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 best control of autumn olive at 100% followed by Vanquish at 99.7% control. The least effective treatment was Freelexx at 128 oz/ac resulting in 71.11% control. With the exception of MSM 60, all remaining treatments showed signs of resprouting from dormant buds at 234 days after treatment. The delayed response to MSM 60 between 19 DAT and 234 DAT deserves further evaluation. Data collection into year two will determine whether the MSM 60 has long-term control potential.

MANAGEMENT IMPLICATIONS

All herbicide treatments showed significant injury to autumn olive except MSM 60. However, by 234 DAT, MSM 60 showed 100% control, while the other herbicide treatments showed resprouts from dormant buds. One and two year after treatment data collection and analysis will determine further recommendations for autumn olive control.

Table 1. Canopy area and height of plant. Each plant is an individual treatment for a total of 11 treatments. Each treatment was replicated 10 times.

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft. sq.)	Dosage (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

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft. sq.)	Dosage (ml.)
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
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

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft. sq.)	Dosage (ml.)
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
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

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft. sq.)	Dosage (ml.)
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
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

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft. sq.)	Dosage (ml.)
108	10	24	24	24	48	16	49
109	9	92	102	97	74	100	303
110	8	72	54	63	77	67	205

Table 2. Percent injury and percent control of autumn olive (*Elaeagnus umbellata*). The experiment was visually rated for percent injury on October 3, 2019, (19 days after treatment, DAT) and percent control on May 5, 2020, (234 DAT). Treatments were applied September 14, 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 $p \leq 0.05$.

Treatment	**Rate (oz/ac)**	**% Injury 10/3/19 19 DAT**	**% Control 05/05/20 234 DAT**
Untreated	--	6.5 a	11 a
Freelexx Method 240SL MSM 60	96 16 0.5	99.6 b	97.22 b
Freelexx Garlon 3A MSM 60	96 64 0.5	96.8 b	82.8 b
Method 240SL	16	81.4 b	96.9 b
Garlon 3A	64	99.7 b	87.4 b
Garlon 3A	128	89.2 b	82.89 b
Garlon 3A	384	97.03 b	91.3 b
Freelexx	96	99.2 b	91.7 b
Freelexx	128	80.6 b	71.11 b
Vanquish	64	96.4 b	99.7 b
MSM 60	0.5	4 a	100 b

EVALUATION OF ESPLANADE 200 SC APPLICATIONS ON TALL FESCUE, KENTUCKY BLUEGRASS, AND FINE FESCUE

Herbicide trade and common names: Esplanade 200 SC (*indaziflam*), Method 240SL (*aminocyclopyrachlor*)

Plant common and scientific names: tall fescue *(Festuca arundinacea),* Kentucky bluegrass *(Poa pratensis),* hard fescue *(Festuca brevipilia),* bromegrass *(Bromus spp.)*, bentgrass *(Agrostis spp.)*, foxtail *(Setaria spp.)*

ABSTRACT

An experiment was conducted to evaluate the effect of Esplanade 200 SC alone and in combination with Method 240SL applied to a roadside turf setting consisting of tall fescue and Kentucky bluegrass turf and a low maintenance lawn site of fine fescue. Treatments included: Esplanade 200 SC at 3.5 oz/ac, Esplanade 200 SC at 5 oz/ac, Esplanade 200 SC at 3.5 oz/ac + Method 240SL at 8 oz/ac + Induce at 0.25% v/v, Esplanade 200 SC at 5 oz/ac + Method 240SL at 8 oz/ac + Induce at 0.25% v/v. A fall application and spring application were applied to 10 by 6-foot plots arranged in a randomized complete block design with 4 replications. All data were subject to analysis of variance, and when treatment effects were significant ($p \leq 0.05$) treatment means were compared using Tukey's HSD separation test. Esplanade 200 SC at 3.5 oz/ac, Esplanade 200 SC at 5 oz/ac, Esplanade 200 SC at 3.5 oz/ac + Method 240SL at 8 oz/ac, and Esplanade 200 SC at 5 oz/ac + Method 240SL at 8 oz/ac significantly reduced fine fescue cover during both fall and spring treatments when compared to the untreated check. Results from these treatments demonstrated that applications of Esplanade 200 SC at 3.5 oz/ac, Esplanade 200 SC at 3.5 oz/ac + Method 240SL at 8 oz/ac, Esplanade 200 SC at 5 oz/ac and Esplanade 200 SC at 5 oz/ac + Method 240SL at 8 oz/ac significantly decreased fine fescue cover, slightly reduced tall fescue cover; however regrowth was observed, and reduced Kentucky bluegrass cover.

INTRODUCTION

Maintenance activities under cable guiderail may include mowing or herbicide applications. One possible maintenance strategy is the use of plant growth regulator's (PGR) in combination with a broadleaf weed herbicide to inhibit seedhead formation and control broadleaf weeds. Over the years sites treated with PGRs plus broadleaf weed herbicides have at times resulted in several summer annual grass weeds (i.e., yellow foxtail) filling in voids left by the herbicide treatments. Speculation on possible pre-emergence herbicides to prevent summer annual grass weed release in combination with cable guiderail treatments led to discussions on the suitability of Esplanade 200 SC. This experiment was conducted to evaluate the safety of various rates of Esplanade 200 SC alone and in combination with Method 240SL applied over two different stands of turf. One site was a roadside mixed stand of tall fescue and Kentucky bluegrass and the other site was a low maintenance stand of fine fescue.

MATERIALS AND METHODS

An experiment was conducted to evaluate the effect of Esplanade 200 SC alone and in combination with Method 240SL. The tall fescue and Kentucky bluegrass site was located in roadside median along a cable guiderail system near the Grazierville exit off I-99 in central Pennsylvania. The stand consisted predominantly of tall fescue, Kentucky bluegrass, with other minor species present including bromegrass, bentgrass, and fine fescue. The fine fescue site was located at the Penn State Russell E. Larson Agricultural Research Center, Horticulture Farm in Rock Springs, PA with hard fescue as the main component. Treatments included: Esplanade 200 SC at 3.5 oz/ac, Esplanade 200 SC at 5 oz/ac, Esplanade 200 SC at 3.5 oz/ac + Method 240SL at 8 oz/ac + Induce at 0.25% v/v, Esplanade 200 SC at 5 oz/ac + Method 240SL at 8 oz/ac + Induce at 0.25% v/v. Fall and spring treatments were applied to 10 by 6 foot plots arranged in a randomized complete block design with 4 replications. All data were subject to analysis of variance, and when treatment effects were significant ($p \leq 0.05$) treatment means were compared using Tukey's HSD separation test.

Fine Fescue Experiment

The fall application occurred November 12, 2018 with an air temperature of 43° F, wind speed of 5-10 MPH, relative humidity of 79%, and soil temperature at 0, 1, 3, and 6-inch depth of 42°F, 43°F, 40°F, and 39°F, respectively. Treatments were applied with a CO_2 powered backpack sprayer, 6-foot boom with 4 8004 VS nozzles at 35 PSI. From the nearest weather station located in Rock Springs, PA, rainfall after application was recorded on November 12, November 13, and November 17 in amounts of 0.12", 0.43", and 0.50", respectively. Percent fine fescue cover was recorded on November 12, 2018, April 18, April 26, May 3, May 9, May 22, and October 3, 2019.

The spring application occurred April 16, 2019 with an air temperature of 52°F, air speed of 5-10 MPH, relative humidity of 37%, soil temperatures at 0, 1, 3, and 6-inch at 56°F, 50°F, 48°F, and 44°F, respectively. Treatments were applied with a CO_2 powered backpack sprayer, 6-foot boom with 4 8004 VS nozzles at 33 PSI. Rainfall after application occurred on April 17 and April 19 in amounts of 0.14", and 1.06" respectively. Percent fine fescue cover was recorded on November 12, 2018, April 18, April 26, May 3, May 9, May 22, June 3, June 24, & October 3, 2019.

Tall Fescue & Kentucky Bluegrass Experiment

The fall application to tall fescue and Kentucky bluegrass was applied November 12, 2018 with an air temperature of 44° F, air speed of 5-10 MPH, relative humidity of 40% , and soil temperature at 0, 1, 3, and 6-inch depth at 42°F, 43°F, 40°F, and 39°F, respectively. Treatments were applied with a CO_2 powered backpack sprayer, 6-foot boom with 4 8004 VS nozzles at 35 PSI. From the nearest weather station located at Rock Springs, PA, rainfall after application occurred on November 12, November 13, and November 17 in amounts of 0.12", 0.43", and 0.50", respectively. Percent total turfgrass cover, percent tall fescue cover, and percent Kentucky bluegrass cover were recorded November 12, 2018; April 16, April 24, May 3, May 9, May 22, & October 8, 2019.

The spring application was applied April 16, 2019 with an air temperature of 63°F, air speed of 5-10 MPH, relative humidity of 26%, and soil temperatures at 0, 1, 3, and 6-inch of 60°F, 58°F, 52°F, and 49°F, respectively. Treatments were applied with a CO_2 powered backpack sprayer, 6-foot boom with 4 8004 VS nozzles at 33 PSI. Rainfall after application occurred on April 17 and April 19 in amounts of 0.14" and 1.06", respectively. Percent total turfgrass cover, percent tall fescue cover, and percent Kentucky bluegrass cover were recorded November 12, 2018; April 16, April 24, May 3, May 9, May 22, June 3, June 24, & October 8, 2019.

RESULTS AND DISCUSSION

Fine Fescue Experiment

For the fall treatment there was no statistical difference in percent fine fescue cover between plots at the onset of the experiment (Table 1). On April 18, 157 days after treatment (DAT), significant damage to fine fescue was observed with treatments of Esplanade 200 SC alone and in combination with Method 240SL when compared to the untreated plots. Percent fine fescue cover ranged from 2.5 to 10.13 for treated plots, while the untreated check was 33.25. The trend continued through the rating of the fall application on May 22, 191 DAT. Plots treated with Esplanade 200 SC at 3.5 oz/ac averaged 6.88% fine fescue cover and Esplanade 200 SC at 5 oz/ac averaged 2.25% fine fescue cover. Esplanade 200 SC at 3.5 oz/ac + Method 240SL at 8 oz/ac averaged 12.5% fine fescue cover and Esplanade 200 SC at 5 oz/ac + Method 240SL at 8 oz/ac averaged 4.75% fine fescue cover. The untreated check averaged 57% fine fescue cover. The last rating occurred on October 3, 2019. The untreated check averaged 67.5% fine fescue cover while plots treated with Esplanade 200 SC at 3.5 oz/ac averaged 5.5% fine fescue cover and Esplanade 200 SC at 5 oz/ac averaged 3% fine fescue cover. Esplanade 200 SC at 3.5 oz/ac + Method 240SL at 8 oz/ac averaged 2.75% fine fescue cover and Esplanade 200 SC at 5 oz/ac + Method 240SL at 8 oz/ac averaged 0.25% fine fescue cover.

For the spring treatments there was no statistical difference in percent fine fescue cover between plots at the prior to the experiment, November 18, 2018, and at the time of application on April 16, 2019 (Table 2). Due to timing the treatment day rating was done two days after treatment on April 18. No visual difference in fine fescue cover or discoloration was observed between April 16 and April 18, 2019. There were no statistical difference in percent cover among the treatments through May 9, 23 DAT. By May 22, 34 DAT, there was a decline in percent fine fescue cover among the treatments from the initial rating 2 DAT. Treatment plots of Esplanade 200 SC at 5 oz/ac and Esplanade 200 SC at 5 oz/ac + Method 240SL at 8 oz/ac resulted in significantly less fine fescue cover compared to the untreated plots. By June 3, 46 DAT, all herbicide treatments resulted in significantly less fine fescue cover than the untreated plots. Esplanade 200 SC at 3.5 oz/ac and Esplanade 200 SC at 3.5 oz/ac + Method 240SL at 8 oz/ac treated plots had 25% fine fescue cover. Fine fescue cover in plots treated with Esplanade 200 SC at 5 oz/ac was 13.75% and Esplanade 200 SC at 5 oz/ac + Method 240SL at 8 oz/ac was 2.69%. On June 24, 67 DAT, the percent fine fescue cover for all herbicide treatments except

Esplanade 200 SC at 3.5 oz/ac was significantly less than the untreated plots. By October 3, 168 DAT, percent fine fescue cover averaged 29.75 in plots treated with Esplanade 200 SC at 3.5 oz/ac and 33 in plots treated with Esplanade 200 SC at 3.5 oz/ac + Method 240SL at 8 oz/ac. Esplanade 200 SC at 3.5 oz/ac and Esplanade 200 SC at 3.5 oz/ac + Method 240SL at 8 oz/ac treated plots were statistically similar to the untreated check plots and the other two herbicide treatments. Fine fescue cover was 15% in plots treated with Esplanade 200 SC at 5 oz/ac and 1.5% in plots treated with Esplanade 200 SC at 5 oz/ac + Method 240SL at 8 oz/ac.

Tall Fescue & Kentucky Bluegrass Experiment

There was no difference among plots based on percent total turf on November 12, 2018; 0 DAT for fall applied experiment (Table 3). All herbicide treatments were significantly less than the untreated plots by May 3, 170 DAT. This trend continued through the rating on May 22, 191 DAT. By October 8, 330 DAT, percent total turf cover ranged from 64.75 to 82.5 with no statistical difference between treatments and the untreated check. On November 12, 2018, 0 DAT, there was no significance between plots based on percent tall fescue cover (Table 4). At every rating through October 8, 330 DAT, there was no statistical difference of percent tall fescue cover between the herbicide treatments and the untreated check. Percent tall fescue cover increased between 0 DAT and 330 DAT for all treatments except Esplanade 200 SC at 5 oz/ac, which remained same. Percent Kentucky bluegrass cover was not significantly different among treatments on November 12, 2018, 0 DAT (Table 5). This trend continued through all rating dates based on percent Kentucky bluegrass cover. The untreated check had 55.5% Kentucky bluegrass cover while the herbicide treatments ranged from 36% to 44.75%.

There was no statistical difference in percent total turfgrass cover among the plots at the onset of the experiment November 12, 2018 and when the spring application was applied on April 16, 2019, 0 DAT (Tables 6). By 175 DAT, the untreated plots were statistically similar to all herbicide treatments. Percent tall fescue cover based on treatments following a spring application were statistically similar at each rating date (Table 7). In general, percent tall fescue cover increased from April 16, 0 DAT to October 8, 175 DAT. The spring applications to Kentucky bluegrass showed no statistical difference in percent cover between the herbicide treatments and the untreated plots except for April 24, 8 DAT (Table 8). All other ratings were statistically similar to the untreated plots. Additionally, between 0 DAT and 175 DAT, the percent Kentucky bluegrass cover in the herbicide treated plots decreased while the untreated plots increased.

CONCLUSIONS

Esplanade 200 SC at 3.5 oz/ac, Esplanade 200 SC at 5 oz/ac, Esplanade 200 SC at 3.5 oz/ac + Method 240SL at 8 oz/ac, and Esplanade 200 SC at 5 oz/ac + Method 240SL at 8 oz/ac significantly reduced fine fescue cover during both fall and spring treatments when compared to the untreated check. The most damage to fine fescue occurred after the fall treatments. Also, Esplanade 200 SC at 5 oz/ac consistently resulted in less fine fescue cover than Esplanade 200 SC at 3.5 oz/ac. The same results occurred when Method 240SL at 8 oz/ac was added to the treatment. Tall fescue and Kentucky bluegrass cover was not statistically effected by treatments of Esplanade 200 SC at 3.5 oz/ac, Esplanade 200 SC at 5 oz/ac, Esplanade 200 SC at 3.5 oz/ac +

Method 240SL at 8 oz/ac, and Esplanade 200 SC at 5 oz/ac + Method 240SL at 8 oz/ac when compared to the untreated plots. The fall application showed percent tall fescue cover increased between 0 DAT and 330 DAT for all treatments except Esplanade 200 SC at 5 oz/ac, which remained at 20%. Whereas, there was no statistical difference in Kentucky bluegrass cover between the herbicide treated plots and the untreated check after fall treatments. The spring application resulted in an increase in percent tall fescue cover from 0 DAT to 175 DAT while the percent Kentucky bluegrass cover decreased in treated plots compared to the untreated check which increased following spring treatments.

Based on results of this experiment, applications of Esplanade 200 SC at 3.5 oz/ac, Esplanade 200 SC at 3.5 oz/ac + Method 240SL at 8 oz/ac, Esplanade 200 SC at 5 oz/ac and Esplanade 200 SC at 5 oz/ac + Method 240SL at 8 oz/ac applied to fine fescue significantly reduced fine fescue cover, while tall fescue cover was slightly reduced and resumed growth with time, and Kentucky bluegrass cover was decreased.

MANAGEMENT IMPLICATIONS

The addition of Esplanade 200 SC at 3.5 oz/ac or Esplanade 200 SC at 5 oz/ac to tank mixtures applied to fine fescue turf appears to significantly reduce fine fescue cover to unacceptable levels. Similar treatments to tall fescue will likely slightly reduce cover although regrowth may occur. The question to be asked is whether short term thinning is an acceptable outcome where other weeds may invade? In cable guiderail sites, maintaining a competitive low maintenance grass ground cover is the ultimate goal regardless of maintenance technique. Therefore, applications of Esplanade 200 SC is not recommended for use as a pre-emergence herbicide in conjunction with tank mixes used in roadside turf settings.

Table 1. Percent fine fescue cover following a fall application 0, 157, 165, 172, 178, 191, & 325. The experiment was visually rated for percent fine fescue cover on November 12, 2018, April 18, April 26, May 3, May 9, May 22, & October 3, 2019. Treatments were applied November 12, 2018. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/acre	% fine fescue cover 11/12/18 0 DAT	% fine fescue cover 4/18/19 157 DAT	% fine fescue cover 4/26/19 165 DAT	% fine fescue cover 5/3/19 172 DAT	% fine fescue cover 5/9/19 178 DAT	% fine fescue cover 5/22/19 191 DAT	% fine fescue cover 10/3/19 325 DAT
Untreated	---	70.5	33.25 b	50.75 b	51.50 b	62.75 b	57 b	67.50 b
Esplanade 200 SC	3.5	68	7.63 a	6.50 a	6.5 a	9.5 a	6.88 a	5.50 a
Esplanade 200 SC	5	65.75	2.5 a	2.25 a	2.25 a	5.25 a	2.25 a	3 a
Esplanade 200 SC Method 240SL	3.5 8	76.3	10.13 a	8.75 a	8.75 a	8.75 a	12.5 a	2.75 a
Esplanade 200 SC Method 240SL	5 8	69.25	7.75 a	9.75 a	7.25 a	7.5 a	4.75 a	0.25 a
		n.s.						

Table 2. Percent fine fescue cover following a spring application 0, 8, 15, 21, 34, 46, 67, & 168 days after treatment (DAT). The experiment was visually rated for percent fine fescue cover on November 12, 2018, April 18, April 26, May 3, May 9, May 22, June 3, June 24, & October 3, 2019. Treatments were applied April 16, 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	% fine fescue cover 11/12/18	% fine fescue cover 4/18/19 2 DAT	% fine fescue cover 4/26/19 8DAT	% fine fescue cover 5/3/19 15 DAT	% fine fescue cover 5/9/19 21 DAT	% fine fescue cover 5/22/19 34 DAT	% fine fescue cover 6/3/19 46 DAT	% fine fescue cover 6/24/19 67 DAT	% fine fescue cover 10/3/19 168 DAT
Untreated	---	70.5	33.25	50.75	51.5	62.75	57 b	58.25 b	58 c	67.5 b
Esplanade 200 SC	3.5	80.5	33.75	52.25	52.25	51.25	31.25 ab	25 a	35 bc	29.75 ab
Esplanade 200 SC	5	68.73	31.88	46	45.75	45	26.25 a	13.75 a	17.5 ab	15 a
Esplanade 200 SC Method 240SL	3.5 8	75.75	51	61.88	60.63	60	27.5 ab	25 a	31.25 b	33 ab
Esplanade 200 SC Method 240SL	5 8	49.75	23	36.13	33.75	33.75	7.75 a	2.69 a	3 a	1.5 a
		n.s.	n.s.	n.s.	n.s.	n.s.				

Table 3. Percent total turf cover following a fall application 0, 155, 163, 172, 178, 191, & 330 days after treatment (DAT). The experiment was visually rated for percent total turf cover on November 12, 2018, April 16, April 24, May 3, May 9, May 22, & October 8, 2019. Treatments were applied November 12, 2018. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/acre	% total turf cover 11/12/18 0 DAT	% total turf cover 4/16/19 155 DAT	% total turf cover 4/24/19 163 DAT	% total turf cover 5/3/19 172 DAT	% total turf cover 5/9/19 178 DAT	% total turf cover 5/22/19 191 DAT	% total turf cover 10/8/19 330 DAT
Untreated	---	97	56.25	62.5 b	65b	65 b	66.25 b	82.5
Esplanade 200 SC	3.5	98.13	43.75	38.75 a	41.25 a	42.5 a	43.75 a	71.25
Esplanade 200 SC	5	94.25	45	42.5 ab	42.5 a	43.75 a	45 a	67.75
Esplanade 200 SC Method 240SL	3.5 8	98.75	36.25	37.5 a	37.5 a	38.75 a	40 a	74.5
Esplanade 200 SC Method 240SL	5 8	98	41.25	36.25a	40 a	41.25 a	37.5 a	64.75
		n.s.	n.s.					n.s.

Table 4. Percent tall fescue cover following a fall application 0, 155, 163, 172, 178, 191, & 330 days after treatment (DAT). The experiment was visually rated for percent tall fescue cover on November 12, 2018, April 16, April 24, May 3, May 9, May 22, & October 8, 2019. Treatments were applied November 12, 2018. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/acre	% tall fescue cover 11/12/18 0 DAT	% tall fescue cover 4/16/19 155 DAT	% tall fescue cover 4/24/19 163 DAT	% tall fescue cover 5/3/19 172 DAT	% tall fescue cover 5/9/19 178 DAT	% tall fescue cover 5/22/19 191 DAT	% tall fescue cover 10/8/19 330 DAT
Untreated	---	22.5	17	16.5	19	19	18.75	24.5
Esplanade 200 SC	3.5	26.13	16.25	12.5	13.75	13.75	13.75	31.25
Esplanade 200 SC	5	20	7.5	10.25	11.75	9.25	8.75	20
Esplanade 200 SC Method 240SL	3.5 8	26.5	10	8.25	9.25	9.25	10.5	35
Esplanade 200 SC Method 240SL	5 8	21.25	13.75	10	11.25	11.25	10	27.5
		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Table 5. Percent Kentucky bluegrass following a fall application 0, 155, 163, 172, 178, 191, & 330 days after treatment (DAT). The experiment was visually rated for percent Kentucky bluegrass cover on November 12, 2018, April 16, April 24, May 3, May 9, May 22, & October 8, 2019. Treatments were applied November 12, 2018. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/acre	% Kentucky bluegrass cover 11/12/18 0 DAT	% Kentucky bluegrass cover 4/16/19 155 DAT	% Kentucky bluegrass cover 4/24/19 163 DAT	% Kentucky bluegrass cover 5/3/19 172 DAT	% Kentucky bluegrass cover 5/9/19 178 DAT	% Kentucky bluegrass cover 5/22/19 191 DAT	% Kentucky bluegrass cover 10/8/19 330 DAT
Untreated	---	74.5	39.25	46	45.75	45.75	45	55.5
Esplanade 200 SC	3.5	72	27.5	26.25	26.25	26.25	28.25	39.75
Esplanade 200 SC	5	74.25	37.5	30	29.5	32	33.75	44.75
Esplanade 200 SC Method 240SL	3.5 8	69.25	26.25	29.25	28.25	29.5	29.25	38.25
Esplanade 200 SC Method 240SL	5 8	74.25	27.5	26.25	28.75	28.75	24.75	36
		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Table 6. Percent total turf cover following a spring application 0, 8, 17, 23, 36, 48, 69, & 175 days after treatment (DAT). The experiment was visually rated for percent total turf cover on November 12, 2018; April 16, April 24, May 3, May 9, May 22, June 3, June 24, & October 8, 2019. Treatments were applied April 16, 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	% total turf cover 11/12/18	% total turf cover 4/16/19 0 DAT	% total turf cover 4/24/19 8 DAT	% total turf cover 5/3/19 17 DAT	% total turf cover 5/9/19 23 DAT	% total turf cover 5/22/19 36 DAT	% total turf cover 6/3/19 48 DAT	% total turf cover 6/24/19 69 DAT	% total turf cover 10/8/19 175 DAT
Untreated	---	97	56.25	62.5	65	65	66.25 b	76.25	77.25	82.5
Esplanade 200 SC	3.5	98.5	62.5	57.5	57.5	57.5	51.25 ab	71.25	68.75	82.5
Esplanade 200 SC	5	98	66.25	63.75	63.75	63.75	58.75 ab	70.75	65	80.5
Esplanade 200 SC Method 240SL	3.5 8	98.5	56.25	57.5	57.5	57.5	50 ab	65	62.5	78.25
Esplanade 200 SC Method 240SL	5 8	98	51.25	45	45	46.25	45 a	61.25	57.5	81.25
		n.s.	n.s.	n.s.	n.s.	n.s.		n.s.	n.s.	n.s.

Table 7. Percent tall fescue following a spring application 0, 8, 17, 23, 36, 48, 69, & 175 days after treatment (DAT). The site was located near a cable guiderail system along the median of a roadside. The experiment was visually rated for percent fine fescue cover on November 12, 2018; April 18, April 26, May 3, May 9, May 22, June 3, June 24, & October 8, 2019. Treatments were applied April 16, 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 11/12/18	% tall fescue cover 4/16/19 0 DAT	% tall fescue cover 4/24/19 8 DAT	% tall fescue cover 5/3/19 17 DAT	% tall fescue cover 5/9/19 23 DAT	% tall fescue cover 5/22/19 36 DAT	% tall fescue cover 6/3/19 48 DAT	% tall fescue cover 6/24/19 69 DAT	% tall fescue cover 10/8/19 175 DAT
Untreated	---	22.5	17	16.5	19	19	18.75	18.75	18.75	24.5
Esplanade 200 SC	3.5	15	9.25	8.75	12	12	15	20	20	36.25
Esplanade 200 SC	5	18.25	13.25	8	7.75	10	15	25	22.5	34.25
Esplanade 200 SC Method 240SL	3.5 8	17.5	12	15.5	16.75	16.75	20	17.5	16.25	43.75
Esplanade 200 SC Method 240SL	5 8	23.75	9.75	14.5	14.5	14.5	14.5	22.5	20	47.5
		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Table 8. Percent Kentucky bluegrass following a spring application 0, 8, 17, 23, 36, 48, 69, & 175 days after treatment (DAT). The site was located near a cable guiderail system along the median of a roadside. The experiment was visually rated for percent fine fescue cover on November 12, 2018; April 16, April 24, May 3, May 9, May 22, June 3, June 24, & October 8, 2019. Treatments were applied April 16, 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	% Kentucky bluegrass cover 11/12/18	% Kentucky bluegrass cover 4/16/19 0 DAT	% Kentucky bluegrass cover 4/24/19 8 DAT	% Kentucky bluegrass cover 5/3/19 17 DAT	% Kentucky bluegrass cover 5/9/19 23 DAT	% Kentucky bluegrass cover 5/22/19 36 DAT	% Kentucky bluegrass cover 6/3/19 48 DAT	% Kentucky bluegrass cover 6/24/19 69 DAT	% Kentucky bluegrass cover 10/8/19 175 DAT
Untreated	---	74.5	39.25	46 ab	45.75	45.75	45	47.5	47.25	55.5
Esplanade 200 SC	3.5	82.25	53.25	48.75 ab	45.5	45.5	32.25	33.75	30	43
Esplanade 200 SC	5	78.75	53	55.75 b	52.5	52.5	38.63	20	17.5	39
Esplanade 200 SC Method 240SL	3.5 8	80.5	44.25	42 ab	40.75	40.75	29.5	27.5	28.5	32.75
Esplanade 200 SC Method 240SL	5 8	74.25	41.5	30.5 a	30.5	31.75	30.5	25	21.25	30
		n.s.	n.s.		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

EVALUATION OF TELAR XP, SEGMENT, AND ASSURE II FOR TALL FESCUE CONTROL AND SAFETY ON FINE FESCUES

Herbicide trade and common names: Telar XP (*chlorsulfuron*), Segment (*sethoxydim*), Assure II (*quizalofop-Q*)
Plant common and scientific names: tall fescue *(Schedonorus arundinaceus),* fine fescue *(Festuca spp.)*, hard fescue (*Festuca brevipila*), red clover (*Trifolium pratense*), white clover (*Trifolium repens*), dandelion (*Taraxacum officinale*), buckhorn plantain (*Plantago coronpus*), broadleaf plantain (*Plantago major*), wild strawberry (*Fragaria virginiana*), wild carrot (*Daucus carota*), yellow woodsorrel (*Oxalis stricata*)

ABSTRACT

This experiment was an attempt to answer the question, can tall fescue be converted to fine fescue under cable guiderails without causing erosion or loss of cover and assure safety on newly interseeded fine fescue? Three herbicides were evaluated for their effectiveness in removing or slowing tall fescue growth while establishing newly seeded fine fescue including: Telar XP, Segment, and Assure II. Three experiments were conducted including a spring and fall treatment on tall fescue and a spring treatment on fine fescue to determine potential for injury. In the fall of 2018, an experiment with plots treated with Telar XP at 1, 1.3, 2, and 2.6 oz/ac; Segment at 36 oz/ac and 60 oz/ac; and Assure II at 8 oz/ac and 14 oz/ac along with an untreated check was conducted. A spring 2019 tall fescue experiment evaluated Telar XP at 1, 2, and 2.6 oz/ac; Segment at 36 and 60 oz/ac; Assure II at 8 and 14 oz/ac; and an untreated check. In addition, a spring 2019 fine fescue experiment evaluated Telar XP at 1, 2, and 2.6 oz/ac; Segment at 36 and 60 oz/ac, Assure II at 8 and 14 oz/ac; and an untreated check. A non-ionic surfactant (i.e. Induce) was added to all herbicide treatments at 0.25% v/v. The experiment was arranged as a randomized complete block design with four replications. Plot sizes were ten feet long and 6 feet wide. Treatments were applied at 50 gallons per acre with a CO_2 powered backpack sprayer equipped with a 6-foot boom, four 8004 VS nozzles, at 32 PSI on the fall 2018 application and 36 PSI on the spring 2019 applications. Fall applied treatments with 90% or more tall fescue reduction included Segment 36 oz/ac and 60 oz/ac and Assure II at 14 oz/ac. In comparison, spring applied treatments with 90% or more tall fescue reduction was only found with Segment at 60 oz/ac. Other spring treatments with 70% or more tall fescue reduction included Assure II at 14 oz/ac and Segment at 36 oz/ac. Telar XP at 2 oz/ac and 2.6 oz/ac significantly injured fine fescue compared to the untreated check.

INTRODUCTION

In Pennsylvania, cable guiderail systems have been installed as a safety device to minimize the severity of a crash by preventing a vehicle from reaching a more hazardous fixed object or terrain feature[6]. Vegetation management around cable guiderails may include mowing, plant growth regulator applications, and in certain sites bareground applications. Roadside medians may contain a mixture of grass species including K-31 tall fescue, Kentucky bluegrass, creeping red fescue, and even bentgrass species. The placement of cable guiderails in the median is often on sloped and easily eroded soils, so disturbing the vegetation may result in

[6] Pennsylvania Department of Transportation. Roadside Safety Pocket Guide 2018 Edition. PUB 652 (5-18)

erosion[7]. Mowing under the rail requires specialized equipment or large amounts of labor[8]. 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[9]. As a result of those past experiments, the question exists of the potential to successfully control tall fescue and at the same time allowing fine fescues to grow and flourish. Previous research, by Dernoden, shows a single application of chlorsulfuron can control tall fescue[10]. The purpose of this experiment was to evaluate herbicides able to control tall fescue and be safe to fine fescues. Three herbicides were evaluated for this experiment: Telar XP, Segment, and Assure II.

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 with three separate field experiments: a fall application, September 19, 2018, to tall fescue; a spring application, May 15, 2019, to tall fescue; and a spring application, May 15, 2019, to fine fescue. The fall 2018 experiment applied to tall fescue evaluated Telar XP at 1 oz/ac, Telar XP at 1.3 oz/ac, Telar XP at 2 oz/ac, Telar XP at 2.6 oz/ac, Segment at 36 oz/ac, Segment at 60 oz/ac, Assure II at 8 oz/ac, Assure II at 14 oz/ac and an untreated check. The spring 2019 experiment applied to tall fescue evaluated Telar XP at 1 oz/ac, Telar XP at 2 oz/ac, Telar XP at 2.6 oz/ac, Segment at 36 oz/ac, Segment at 60 oz/ac, Assure II at 8 oz/ac, Assure II at 14 oz/ac and an untreated check. The spring 2019 experiment applied to fine fescue evaluated Telar XP at 1 oz/ac, Telar XP at 2 oz/ac, Telar XP at 2.6 oz/ac, Segment at 36 oz/ac, Segment at 60 oz/ac, Assure II at 8 oz/ac, Assure II at 14 oz/ac and an untreated check. The experiment was arranged as a randomized complete block design with four replications. Plot sizes were 10-feet long and 6-feet wide. A non-ionic surfactant (i.e. Induce) was added to all herbicide treatments at 0.25% v/v. Treatments were applied at 50 gallons per acre with a CO_2 powered backpack sprayer equipped with a 6-foot boom, four 8004 VS nozzles, at 32 PSI for the fall 2018 application and 36 PSI for the spring 2019 applications.

The fall 2018 tall fescue experiment was visually rated for percent tall fescue and broadleaf weed cover on September 19, 2018, 0 DAT. Percent tall fescue and broadleaf weed injury on October 17, 29 DAT, and October 31, 2018 43 DAT. Percent tall fescue cover was

[7] 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
[8] 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
[9] 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
[10] Dernoden, P.H. Comparison of Three Herbicides for Selective Tall Fescue Control in Kentucky Bluegrass. Agronomy Journal 82:278-282 (1990)

visually rated April 19, 213 DAT and May 20, 2019, 244 DAT. The spring 2019 tall fescue experiment was visually rated for percent tall fescue cover or injury and broadleaf weed cover on May 14, June 19, and July 31, 2019 0, 35, and 77 DAT. Also, in the spring 2019, fine fescue and broadleaf cover was visually rated on May 14, 2019, 0 DAT. Fine fescue injury was rated on June 19, 2019, 35 DAT. All data were subjected 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

The site was a mixed stand of grasses and broadleaf weeds. Tall fescue was the main grass species present however, orchardgrass, timothy, and Kentucky bluegrass were present as well. Two common summer annual grasses present included foxtail and crabgrass. Broadleaf weed species present included red clover, white clover, dandelion, buckhorn plantain, broadleaf plantain, wild strawberry, wild carrot, and yellow woodsorrel. Initial tall fescue cover ranged from 37.5 percent to 60 percent and was not significant between treatments (Table 1). Percent broadleaf weed cover, at 0 DAT, ranged from 8.75 to 26.25, was not significant between treatments. By 29 DAT, tall fescue injury ranged between 50 and 95.75 percent for the herbicide treated plots and were significantly different from the untreated check. On October 31, 2018, 43 DAT, tall fescue injury from herbicide treatments showed Telar XP at 2.6 oz/ac was 71.25 percent, Segment at 36 oz/ac was 92.5 percent, Segment at 60 oz/ac was 93.75 percent, Assure II at 8 oz/ac 87.5 percent and Assure II at 14 oz/ac was 90 percent. Broadleaf weed injury from the Telar XP treatments ranged from 73.73 to 75 percent and was significantly higher compared to the untreated check, Segment and Assure II treatments. By May 20, 2019, 244 DAT, tall fescue cover for the herbicide treatments ranged from 1.25 to 37.5 percent (Table 2). The untreated check showed 50 percent tall fescue cover. Percent change in tall fescue was the comparison of the initial tall fescue cover at 0 DAT and the tall fescue cover at 244 DAT. Percent tall fescue cover for Segment at 36 oz/ac was 1.25 percent and represented a 98 percent reduction in tall fescue when compared to the initial tall fescue cover. Similarly, Segment at 60 oz/ac showed 1.68 percent tall fescue cover and a reduction in tall fescue of 97 percent. Assure II at 14 oz/ac showed 3.13 percent tall fescue cover and a reduction of 94 percent tall fescue cover. Tall fescue cover was 16.25 percent for Assure II at 8 oz/ac treatment and represented a 67 percent tall fescue reduction. Telar XP at 2.6 oz/ac showed 12.5 percent tall fescue cover and tall fescue reduction of 79 percent. Telar XP at 1 oz/ac, 1.3 oz/ac, and 2 oz/ac showed tall fescue reduction of 43 percent, 25 percent, and 59 percent respectively.

The same treatments, except Telar XP at 1.3 oz/ac, were evaluated the following spring to determine differences in seasonal timing of applications (Table 3). Percent tall fescue and broadleaf weed cover was visually rated on May 14, 2019, 0 DAT, and were statistically similar amongst treatments. Tall fescue cover ranged from 53.25 to 62.5 percent and broadleaf weed cover ranged from 13.75 to 20 percent. By June 19, 2019, 35 DAT, tall fescue injury ranged from 50.5 to 70.63 percent for herbicide treated plots. All Telar XP treatments reduced broadleaf weed cover and ranged from 3.75 to 5.75 percent. On July 31, 2019, 77 DAT, all herbicide treated plots reduced tall fescue cover and ranged from 2.65 to 43.75 percent (Table 4), whereas, the untreated check showed an increase in tall fescue cover to 68.75 percent. Percent change in tall fescue was the comparison of the initial tall fescue cover at 0 DAT and the tall fescue cover at 77 DAT. Percent tall fescue cover and reduction, based on herbicide treatments; Segment at 60 oz/ac showed 2.65% tall fescue cover and 96% reduction; Assure II at 14 oz/ac showed 12% tall fescue cover and 78% reduction; Segment at 36 oz/ac showed 18.75% tall fescue cover and 70% reduction; Telar XP at 2.6 oz/ac showed 22.5% tall fescue cover and 63% reduction. The remaining treatments showed less than 50% reduction in tall fescue cover.

In general, the fall applied herbicide treatments performed better than the spring applied herbicide treatments (Table 5). The exception was Telar XP at 1 oz/ac which showed a greater reduction in tall fescue cover from a spring application compared to a fall application. Segment at 60 oz/ac treatment resulted in the highest tall fescue reduction and consistently performed well as a fall application or spring application. Overall, the spring treatments were less effective in controlling tall fescue than the fall treatments.

Herbicide treatments, Telar XP at 1oz/ac, 2 oz/ac, and 2.6 oz/ac, Segment at 36 oz/ac and 60 oz/ac and Assure II at 8 oz/ac and 14 oz/ac were applied to a stand of fine fescue to evaluate injury to fine fescue (Table 6). The stand was a mix stand fine fescue and broadleaf weeds. Hard fescue was the most common of the fine fescues. Common broadleaf weed species present included: red clover, white clover, dandelion, and buckhorn plantain. Initial fine fescue cover ranged from 53.75 to 67.25 percent and broadleaf weed cover ranged from 32.5 to 46.25 percent, both being statistically similar between treatments. On June 19, 2019, 35 DAT, fine fescue injury was rated on a scale (1-5) with 1 being dead, necrotic and 5 being green, healthy. The untreated check was 4.63 and statistically similar to Segment at 36 oz/ac and 60 oz/ac, Assure II at 8 oz/ac and 14 oz/ac, and Telar XP at 1 oz/ac. Telar XP at 2 oz/ac and 2.6 oz/ac were significantly different from the untreated check. Observations of fine fescue in plots treated with Telar XP at 2 oz/ac or 2.6 oz/ac showed yellowing of fine fescue, reduced seedheads and stunted growth.

CONCLUSIONS

In general, fall applications of Telar XP, Segment, and Assure II resulted in higher reductions of tall fescue cover than spring applications. Fall applied treatments with 90% or more tall fescue reduction included Segment 36 oz/ac and 60 oz/ac and Assure II at 14 oz/ac. In comparison, spring applied treatments with 90% or more tall fescue reduction was found with Segment at 60 oz/ac. Other spring treatments with 70% or more tall fescue reduction included Assure II at 14 oz/ac and Segment at 36 oz/ac. Telar XP at higher rates reduced tall fescue cover and provided some broadleaf weed control. Telar XP at 2 oz/ac and 2.6 oz/ac significantly injured fine fescue compared to the untreated check.

MANAGEMENT IMPLICATIONS

None of the herbicide treatments completely eliminated tall fescue cover. Several herbicides such as Segment and Assure II will provide reduction of tall fescue cover and are safely applied to fine fescue. Caution should be exercised if utilizing this technique to remove tall fescue. Roadside sites containing both tall fescue and fine fescue are well suited for a Segment or Assure II application. Before applications are made to roadside turf, the roadside specialist should determine the amount of fine fescue cover present and if there is adequate fine fescue cover for this technique to be successful. Assure II label cautions tank mixing with broadleaf weed herbicides as some grass control may be reduced in certain situation[11]. 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. The Segment 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[12]. Telar XP does have the added benefit of some broadleaf weed control, however, it can be injurious to fine fescue and we don't recommend using this product. As always, read and follow all label directions. Future research should evaluate these herbicides along a roadside cable guiderail system and evaluate treatment effects.

Table 1. Percent tall fescue cover and broadleaf cover and injury ratings for fall 2018 experiment. Initial percent tall fescue cover and broadleaf cover were visually rated on September 19, 2018, 0 days after treatment (DAT). Percent tall fescue injury and broadleaf weed injury were visually rated October 17, 2018, 29 DAT and October 31, 2018, 43 DAT. Treatments were applied September 19, 2018. All herbicide treatments contained a non-ionic surfactant (i.e. Induce) 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/acre	% Tall fescue cover 9/19/18 0 DAT	% Broadleaf weed cover 9/19/18 0 DAT	% Tall fescue injury 10/17/18 29 DAT	% Broadleaf weed injury 10/17/18 29 DAT	% Tall fescue injury 10/31/18 43 DAT	% Broadleaf weed injury 10/31/18 43 DAT
Untreated	--	42.5	26.25	0 a	0 a	5.75 a	0 a
Telar XP	1	37.5	20.25	51.25 b	52.5 b	45 b	74.75 b
Telar XP	1.3	50	12.5	43.75 b	67.5 b	48.75 b	75 b
Telar XP	2	55	12	50 b	62.5 b	60 bc	73.75 b
Telar XP	2.6	60	11.25	65 bc	68.75 b	71.25 c	75b
Segment	36	50	10.5	87.5 cd	6.25 a	92.5 d	3.5 a
Segment	60	60	10	95.75 d	3.75 a	93.75 d	4.25 a
Assure II	8	50	10	78.75 cd	5 a	87.5 d	3.5 a
Assure II	14	52.5	8.75	85 cd	0 a	90 d	3.5 a
		n.s.	n.s.				

[11] Corteva agriscience. DuPont Assure II. Internet February 12, 2020.
[12] BASF. Segment. Label.

Table 2. Percent tall fescue cover and change in cover for fall 2018 experiment. Plots were visually rated on September 19, 2018, 0 days after treatment (DAT), April 19, 2019, 213 DAT, and May 20, 2019, 244 DAT. Treatments were applied September 19, 2018. All herbicide treatments contained a non-ionic surfactant (i.e. Induce) at 0.25% v/v. Percent change in tall fescue cover is the comparison between percent tall fescue cover at 0 DAT and 244 DAT. A (+) represents an increase and a (-) represents a reduction in tall fescue cover. 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 9/19/18 0 DAT	% Tall fescue cover 4/19/19 213 DAT	% Tall fescue cover 5/20/19 244 DAT	% Change tall fescue cover
Untreated	--	42.5	50 c	50 c	+ 8
Telar XP	1	37.5	17.5 ab	21.25 ab	- 43
Telar XP	1.3	50	46.25 c	37.5 bc	- 25
Telar XP	2	55	30 bc	22.5 ab	- 59
Telar XP	2.6	60	15 ab	12.5 a	- 79
Segment	36	50	1.75 a	1.25 a	- 98
Segment	60	60	2.94 a	1.68 a	- 97
Assure II	8	50	16.25 ab	16.25 ab	- 67
Assure II	14	52.5	3.13 a	3.13 a	- 94
		n.s.			

Table 3. Percent tall fescue and broadleaf weed cover and injury for spring 2019 experiment. Plots were visually rated on May 15, 2019, 0 days after treatment (DAT), June 19, 2019, 35 DAT, and July 31, 2019, 77 DAT. Treatments were applied May 15, 2019. All herbicide treatments contained a non-ionic surfactant (i.e. Induce) 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/acre	% Tall fescue cover 5/14/19 0 DAT	% Broadleaf weed cover 5/14/19 0 DAT	% Injured tall fescue 6/19/19 35 DAT	% Broadleaf weed cover 6/19/19 35 DAT	% Tall fescue cover 7/31/19 77 DAT	% Broadleaf weed cover 7/31/19 77 DAT
Untreated	--	62.5	20	0 a	17.5	68.75 c	13.5 a
Telar XP	1	61.75	15	61.5 b	5.75	32.5 ab	5.5 a
Telar XP	2	61.25	15	50.5 ab	3.75	43.75 bc	12.75 a
Telar XP	2.6	60	13.75	56.73 b	4.03	22.5 ab	4.38 a
Segment	36	62.25	15	69.5 b	23.75	18.75 ab	35 ab
Segment	60	59.5	15	70.63 b	28.75	2.65 a	48.75 b
Assure II	8	58.25	18	59.25 b	26.25	30 ab	27.5 ab
Assure II	14	53.25	18.75	70.25 b	27.5	12 ab	51.25 b
		n.s.	n.s.		n.s.		

Table 4. Percent tall fescue cover and change in cover for spring 2019. Plots were visually rated for percent tall fescue cover on May 15, 2019, 0 days after treatment (DAT) and July 31, 2019, 77 DAT. Treatments were applied May 15, 2019. All herbicide treatments included a non-ionic surfactant (i.e. Induce) at 0.25% v/v. Percent change in tall fescue cover is the comparison between percent tall fescue cover at 0 DAT and 77 DAT. A (+) represents an increase and a (-) represents a reduction in tall fescue cover. 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 5/14/19 0 DAT	% Tall fescue cover 7/31/19 77 DAT	% Change tall fescue cover
Untreated	--	62.5	68.75 c	+ 6
Telar XP	1	61.75	32.5 ab	- 47
Telar XP	2	61.25	43.75 bc	- 29
Telar XP	2.6	60	22.5 ab	- 63
Segment	36	62.25	18.75 ab	- 70
Segment	60	59.5	2.65 a	- 96
Assure II	8	58.25	30 ab	- 49
Assure II	14	53.25	12 ab	- 78
		n.s.		

Table 5. Comparison of tall fescue cover and change in cover for fall and spring applied herbicide treatments. The fall applied treatments were applied September 19, 2018. The spring applied treatments were applied May15, 2019. Percent change in tall fescue cover is the comparison between percent tall fescue cover at 0 days after treatment (DAT) and 244 DAT, fall applied, and 77 DAT, spring applied. A (+) represents an increase and a (-) represents a reduction in tall fescue cover. 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 applied			Spring applied		
Product	Rate oz/acre	% Tall fescue Cover 9/19/18 0 DAT	% Tall fescue Cover 5/20/19 244 DAT	% Change tall fescue cover	% Tall fescue cover 5/14/19 0 DAT	% Tall fescue cover 7/31/19 77 DAT	% Change tall fescue cover
Untreated	--	42.5	50 c	+ 8	62.5	68.75 c	+ 6
Telar XP	1	37.5	21.25 ab	- 43	61.75	32.5 ab	- 47
Telar XP	2	55	22.5 ab	- 59	61.25	43.75 bc	- 29
Telar XP	2.6	60	12.5 a	- 79	60	22.5 ab	- 63
Segment	36	50	1.25 a	- 98	62.25	18.75 ab	- 70
Segment	60	60	1.68 a	- 97	59.5	2.65 a	- 96
Assure II	8	50	16.25 ab	- 67	58.25	30 ab	- 49
Assure II	14	52.5	3.13 a	- 94	53.25	12 ab	- 78
		n.s.			n.s.		

Table 6. Fine fescue injury for fall experiment. The experiment was visually rated for fine fescue injury where 0 = dead, necrotic and 5= green, healthy. Percent fine fescue and broadleaf cover was rated on May14, 0 days after treatment (DAT). Fine fescue injury was visually rated June 19, 35 DAT. The treatments were applied May15, 2019. All herbicide treatments contain a non-ionic surfactant (i.e. Induce) 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/ac	% Fine fescue Cover 5/14/19 0 DAT	% Broadleaf weed Cover 5/14/19 0 DAT	Fine fescue injury (1-5) 6/19/19 35 DAT
Untreated	--	67.25	32.5	4.63 c
Telar XP	1	58.75	41.75	3.75 bc
Telar XP	2	65	35	3.13 ab
Telar XP	2.6	62.5	37.5	2.75 a
Segment	36	60	40	4.25 c
Segment	60	53.75	46.25	4.38 c
Assure II	8	65	34.75	4 bc
Assure II	14	55	44.75	4.38 c
		n.s.	n.s.	

CONVERSION OF EXISTING ROADSIDE TURF TO A LOW GROWING FINE FESCUE GROUNDCOVER AROUND CABLE GUIDERAILS – SECOND YEAR RESULTS

Plant common and scientific names: tall fescue (*Schedonorus arundinaceus*), Kentucky bluegrass (*Poa pratensis*), creeping red fescue (*Festuca rubra*), bentgrass (*Agrostis spp.*), hard fescue (*Festuca brevipilia*), annual ryegrass (*Lolliom multiflorum*)

ABSTRACT

Vegetation management around cable guiderails may include mowing, plant growth regulator applications, and bareground treatments. This experiment evaluated the efficacy of three seeding methods, two seed mixes, and timing (i.e. spring versus fall seeding) to establish a permanent, sustainable, low growing fine fescue ground cover near cable guiderails. The three seeding methods were: broadcast seeding with no soil preparation, a no-till drill pulled with a Ford 4610 tractor, and a disc harrow pulled by a Kubota 2500 tractor followed by broadcast seeding. Two different seed mixes were used, Penn DOT formula L and modified formula L. Formula L contained 55% hard fescue 35% creeping red fescue and 10% annual ryegrass by weight. Modified formula L contained 55% sheep fescue in place of the hard fescue with creeping red fescue and annual ryegrass remaining the same by weight. Initially, the spring seeded fine fescue turf germinated well, but by the end of the first growing season, the fine fescue seedlings appeared unable to compete with the existing tall fescue and Kentucky bluegrass. There was very little fine fescue cover through the second growing season. The fall seeded fine fescue showed initial establishment rates similar to spring seeded plots. One year after the fall seeding treatments, fine fescue established in all treatments, but at unacceptable levels. Both spring and fall seeded treatments failed to establish a permanent low growing groundcover around cable guiderails. Future research may include suppressing the resident tall fescue while promoting fine fescue establishment and spread.

INTRODUCTION

In Pennsylvania, cable guiderail systems have been installed as a safety device to minimize the severity of a crash by preventing a vehicle from reaching a more hazardous fixed object or terrain feature[13]. Vegetation management around cable guiderails may include mowing, plant growth regulator applications, and in certain sites bareground applications. Roadside medians may contain a mixture of grass species including K-31 tall fescue, Kentucky bluegrass, creeping red fescue, and even bentgrass species. The placement of cable guiderails in the median is often on sloped and easily eroded soils, so disturbing the vegetation may result in erosion[14]. Mowing under the rail requires specialized equipment or large amounts of labor[15]. This experiment evaluated three seeding methods, two seed mixes, and timing (i.e. spring versus fall seeding) into established roadside turf cover under cable guiderail with the intention to convert the ground cover under the guiderail to fine fescue. The goal of this experiment was to

[13] Pennsylvania Department of Transportation. Roadside Safety Pocket Guide 2018 Edition. PUB 652 (5-18)
[14, 15] 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

establish a permanent, sustainable low growing fine fescue ground cover near cable guiderails into existing tall fescue stands. This paper summarizes results of the establishment of spring seeded plots and fall seeded plots through two growing seasons.

MATERIALS AND METHODS

The experimental site was located along a cable guiderail in the median of I-99 between Tyrone and Grazierville exits in central Pennsylvania. The three seeding methods were: broadcast with no soil preparation, a no-till drill pulled by a Ford 4610 tractor, and a disc harrow pulled by a Kubota 2500 tractor followed by broadcast seeding. The no-till drill used was an Interseeder developed at Penn State to seed cover crops into corn. For this experiment, two passes were made to reduce the spacing of the drill resulting in about 3 inch spacing between rows. Two different seed mixes were used, Penn DOT formula L and modified formula L. Formula L contains 55% hard fescue 35% creeping red fescue and 10% annual ryegrass. Modified formula L contains 55% sheep fescue in place of the hard fescue with creeping red fescue and annual ryegrass remaining the same. Both formula L and modified formula L treatments were seeded at a rate of 48 pounds per 1000 square yards.

A second factoring in the experiment was to determine the best timing for seeding fine fescue into a tall fescue stand under cable guiderails. A spring seeding was completed May 11, 2018 and a fall seeding was completed October 4, 2018. The spring seeded plots were mowed with a Steiner 480, rotary deck mower at a height of 4 inches on May 7, 2018. Initial percent turfgrass and fine fescue cover was visually rated on May 8, 2018, 0 DAT (days after treatment). The disc harrow/broadcast plots were seeded on May 8, 2018, and the no-till drill and broadcast plots were seeded on May 11, 2018. The soil temperatures at the soil surface, 1-inch, 3-inch, and 6-inch depths were 68°F, 62°F, 58°F, and 52°F, respectively on May 11, 2018. The spring seeded plots were evaluated July13, 2018, 63 DAT and September 27, 2018, 139 DAT, May 21, 2019, 375 DAT, and October 17, 2019, 524 DAT. Plots were mowed by PennDOT contractors using tractors with rotary decks the first week of June 2018. The plots were mowed with a Steiner 480 disk blade mower to a height of 6 inches on September 24, 2018 to assist with rating on September 27, 2018. All plots were mowed mid-June 2019 by PennDOT crews.

The fall seeded plots were mowed with a Steiner 480 with a disc blade deck mower at a height of 5-6 inches on September 24, 2018. Due to an unsatisfactory mow, plots were mowed a second time with a Kubota ZD 331 zero turn mower to a height of 4 inches on October 1, 2018. Initial percent turfgrass and fine fescue cover was visually rated on October 1, 2018, 0 DAT. The disc harrow/broadcast and broadcast plots were seeded October 2, 2018, and the no-till drill plots were seeded October 4, 2018. The soil temperatures at the soil surface, 1-inch, 3-inch, and 6-inch depths were 67°F, 66°F, 64°F and 62°F, respectively on October 2, 2018. The fall seeded plots were visually evaluated on October 30, 2018, 26 DAT, May 21, 2019, 229 DAT, and October 21, 2019, 382 DAT. All plots were mowed by PennDOT crews in mid-June 2019.

Plots were 20 feet by 6 feet in size and arranged as a randomized complete block design. Four fixed subplots per plot were established to evaluate turfgrass cover and fine fescue cover. Ratings were performed using a square meter sampling square. All data were subject to analysis of variance, and when treatment effects were significant ($p \leq 0.05$) treatment means were compared using Tukey's HSD separation test.

RESULTS AND DISCUSSION

Turfgrass cover before treatment were applied (0 DAT) ranged from 55 to 65.42 percent and fine fescue cover ranged from 0 to 2.33 percent with no significance between treatments for the spring seeded plots (Table 1). By 63 DAT, turfgrass cover ranged from 89.42 to 94.83 percent. Fine fescue cover ranged from 0 to 8.33 percent. There was no statistical significance between treatments based on percent turf cover. However, the disc/broadcast modified formula L treatment, no till drill formula L treatment, and the disc/broadcast formula L treatment were significantly higher than the untreated check based on percent fine fescue cover. At 139 DAT, turfgrass cover ranged from 81.25 to 86.25 percent with no significance between treatments and percent fine fescue cover ranged from 0.06 to 2.33 percent. By the end of the first growing season, the spring seeded plots showed the effects of seeding a slow to establish turfgrass mix into a dense, competitive turfgrass cover consisting of tall fescue and Kentucky bluegrass. The fine fescue seedlings could not establish and compete with the existing tall fescue and Kentucky bluegrass roadside turf. The spring seeded treatments were visually rated for percent turf and fine fescue cover through the 2019 growing season (Table 2). By October 21, 2019, 524 DAT, turf cover ranged from 80 to 86.25 percent with no significance between treatments. Also, by 524 DAT, fine fescue cover ranged from 0 to 1.76 percent with no significance between treatments. The results from the second growing season after treatments confirmed the results from year one.

For the fall seeded plots, turfgrass cover before treatment were applied (0 DAT) ranged from 65.42 to 72.5 percent and fine fescue cover ranged from 0 to 0.02 percent with no significance between treatments (Table 3). By October 30, 2018, 26 DAT, turfgrass cover ranged from 70.83 to 87.5 percent. The fine fescue cover ranged from 0 percent for the untreated check to 9.83 percent for disc/broadcast modified formula L treatment. Fine fescue cover for the disc/broadcast modified formula L treatment was 9.83 percent and for the disc/broadcast formula L treatment was 7.5 percent, with both being significantly higher than all other treatments. The remaining treatments were statistically similar to the untreated check based on percent fine fescue cover. The fall seeded plots were visually rated through the 2019 growing season (Table 4). By October 21, 2019, 382 DAT, fine fescue cover ranged from 1.17 percent for the untreated check to 10.08 percent for the disc/broadcast modified formula L treatment. All treatments were statistically similar to the untreated check.

CONCLUSIONS

At the start of this experiment, the expectation was fine fescue would establish into the existing turf by the end of the second growing season. Even though there was initial establishment of spring seeded fine fescue mixes, by the end of the second season, very little fine fescue survived in the plots. It appears that the spring seeded fine fescue seedlings simply could not compete with the established turf. The fall seeded plots once again demonstrated adequate initial germination of fine fescue. By the end of the second growing season, minimal fine fescue established and was unsuccessful. Although, the fall seeded had more fine fescue cover compared to the spring seeded treatments, both did not achieve the goal of establishing a low growing fine fescue cover. The experimental site had a competitive stand of tall fescue and Kentucky bluegrass. Successful seedling establishment requires good seed to soil contact, light, and adequate rainfall to support seedling growth. Future experiments may include evaluating the effect of more frequent mowing during the establishment period or treating plots with herbicides to suppress or eliminate the existing turf prior to seeding. Additional experiments should evaluate various seed mixes for overseeding into exiting roadside turf cover including formula L, sheep fescue substituted for hard fescue in formula L, modified formula L, and Chewing's fescue substituted for hard fescue in formula L following applications of Telar XP, Segment II, or Assure II to suppress tall fescue growth.

MANAGEMENT IMPLICATIONS

Previous research has demonstrated successful fine fescue establishment when seeding into existing roadside turf sites[16]. Every site presents its own characteristics and challenges. Specific site conditions will dictate the soil preparation, turf suppression, mowing frequency, and seeding methods necessary to achieve the desired results. This experimental site demonstrates a need to either eliminate or reduce the competition of the existing turf to assist in the establishment of the desirable fine fescues.

[16] 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

Table 1. Spring seeded percent turf and fine fescue cover in 2018. Initial percent turfgrass and fine fescue cover were visually rated on May 8, 2018 0 DAT (days after treatment). The disc/broadcast plots were seeded May 8, 2018. The broadcast and no-till drill plots were seeded May 11, 2018. Percent turfgrass cover and fine fescue cover was visually rated on July 13, 2018 63 DAT and September 27, 2018, 139 DAT. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Treatment		% turf cover 5/8/18 0 DAT	% fine fescue cover 5/8/18 0 DAT	% turf cover 7/13/18 63 DAT	% fine fescue cover 7/13/18 63 DAT	% turf cover 9/27/18 139 DAT	% fine fescue cover 9/27/18 139 DAT
Untreated	--	61.67	1.17	89.5	0 a	84.58	0.17 ab
Broadcast	Mod L	56.67	0.03	91.25	4 ab	84.85	0.32 ab
No-Till Drill	Mod L	56.67	0.25	93.75	6 ab	81.25	0.48 ab
Disc, Broadcast	Mod L	65.42	2.33	94.83	8.33 b	85.83	2.33 b
Broadcast	Form L	62.5	0	94.5	3.25 ab	85.42	0.06 a
No-Till Drill	Form L	57.5	1.75	89.42	7.67 b	84.17	0.32 ab
Disc, Broadcast	Form L	55	0.83	92.17	7.21 b	86.25	0.13 ab
		n.s.	n.s.	n.s.		n.s.	

Table 2. Spring seeded percent turf and fine fescue cover in 2019. Initial percent turfgrass and fine fescue cover were visually rated on May 8, 2018 0 DAT (days after treatment). The disc/broadcast plots were seeded May 8, 2018. The broadcast and no-till drill plots were seeded May 11, 2018. Percent turfgrass cover and fine fescue cover was visually rated on May 21, 2019, 375 DAT and October 17, 2018, 524 DAT. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Treatment		% turf cover 5/8/18 0 DAT	% fine fescue cover 5/8/18 0 DAT	% turf cover 5/21/19 375 DAT	% fine fescue cover 5/21/19 375 DAT	% turf cover 10/17/19 524 DAT	% fine fescue cover 10/17/19 524 DAT
Untreated	--	61.67	1.17	65.42	0.04 a	83.33	0.17
Broadcast	Mod L	56.67	0.03	65.83	0.03 a	83.33	0.01
No-Till Drill	Mod L	56.67	0.25	70	0.01 a	86.25	1.71
Disc, Broadcast	Mod L	65.42	2.33	67.92	0.01 a	81.25	1.76
Broadcast	Form L	62.5	0	65	0.02 a	80	0.08
No-Till Drill	Form L	57.5	1.75	65	0.88 b	82.92	0.33
Disc, Broadcast	Form L	55	0.83	66.25	0.29 ab	83.33	0
		n.s.	n.s.	n.s.		n.s.	n.s.

Table 3. Fall seeded percent turf and fine fescue cover in 2018. Initial percent turfgrass and fine fescue cover were visually rated on October 1, 2018 0 DAT (days after treatment). The disc/broadcast and broadcast plots were seeded October 2, 2018. The no-till drill plots were seeded October 4, 2018. Percent turfgrass cover and fine fescue cover was visually rated on October 30, 2018, 26 DAT. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Treatment		% turf cover 10/1/18 0 DAT	% fine fescue cover 10/1/18 0 DAT	% turf cover 10/30/18 26 DAT	% fine fescue cover 10/30/18 26 DAT
Untreated	--	65.42	0	75.83 ab	0 a
Broadcast	Mod L	71.67	0	85 ab	2.46 a
No-Till Drill	Mod L	72.08	0	79.58 ab	0.35 a
Disc/Broadcast	Mod L	68.75	0	85.42 ab	9.83 b
Broadcast	Form L	72.5	0	87.5 b	2.83 a
No-Till Drill	Form L	67.5	0.02	70.83 a	0.40 a
Disc/Broadcast	Form L	72.5	0	85 ab	7.5 b
		n.s.	n.s.		

Table 4. Fall seeded percent turf and fine fescue cover in 2019. Initial percent turfgrass and fine fescue cover were visually rated on October 1, 2018 0 DAT (days after treatment). The disc/broadcast and broadcast plots were seeded October 2, 2018. The no-till drill plots were seeded October 4, 2018. Percent turfgrass cover and fine fescue cover was visually rated on May 21, 2019, 229 DAT, & October 17, 2019, 382 DAT. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Treatment		% turf cover 10/1/18 0 DAT	% fine fescue cover 10/1/18 0 DAT	% turf cover 5/21/19 229 DAT	% fine fescue cover 5/21/19 229 DAT	% turf cover 10/21/19 382 DAT	% fine fescue cover 10/21/19 382 DAT
Untreated	--	65.42	0	64.58 bc	0 a	86.25	1.17
Broadcast	Mod L	71.67	0	63.33 b	2.51 abc	87.5	3.08
No-Till Drill	Mod L	72.08	0	61.25 ab	0.71 a	87.5	3.58
Disc/Broadcast	Mod L	68.75	0	70.83 c	7.75 d	87.08	10.08
Broadcast	Form L	72.5	0	67.5 bc	7.04 cd	86.25	4.5
No-Till Drill	Form L	67.5	0.02	56.67 a	1.39 ab	84.58	9.63
Disc/Broadcast	Form L	72.5	0	66.25 bc	5.75 bcd	87.92	5.33
		n.s.	n.s.			n.s.	n.s.

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

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

<u>Plant common and scientific names:</u> 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, '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. 'K-31' tall fescue has been the standard because of the following characteristics : dependability, adaptability to thrive over a wide range of soils, persistence, and drought tolerance. Over the years the question has arisen as to whether 'K-31' is still the best choice? This comparison was designed to determine the effectiveness of three forms of sheep fescue: a species and two cultivars 'Quatro', and 'Marco Polo'; four turf-type tall fescues: 'Arid 3', 'No-Net', 'Technique', and 'Patagonia'; a forage tall fescue: 'Fawn'; as well as buffalograss 'Bowie', as potential low maintenance turfgrass replacement for 'K-31'. At the end of the first growing season, for all characteristics that were evaluated, except for turfgrass color, 'K-31' remained one of the strongest performers although not significantly different from the turf-type tall fescue cultivars tested. All sheep fescue entries and buffalograss were slow to establish and provided less than 50% turfgrass cover at the end of the first growing season. During the second growing season, all turfgrass entries continued to grow and develop except for 'Bowie' buffalograss which showed reduced turfgrass cover. The forage tall fescues of 'K-31' and 'Fawn', along with the turf-type tall fescue cultivars 'Arid 3', 'No-Net', 'Technique', and 'Patagonia', and the sheep fescue species and cultivars 'Quatro' and 'Marco Polo' produced acceptable cover and showed good establishment characteristics. Each of the new turfgrass cultivars and species merit consideration as a replacement for 'K-31' if 'K-31' is determined to be invasive or detrimental when planted adjacent to cattle operations along the roadside.

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', widespread forage plantings occurred in pastures and along roadsides for turf cover.[17] 'KY-31' is known as 'K-31' tall fescue.

[17] 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).

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 turfgrass species that survive and thrive in harsh roadside environments is an important part of successfully establishing and managing turfgrass along the roadside corridor. K-31 tall fescue has been widely used as a roadside cover crop in Pennsylvania and Maryland[18]to Illinois[19] and Nebraska[20]. PennDOT specifications utilize several different seeding mixes in new construction and revitalization projects. Two common formulations are Formula D, which consists of 60% 'K-31' tall fescue, 30% creeping red fescue or Chewing's fescue, and 10% annual ryegrass by weight, 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) some federal and state agencies are concerned that 'K-31' tall fescue is invasive, although; it does not show up on invasive species lists; 2) recently 'K-31' tall fescue 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) [21,22]the question arose whether there are other turfgrass species or cultivars that would be more suitable in that environment? The above reasons, initiated conversations on whether turf-type tall fescue with a finer texture, reduced vertical growth, and higher tiller densities 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 central Pennsylvania.

MATERIALS AND METHODS

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 a 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

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

[19] https://natseed.com/illinois-tollway-seed-mixtures.htm#26

[20] https://dot.nebraska.gov/media/4016/veg-manual.pdf

[21] 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.

[22] 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.

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.

The plots were visually rated for percent turfgrass cover and turfgrass density on July 10, August 6, September 5, October 10, 2018; 34, 61, 91, 126 days after seeding (DAS), respectively and on May 6, June 5, July 2, July 30, September 5, 2019; 334, 364, 391, 419, 456 DAS, respectively. Percent turfgrass cover was also rated 489 DAS. Percent turfgrass cover was a visual estimate of the percent of species or cultivar seeded. Turfgrass density was a visual estimate of the number of turfgrass plants or tillers per square foot evaluating three subplots within each plot. Turf density was evaluated on a scale from 1-10, (1=minimum turfgrass plants or tillers/ft^2-10=maximum turfgrass plants or tillers/ft^2). Percent weed cover was evaluated on July 10, August 6, September 5, October 10, 2018; 34, 61, 91, 126 DAS. 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). Turfgrass color was visually rated July 10, 2018, 34 DAS on a scale 1-10 (1=light green-10=dark green) and reflects the inherent genetic color of the entry, not yellowing or browning due to mowing, drought stress, disease, etc. Spring green up and turfgrass color was rated on May 6, 2019, 334 DAS. Spring green up was visually rated on a scale from 1-10 (1=straw brown-10=dark green). Percent broadleaf weed cover was visually rated on May 6, June 5, July 2, July 30, September 5, 2019; 334, 364, 391, 419, 456, and 489 DAS, respectively. Turfgrass height and seedhead height was measured 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 (Table 1), rated on a scale 1-10 (1=light green-10=dark green) was evaluated 34 DAS and ranged from 6.5 to 9. Buffalograss had the lowest rating of 6.5, while three turf-type tall fescues, 'Arid-3', 'No-Net', and 'Technique', had the highest turfgrass color rating of 9. There was no significance in turfgrass color between the sheep fescue and the tall fescue entries, however, 'Bowie' buffalograss has an inherent light green genetic color and was rated significantly lower than other entries. Seedling vigor was a visual estimate of percent ground cover and plant height during the early stages of seedling establishment. Seedling vigor

(Table 1), rated on a scale 1-10 (1=least vigorous seedling growth-10=most vigorous seedling growth), was rated 34 and 61 DAS. By 34 DAS, seedling vigor ranged from 1.5 to 7.3; 'Bowie' buffalograss had the lowest vigor rating at 1.5 and 'K-31' tall fescue had the highest vigor rating at 7.3. At 61 DAS, seedling vigor results showed 'Marco Polo' sheep fescue as the lowest in vigor at 3.3 and the highest rated was observed with 'K-31' tall fescue at 8.5. All entries increased in seedling vigor except the sheep fescue entries. 'Marco Polo' sheep fescue was statistically less than all other entries. At 61 DAS, 'Quatro' sheep fescue remained the same but 'Marco Polo' sheep fescue and the species sheep fescue declined in seedling vigor when compared to the 34 DAS rating. Fine fescues in general and sheep fescue in particular are slow to establish[23]. According to Penn State Extension factsheet on turfgrass establishment, late summer to early fall is the best time to seed permanent turfgrass[24]. The earlier than recommended seeding time may have caused the reduction in seedling vigor by midsummer, 61 DAT. Previous NTEP 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)[25]. 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 happen to close out a project or to prevent erosion. This may stress the new seedlings for a time and require longer for them to fill in and develop as planned. This may mean more maintenance to prevent weed invasion.

The experiment was visually rated for turfgrass density during the first growing season, (Table 2) and during the second growing season (Table 3), on a scale from 1-10 (1=minimum turfgrass plants or tillers/ft^2-10=maximum turfgrass plants or tillers/ft^2), on July 10, August 6, September 5, October 10, 2018; 34, 61, 91,126 DAS, and on May 6, June 5, July 2, July 30, September 5, 2019; 334, 364, 391, 419, 456 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. By 126 DAS, turfgrass density ranged from 3.5 to 9.4, 'Marco Polo' and 'Quatro' sheep fescue had the lowest rating and 'K-31' tall fescue had the highest rating. One year after seeding (364 DAS-Table 3), turfgrass density ranged from 2.5 to 7.92. 'Bowie' buffalograss was the lowest rated and 'Fawn' forage tall fescue was the highest rated for turfgrass density. By 456 days after seeding, all entries except 'Bowie' buffalograss were statistically similar based on turfgrass density and ranged from 2 to 7.75. 'Patagonia' turf-type tall fescue had the highest rated turfgrass density at 7.75. All tall fescue entries had turfgrass density ratings over 7.33. The three sheep fescue entries ranged from 5.92 to 6.67. 'Bowie' buffalograss had a turfgrass density rating of 2.

Percent turfgrass cover, of species or cultivars seeded per plot, was rated 34, 61, 91, 126, 334, 364, 391, 419, 456, and 489 DAS, respectively (Tables 4 and 5). All entries, except the species sheep fescue, increased in percent turfgrass cover between 34 and 126 DAS. By 126

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

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

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

DAS, percent turfgrass cover ranged from 37.5 for ‘Marco Polo’ sheep fescue to 87 for ‘K-31’ tall fescue. ‘Marco Polo’ sheep fescue was statistically similar to the other two sheep fescue and ‘Bowie’ buffalograss. ‘K-31’ tall fescue was statistically similar to all other tall fescue entries. Almost one year after seeding, 364 DAS (Table 5), ‘Fawn’ tall fescue had the highest percent turfgrass cover at 87.5 and ‘Bowie’ buffalograss had the lowest percent turfgrass cover at 31.25. By 489 DAS, percent turfgrass cover for all tall fescue and sheep fescue entries were significantly higher than ‘Bowie’ buffalograss. ‘Patagonia’ turf-type tall fescue, ‘Technique’ turf-type tall fescue, ‘Fawn’ tall fescue, and ‘K-31’ tall fescue had over 90 percent turfgrass cover. ‘No-Net’ turf-type tall fescue, and ‘Arid 3’ turf-type tall fescue had over 85 percent turfgrass cover. ‘Marco Polo’ sheep fescue, the species sheep fescue, and ‘Quatro’ sheep fescue had over 75 percent turfgrass cover.

Percent weed cover (Table 6) was rated on July 10, August 6, September 5, and October 10, 2018, 34, 61, 91, and 126 DAS, respectively. Weed cover ratings represent the percent cover by any broadleaf or grass species present in plots other than the seeded turfgrass cultivar. By August 6, 2018, weed cover ranged from 5.75-20 percent. On August 7, 2018, 62 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 126 DAS, percent weed cover ranged between 2.75-17. ‘Bowie’ buffalograss had the highest weed cover at 17 percent and was statistically similar to the sheep fescues. ‘K-31’ tall fescue had the lowest weed cover, 2.75 percent, and was significantly lower than ‘Bowie’ buffalograss. There was no significant difference in weed cover among the tall fescue entries and little difference in weed percentage between K-31, Technique, Patagonia, Arid 3, No-Net, and Fawn at 2.75, 2.75, 3, 4.25, 5.5, and 5.75% weed cover. In addition, all of the sheep fescues; the species, Quatro, and Marco Polo were similar to ‘K-31’ tall fescue.

Percent broadleaf weed cover (Table 7) was rated on June 5, July 3, July30, September 5, and October 8, 2019, 364, 391, 419, 456, and 489 DAS. On August 7, 2018, 62 DAS, and August 1, 2019, 421 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. On July 2, 2019, all plots had under 10 percent broadleaf weed cover except buffalograss which had 15 percent. July 30, 2019, 419 DAS broadleaf weed cover ranged from 0.75 to 17 percent. By 489 DAS, percent broadleaf weed cover reduced for all entries except ‘No-Net’ tall fescue which remained the same.

Turfgrass height and seedhead height (Table 8) were measured on June 5, 2019, 364 DAS, at each permanent subplot per plot. ‘Bowie’ buffalograss had the shortest average turfgrass height of 3.38 inches and was statistically similar to ‘Marco Polo’ sheep fescue. ‘Fawn’ tall fescue had the tallest average height of 11.33 inches, with’K-31’ tall fescue and ‘Arid 3’ tall fescue being statistically similar. All of the turf-type tall fescues, Arid 3, No-Net, Patagonia, and Technique were shorter in turfgrass height than ‘K-31’ tall fescue. Additionally, the sheep fescues were statistically similar based on turfgrass height. The species sheep fescue, ‘Quatro’ sheep fescue, and ‘Marco Polo’ sheep fescue were shorter in seedhead height than ‘K-31’ tall fescue. For average seedhead height, ‘Bowie’ buffalograss had the shortest height of 5.33 inches and ‘Fawn’ tall fescue was the tallest at 30.83 inches. ‘K-31’ tall fescue was statistically similar to ‘Fawn’ tall fescue. Seedhead height was similar amongst the turf-type tall fescues and were shorter than ‘K-31’ tall fescue. All of the sheep fescue seedhead height were shorter than 'K-31' and varied with 'Quatro' being statistically similar to 'Marco Polo' and shorter than the species sheep fescue.

CONCLUSIONS

The experimental site was seeded slightly beyond the typical spring seeding window of May 15. However, the growing season was anything but normal. The area received above average rainfall allowing the turfgrass seed to germinate and seedlings to establish under above average soil moisture conditions. In fact, the rainfall for 2018 registered as the wettest year on record for Pennsylvania[26]. During the second growing season, all turfgrass entries continued to grow and develop except for 'Bowie' buffalograss which showed reduced growth and development. In fact, grasses such as tall fescue and fine fescue started to outcompete the buffalograss.

All tall fescue seeded plots germinated well among the species evaluated and provided acceptable turfgrass cover by 126 DAS. The turf-type tall fescues were similar to 'K-31' tall fescue; however, 'K-31' tall fescue remained the highest rated overall in density, vigor, and turf cover by the end of the first season. By the end of the second growing season, all of the tall fescues provided over 85 percent turfgrass cover. 'Fawn' tall fescue performed similar to 'K-31 tall fescue. All of the turf-type tall fescues performed equivalent to the standards set by 'K-31' tall fescue. Arid3, No-Net, Technique, and Patagonia consistently performed similar or superior to 'K-31 tall fescue based on turfgrass density, turfgrass cover, turfgrass height and seedhead height.

The three sheep fescue entries were slow to establish and did not provide greater than 50 percent turfgrass cover 126 days after seeding. Sheep fescue is a low growing fine textured turfgrass species. Several publications advise and this experiment confirms the slow establishment of sheep fescue.[27] However, by 489 DAS, all sheep fescue showed turfgrass cover of 75 percent or better. 'Quatro', 'Marco Polo' and the species sheep fescue were similar to 'K-31' tall fescue 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.

'Bowie' buffalograss, a low growing warm season grass, was slower to germinate than the other entries but was similar to the sheep fescues in turfgrass cover 126 days after seeding. By the end of the second growing season, buffalograss continued to decline well below unacceptable levels, lacking the ability to compete in this environment. Buffalograss is not native to Pennsylvania. Buffalograss is native from Minnesota west to Montana south to Arizona and east to Louisiana. It grows in medium to fine textured soils and areas with low to moderate rainfall (15-30 inches annually)[28]. Buffalograss is dominant on the upland short grass

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[26] https://www.weather.gov/ctp/RecordPrecip2018 February 14, 2019
[27] K.M. Engelhartdt and Hawkins, K. Identification of Low Growing , Salt Tolerant Turfgrass species Suitable for Use Along Highway Right of Way. November 2016. pp64-69.
[28] https://plants.usda.gov/plantguide/pdf/pg_boda2.pdf April 23, 2020

prairie of the Great Plains[29]. Pennsylvania's humidity and rainfall may cause Buffalograss to be outcompeted by grass species more adaptable to Pennsylvania's climate.

MANAGEMENT IMPLICATIONS

After the establishment phase of this experiment and through the second growing season turf-type tall fescue demonstrated as an effective 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 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 substitutions for 'K-31' tall fescue in seed mixes. Further data collection will determine the differences between the turfgrass species and cultivars.

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[29] Hitchcock, A.S. 1951. Manual of the grasses of the United States. Misc. Publ. No. 200. Washington, DC: US Department of Agriculture, Agricultural Research Administration. 1051p.

Table 1. Turfgrass Color, Seedling Vigor, Spring Green-Up. The experiment was visually rated for turfgrass genetic color on July 10, 2018, 34 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 days after seeding (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. 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- First Growing Season. 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 July 10, August 6, September 5, October 10, 2018; 34, 61, 91,126 days after treatment (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. 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. 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	Cultivar	Turfgrass Density 7/10/18 34 DAS	Turfgrass Density 8/6/18 61 DAS	Turfgrass Density 9/5/18 91 DAS	Turfgrass Density 10/10/18 126 DAS
Sheep fescue	Quatro	3 c	2.5 ab	2.8 a	3.5 a
Sheep fescue		2.5 ab	3.1 ab	3.3 ab	4.3 a
Sheep fescue	Marco Polo	2.3 ab	2.8 ab	3 a	3.5 a
Tall fescue	K-31	4.8 d	7.6 d	8.5 c	9.4 b
Tall fescue turf-type	Arid 3	3.9 bc	5.6 cd	6.5 c	7.4 b
Tall fescue turf-type	No-Net	3.1 bc	4.7 bc	5.8 bc	7.3 b
Tall fescue	Fawn	3.8 bc	6.9 d	7.5 c	8.8 b
Tall fescue turf-type	Technique	3.9 bc	6.7 cd	7.8 c	8.7 b
Tall fescue turf-type	Patagonia	3.5 bc	5.8 cd	6.5 c	8.3 b
Buffalograss	Bowie	0.9 a	2.2 a	2.5 a	3.8 a

Table 3. Turfgrass Density- Second Growing Season. 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 May 6, June 5, July 2, July 30, September 5, 2019; 334, 364, 391, 419, 456 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. On August 1, 2019, all plots were treated with Triplet L/O at 64 oz/ac, including a non-ionic surfactant (Induce) at 0.25% v/v. On August 14, 2019, all plots were mowed to 5-inch height. 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 Density 5/6/19 334 DAS	Turfgrass Density 6/5/19 364 DAS	Turfgrass Density 7/2/19 391 DAS	Turfgrass Density 7/30/19 419 DAS	Turfgrass Density 9/5/19 456 DAS
Sheep fescue	Quatro	5.58 b	5.58 bc	6.75 bc	6.58 bc	6.67 b
Sheep fescue		4.92 b	5.42 bc	5.83 b	6.67 bc	6.5 b
Sheep fescue	Marco Polo	4.83 b	4.83 ab	6.33 bc	5.33 b	5.92 b
Tall fescue	K-31	5.42 b	6.92 bc	7.67 bc	7.67 c	7.58 b
Tall fescue turf-type	Arid 3	5.08 b	6.67 bc	7 bc	7.17 bc	7.5 b
Tall fescue turf-type	No-Net	4.83 b	5.67 bc	6.25 bc	6.42 bc	7.33 b
Tall fescue	Fawn	5.42 b	7.92 c	8.42 c	7.75 c	7.33 b
Tall fescue turf-type	Technique	5.67 b	6.67 bc	7.17 bc	6.75 bc	7.42 b
Tall fescue turf-type	Patagonia	5.42 b	6.33 bc	7.25 bc	6.08 bc	7.75 b
Buffalograss	Bowie	0.75 a	2.5 a	2.33 a	1.83 a	2 a

Table 4. Turfgrass Cover- First Growing Season. The experiment was visually rated for percent turfgrass cover on July 10, August 6, September 5, October 10, 2018; 34, 61, 91, 126 days after treatment (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. 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. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at p≤0.05.

Turfgrass	Cultivar	% Turfgrass Cover 7/10/18 34 DAS	% Turfgrass Cover 8/6/18 61 DAS	% Turfgrass Cover 9/5/18 91 DAS	% Turfgrass Cover 10/10/18 126 DAS
Sheep fescue	Quatro	37.5 ab	34 abc	29.25 a	40 ab
Sheep fescue		53.75 b	32.5 ab	36.25 abcd	45 abc
Sheep fescue	Marco Polo	35 ab	26.5 a	30.25 ab	37.5 a
Tall fescue	K-31	65 b	81.25 d	82.5 e	87 d
Tall fescue turf-type	Arid 3	48.75 ab	68.75 cd	62.5 abcde	77.5 bcd
Tall fescue turf-type	No-Net	48.75 ab	63.75 bcd	68.75 bcde	77.5 bcd
Tall fescue	Fawn	31.5 ab	75 d	73.75 de	81.25 cd
Tall fescue turf-type	Technique	45 ab	73.75 d	68.75 bcde	81 cd
Tall fescue turf-type	Patagonia	51.25 ab	75 d	71.25 cde	85 d
Buffalograss	Bowie	16.25 a	26.25 a	32.5 abc	45 abc

Table 5. Turfgrass Cover-Second Growing Season. The experiment was visually rated for percent turfgrass cover on May 6, June 5, July 2, July 30, September 5, 2019; 334, 364, 391, 419, 456 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. On August 1, 2019, all plots were treated with Triplet L/O at 64 oz/ac including a non-ionic surfactant (Induce) at 0.25% v/v. On August 14, 2019, all plots were mowed to 5-inch height. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at p≤0.05.

Turfgrass	Variety	% Turfgrass Cover 5/6/19 334 DAS	% Turfgrass Cover 6/5/19 364 DAS	% Turfgrass Cover 7/2/19 391 DAS	% Turfgrass Cover 7/30/19 419 DAS	% Turfgrass Cover 9/5/19 456 DAS	% Turfgrass Cover 10/8/19 489 DAS
Sheep fescue	Quatro	46.25 a	63.75 bc	72.5 b	73.5 b	78.75 b	78.75 b
Sheep fescue		50 ab	62.5 abc	70 b	69.25 b	69.5 b	75 b
Sheep fescue	Marco Polo	56.25 ab	55 ab	66.25 b	67.5 b	66.25 b	75 b
Tall fescue	K-31	66.25 ab	80.75 bc	90 b	91.25 b	87 b	93.75 b
Tall fescue turf-type	Arid 3	65 ab	78.75 bc	85 b	85 b	81.25 b	88.75 b
Tall fescue turf-type	No-Net	63.75 ab	76.25 bc	83.75 b	78.75 b	81.25 b	85 b
Tall fescue	Fawn	68.75 ab	87.5 c	95 b	92.5 b	85 b	92.5 b
Tall fescue turf-type	Technique	65 ab	77.5 bc	87.5 b	81.25 b	85.75 b	90.75 b
Tall fescue turf-type	Patagonia	70 b	81.25 bc	87.5 b	83.75 b	87.5 b	90.75 b
Buffalograss	Bowie	50 ab	31.25 a	26.25 a	16.25 a	18.75 a	14.75 a

Table 6. Weed Cover. The experiment was visually rated for percent weed cover on July 10, August 6, September 5, and October 10, 2018; 34, 61, 91, 126 days after treatment (DAS), respectively. The soil within 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	Cultivar	% Weed Cover 7/10/18 34 DAS	% Weed Cover 8/6/18 61 DAS	% Weed Cover 9/5/18 91 DAS	% Weed Cover 10/10/18 126 DAS
Sheep fescue	Quatro	3.25	13.75	8.75	10 ab
Sheep fescue		2.38	17.25	6.75	7.5 ab
Sheep fescue	Marco Polo	4.13	20	10.75	11.25 ab
Tall fescue	K-31	1	5.75	4.5	2.75 a
Tall fescue turf-type	Arid 3	1.5	6.25	8.5	4.25 a
Tall fescue turf-type	No-Net	1.13	11.25	7	5.5 a
Tall fescue	Fawn	1.13	7.5	5.5	5.75 a
Tall fescue turf-type	Technique	4.5	10	3.25	2.75 a
Tall fescue turf-type	Patagonia	1.75	8.75	4.75	3 a
Buffalograss	Bowie	2.25	16.25	10.25	17 b
		n.s.	n.s.	n.s.	

Table 7. Broadleaf Weed Cover. The experiment was visually rated for percent broadleaf weed cover on June 5, July 2, July 30, September 5, and October 8, 2019; 364, 391, 419, 456, and 489 days after treatment (DAS), respectively. The soil within 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 and August 1, 2019, all plots were treated with Triplet L/O at 64 oz/ac including a non-ionic surfactant (Induce) at 0.25% v/v. On August 14, 2019, all plots were mowed to 5-inch height. 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	% Broadleaf Weed Cover 6/5/19 364 DAS	% Broadleaf Weed Cover 7/2/19 391 DAS	% Broadleaf Weed Cover 7/30/19 419 DAS	% Broadleaf Weed Cover 9/5/19 456 DAS	% Broadleaf Weed Cover 10/8/19 489 DAS
Sheep fescue	Quatro	2.75 ab	5.13 ab	8.88	2.56	4.13
Sheep fescue		5.25 abc	7.5 ab	6.13	0.75	1.75
Sheep fescue	Marco Polo	5.63 bc	9.63 ab	10.75	8.63	9.5
Tall fescue	K-31	1.5 ab	0.38 a	0.88	0.09	0
Tall fescue turf-type	Arid 3	0.38 a	0.31 a	1	0.38	0.5
Tall fescue turf-type	No-Net	1.5 ab	2.25 a	1.5	1.38	1.5
Tall fescue	Fawn	0.88 ab	1.53 a	0.69	0.19	0
Tall fescue turf-type	Technique	0.38 a	0.56 a	1.38	1.88	1.25
Tall fescue turf-type	Patagonia	0.38 a	0.31 a	0.75	0.13	0
Buffalograss	Bowie	8 c	15 b	17	7.38	10.5
				n.s.	n.s.	n.s.

Table 8. Turf height and seedhead height. The experiment was measured for turf height and seedheads height on June 5, 2019; 364 days after treatment (DAS). Turf 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	Turf 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 FLUMIOXAZIN + PYROXASULFONE ALONE AND COMBINATIONS COMPARED TO OTHER TOTAL VEGETATION CONTROL MIXES FOR SEASON LONG TOTAL VEGETATION CONTROL

Herbicide trade and common names: Razor Xtreme (*glyphosate*), Piper (*flumioxazin + pyroxasulfone*), Payload (*flumioxazin*), NuFarm Imazapic (*imazapic*), Depth Charge (*flumioxazin + 2,4-D*), Polaris (*imazapyr*), Spyder Extra (*sulfometuron + metsulfuron*), Esplanade 200 SC (*indaziflam*), Method 240SL (*aminocyclopyrachlor*), Milestone VM (*aminopyralid*)

Plant common and scientific names: wild carrot *(Daucus carota),* common evening primrose *(Oenothera biennis),* spotted spurge *(Euphorbia maculata),* nodding spurge *(Euphorbia nutans),* devil's beggarticks *(Bidens frondosa),* spotted knapweed *(Centurea stoebe var. microanthus)*, white sweetclover *(Melilotus alba)*, marestail *(Conyza canadensis),* teasel *(Dipsacus fullonum),* goldenrod *(Solidago spp.)* white heath aster *(Aster pilosus),* tufted lovegrass *(Eragrostis pectinacea),* woolly lovegrass *(Eragrostis cilianensis), poverty* dropseed *(Sporobolus vaginiflorus),* foxtail *(Setaria spp.),* witchgrass *(Panicum capillare)*

ABSTRACT

Areas directly adjacent to roadways (i.e., under guiderails and around signs) are kept free of vegetation. The emphasis of a bareground program is to provide cost effective, season long weed control. The components of a successful bareground program tank mix includes; a broad-spectrum residual, preemergence herbicide, and a post emergence herbicide. This experiment evaluated several bareground mixes. The treatments included Razor Xtreme at 32 oz/ac; Piper at 10 oz/ac + Razor Xtreme at 32 oz/ac; Piper at 10 oz/ac + Payload at 3 oz/ac + Razor Xtreme at 32 oz/ac; Piper at 10 oz/ac + Depth Charge at 32 oz/ac + Razor Xtreme at 32 oz/ac; Piper at 10 oz/ac + Payload at 3 oz/ac + NuFarm Imazapic at 12 oz/ac + Razor Xtreme at 32 oz/ac; Piper at 10 oz/ac + Payload at 3 oz/ac + Polaris at 24 oz/ac + Razor Xtreme at 32 oz/ac; Piper at 10 oz/ac + Payload at 3 oz/ac + Spyder Extra at 4 oz/ac + Razor Xtreme at 32 oz/ac; Esplanade 200 SC at 5 oz/ac + Method 240SL at 12 oz/ac + Razor Xtreme at 32 oz/ac; and Milestone VM at 7 oz/ac + Esplanade 200 SC at 5 oz/ac + Razor Xtreme at 32 oz/ac. Methylated seed oil (MSO) was added to all treatments at 1% v/v. By September 19, 148 DAT (days after treatment), the following treatments showed 10 percent or less total vegetative cover; Esplanade 200 SC at 5 oz/ac + Method 240SL at 12 oz/ac + Razor Xtreme at 32 oz/ac (3%); Piper at 10 oz/ac + Payload at 3 oz/ac + Polaris at 24 oz/ac + Razor Xtreme at 32 oz/ac (5.25%); Milestone VM at 7 oz/ac + Esplanade 200 SC at 5 oz/ac + Razor Xtreme at 32 oz/ac (6.25%); and Piper at 10 oz/ac + Depth Charge at 32 oz/ac + Razor Xtreme at 32 oz/ac (10%). In addition, Piper at 10 oz/ac + Payload at 3 oz/ac + Spyder Extra at 4 oz/ac + Razor Xtreme at 32 oz/ac resulted in 10.5% total vegetative cover.

INTRODUCTION

Bareground weed control is an essential part of a roadside vegetation management program. Keeping guiderails, signs, bridge abutments, and other concrete structures free of weeds allows for proper water flow off the roadway, enhanced motorist visibility, and greater ease of maintenance around the structures. A successful bareground weed control program will control existing vegetation, provide soil residual activity and prevent weed seeds from germinating. In an effort to identify preemergence herbicides with different chemical site of action compared to those currently used in bareground application; Piper a combination product containing flumioxazin and pyroxasulfone was evaluated. According to the Weed Science Society of America compiled list of herbicide mechanisms of action, flumioxazin is a category 14 and pyroxasulfone is a category 15 herbicide[30]. Mechanism of action, also known as site of action, identifies the specific site the herbicide inhibits or binds in the plant. A variety of herbicides are necessary to allow for the rotation of herbicides with different site of action to reduce herbicide resistance within targeted weed species. The overarching goal of this experiment was to evaluate Piper a new product on the market as to its effectiveness compared to standardly used products in bareground operations.

MATERIAL AND METHODS

An experiment was established along I-99 south bound approximately ½ mile south of the Tyrone interchange near Tyrone, Pennsylvania as a randomized complete block design with four replications. Treatments included Razor Xtreme at 32 oz/ac; Piper at 10 oz/ac + Razor Xtreme at 32 oz/ac; Piper at 10 oz/ac + Payload at 3 oz/ac + Razor Xtreme at 32 oz/ac; Piper at 10 oz/ac + Depth Charge at 32 oz/ac + Razor Xtreme at 32 oz/ac; Piper at 10 oz/ac + Payload at 3 oz/ac + NuFarm Imazapic at 12 oz/ac + Razor Xtreme at 32 oz/ac; Piper at 10 oz/ac + Payload at 3 oz/ac + Polaris at 24 oz/ac + Razor Xtreme at 32 oz/ac; Piper at 10 oz/ac + Payload at 3 oz/ac + Spyder Extra at 4 oz/ac + Razor Xtreme at 32 oz/ac; Esplanade 200 SC at 5 oz/ac + Method 240SL at 12 oz/ac + Razor Xtreme at 32 oz/ac; and Milestone VM at 7 oz/ac + Esplanade 200 SC at 5 oz/ac + Razor Xtreme at 32 oz/ac. Methylated seed oil (MSO) was added to all treatments at 1% v/v. Plots were 20-feet by 6-feet in size. Treatments were pre-measured, mixed, and applied on April 29, 2019, using a CO_2 powered backpack sprayer equipped with a six-foot boom and four 8004 VS nozzles. The treatments were applied at 35 PSI and a rate of 50 gallons per acre. Weather at the time of application consisted of mostly cloudy skies with some sun, wind speeds of 5-10 mph, 26% relative humidity, and air temperatures of 66° F. The soil moisture was average and soil temperatures of 62° F, 64° F, 60° F, and 60° F at 0, 1, 3, and 6-inch depths, respectively. Local rain events occurred on April 29, 30, May 1, 3, 4, 5, and 6, 2019; with 0.01”, 0.02”, 0.02”, 0.62”, 0.32”, 0.23”, and 0.32” respectively, according to httpp://newa.cornell.edu. The nearest weather station was located at Rock Springs, PA.

The experiment was visually rated for percent total vegetative cover and stem counts conducted on April 26, May 29, June 26, July 29, August 29, and September 24, 2019. Four 1-foot by 1-foot subplots were established within each plot to conduct stem counts. All data were

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

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 site offered a diverse population of annual and perennial grasses and broadleaf weeds. On April 26, total vegetative cover ranged from 26.25 to 41.25 percent with no significant difference among plots (Table 1). Similarly, stem counts per square foot ranged from 17.38 to 28.56 with no significant difference among plots (Table 2). By 30 DAT (days after treatment), total cover was reduced and ranged from 0.2 to 4.25 percent for all treatments except Razor Xtreme at 32 oz/ac which increased to 31.75 percent. On July 29, 91 DAT, the following treatments showed less than 2 percent vegetative cover: Piper at 10 oz/ac + Depth Charge at 32 oz/ac + Razor Xtreme at 32 oz/ac; Piper at 10 oz/ac + Payload at 3 oz/ac + NuFarm Imazapic at 12 oz/ac + Razor Xtreme at 32 oz/ac; Piper at 10 oz/ac + Payload at 3 oz/ac + Polaris at 24 oz/ac + Razor Xtreme at 32 oz/ac; Piper at 10 oz/ac + Payload at 3 oz/ac + Spyder Extra at 4 oz/ac + Razor Xtreme at 32 oz/ac; Esplanade 200 SC at 5 oz/ac + Method 240SL at 12 oz/ac + Razor Xtreme at 32 oz/ac; and Milestone VM at 7 oz/ac + Esplanade 200 SC at 5 oz/ac + Razor Xtreme at 32 oz/ac.

By August 29, 2019, 122 DAT, treatment plots showed less than 5 percent total vegetative cover included: Esplanade 200 SC at 5 oz/ac + Method 240SL at 12 oz/ac + Razor Xtreme at 32 oz/ac (0.78%); Piper at 10 oz/ac + Payload at 3 oz/ac + Spyder Extra at 4 oz/ac + Razor Xtreme at 32 oz/ac (1.71%); Milestone VM at 7 oz/ac + Esplanade 200 SC at 5 oz/ac + Razor Xtreme at 32 oz/ac (1.94%); Piper at 10 oz/ac + Payload at 3 oz/ac + Polaris at 24 oz/ac + Razor Xtreme at 32 oz/ac (3.06%); Piper at 10 oz/ac + Depth Charge at 32 oz/ac + Razor Xtreme at 32 oz/ac (3.25%); and Piper at 10 oz/ac + Payload at 3 oz/ac + NuFarm Imazapic at 12 oz/ac + Razor Xtreme at 32 oz/ac (3.5%). Treatment plots with less than 10 percent total vegetative cover included: Piper at 10 oz/ac + Razor Extreme at 32 oz/ac (8%) and Piper at 10 oz/ac + Payload at 3 oz/ac + Razor Xtreme at 32 oz/ac (8.75%). Razor Xtreme at 32 oz/ac treatment showed 57.5 percent total vegetative cover. Also, on August 29, 2019, weed species information was collected for each plot. Common plants identified across the site included a mix of summer annual grasses, wild carrot, common evening primrose, spotted spurge, devil's beggarticks, spotted knapweed, and white sweetclover.

On September 24, 2019, the following plots were damaged due to a nearby pavement repair operation: 107 (Piper at 10 oz/ac + Payload at 3 oz/ac + Spyder Extra at 4 oz/ac + Razor Xtreme at 32 oz/ac), 108 (Razor Xtreme at 32 oz/ac), 109 (Piper at 10 oz/ac + Razor Xtreme at 32 oz/ac), 201 (Piper at 10 oz/ac + Razor Xtreme at 32 oz/ac), and 202 (Piper at 10 oz/ac + Payload at 3 oz/ac + NuFarm Imazapic at 12 oz/ac + Razor Xtreme at 32 oz/ac). Additionally, minor damage from tire tracks were observed in plots 204 (Razor Xtreme at 32 oz/ac) and 205 (Piper at 10 oz/ac + Depth Charge at 32 oz/ac + Razor Xtreme at 32 oz/ac).
Percent total vegetative cover and stem counts were collected from only rep 3 and rep 4 and statistically analyzed. The following treatments showed 10 percent total vegetative cover or less included Esplanade 200 SC at 5 oz/ac + Method 240SL at 12 oz/ac + Razor Xtreme at 32 oz/ac (3%); Piper at 10 oz/ac + Payload at 3 oz/ac + Polaris at 24 oz/ac + Razor Xtreme at 32 oz/ac (5.25%); Milestone VM at 7 oz/ac + Esplanade 200 SC at 5 oz/ac + Razor Xtreme at 32 oz/ac

(6.25%); and Piper at 10 oz/ac + Depth Charge at 32 oz/ac + Razor Xtreme at 32 oz/ac (10%). Another treatment which showed similar percent total vegetative cover was Piper at 10 oz/ac + Payload at 3 oz/ac + Spyder Extra at 4 oz/ac + Razor Xtreme at 32 oz/ac (10.5%). Weed species identified in the Razor Xtreme at 32 oz/ac treatment included common evening primrose, wild carrot, poverty dropseed, tufted lovegrass, teasel, birdsfoot trefoil and occasionally woolly lovegrass, marestail, and common ragweed. It should be noted that marestail was only identified in Razor Xtreme at 32 oz/ac plots. Also, spotted spurge or nodding spurge was found in at least one plot in each treatment.

On April 26, stem counts per square foot ranged from 17.38 to 28.56 with no significant difference among plots (Table 2). By 30 DAT, stem counts per square foot declined and all treatments were statistically lower than Razor Xtreme at 32 oz/ac treatment. This trend continued through the last rating 148 DAT.

CONCLUSIONS

The addition of Payload at 3 oz/ac to Piper at 10 oz/ac + Razor Xtreme at 32 oz/ac did not show a reduction in percent total vegetative cover compared to Piper at 10 oz/ac + Razor Xtreme at 32 oz/ac. Both mixes provided unacceptable season long bareground control. The addition of Depth Charge to Piper at 10 oz/ac + Razor Xtreme at 32 oz/ac, or products such as NuFarm Imazapic, Polaris, or Spyder Extra to Piper at 10 oz/ac + Payload at 3 oz/ac + Razor Xtreme at 32 oz/ac, showed a reduction in percent total vegetative cover when compared to Piper at 10 oz/ac + Payload at 3 oz/ac + Razor Xtreme at 32 oz/ac. However, the Esplanade 200 SC at 5 oz/ac + Method 240SL at12 oz/ac + Razor Xtreme at 32 oz/ac treated yielded the lowest total vegetative cover (3%) at the end of the season.

MANAGEMENT IMPLICATIONS

None of the herbicide treatments provided complete season long bareground weed control. Bareground mixes containing Piper + Depth Charge + Razor Xtreme, Piper + Payload + Polaris + Razor Xtreme, Piper + Payload + Spyder Extra + Razor Xtreme, Piper + Payload + NuFarm Imazapic + Razor Xtreme may offer a preemergence site of action rotation in a bareground weed control program. Future experiments are warranted to verify long-term control. At that time, recommendations would have more data to determine feasibility.

Roadside specialist should exercise caution with treatments containing aminopyralid, aminocyclopyrachlor, and imazapyr especially on secondary roads. Damage to desirable vegetation may occur if the products are applied over the top or move into the root zones of desirable trees. Milestone VM contains statements warning of potential injury to trees or shrubs with root zones extending into the treated area[31]. Products containing aminocyclopyrachlor, i.e. Method 240SL, require judicious use due to potential of desirable plant injury caused from root systems extending into treated areas[32]. Products containing imazapyr, i.e. Polaris, should be used with caution due to the injury to plants with root systems extending into treatment areas[33].

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[31] Corteva Agrisciences. Dow Agro Sciences LLC. Milestone VM. Internet January 27, 2020.
[32] Bayer CropScience LP. Method 240SL. Internet January 27, 2020.
[33] NuFarm Americas Inc. Polaris. Internet January 27, 2020.

Table 1. Effectiveness of herbicide treatments based on percent total vegetative cover. The site was visually rated on April 26, May 29, June 26, July 29, August 29, & September 24, 2019, 0, 30, 58, 91, 122, & 148 days after treatment (DAT). Treatments were applied April 29, 2019. Methylated seed oil (MSO) was added to all treatments 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	% Total Cover 4/26/19 0 DAT	% Total Cover 5/29/19 30 DAT	% Total Cover 6/26/19 58 DAT	% Total Cover 7/29/19 91 DAT	% Total Cover 8/29/19 122 DAT	% Total Cover 9/24/19 148 DAT*
Razor Xtreme	32	26.25	31.75 b	45 b	48.75 c	57.5 b	60 b
Piper Razor Xtreme	10 32	41.25	4.25 a	6.5 a	14.38 b	8 a	15 a
Piper Payload Razor Xtreme	10 3 32	35	2.63 a	7.5 a	11.63 ab	8.75 a	18.5 a
Piper Depth Charge Razor Xtreme	10 32 32	41.25	0.2 a	0.81 a	1.75 ab	3.25 a	10 a
Piper Payload NuFarm Imazapic Razor Xtreme	10 3 12 32	36.25	1.03 a	1.75 a	1.81 ab	3.5 a	15.5 a
Piper Payload Polaris Razor Xtreme	10 3 24 32	37.5	0.58a	0.43 a	1.56 ab	3.06 a	5.25 a
Piper Payload Spyder Extra Razor Xtreme	10 3 4 32	36.25	0.3 a	0.08 a	0.15 a	1.71 a	10.5 a
Esplanade 200 SC Method 240SL Razor Xtreme	5 12 32	27.5	0.2 a	0.23 a	0.28 a	0.78 a	3 a
Milestone VM Esplanade 200 SC Razor Xtreme	7 5 32	36.25	0.78 a	1.25 a	1.5 ab	1.94 a	6.25 a
		n.s.					

* Means from 2 replications (rep #3 & rep #4).

Table 2. Effectiveness of herbicide treatments based on stem counts. Stem counts were conducted on April 26, May 29, June 26, July 29, August 29 & September 24, 2019, 0, 30, 58, 91, 122, & 148 days after treatment. Treatments were applied April 29, 2019. Methylated seed oil (MSO) was added to all treatments 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	Stem Count 4/26/19 0 DAT	Stem Count 5/29/19 30 DAT	Stem Count 6/26/19 58 DAT	Stem Count 7/29/19 91 DAT	Stem Count 8/29/19 122 DAT	Stem Count 9/24/19 148 DAT*
Razor Xtreme	32	23.56	21.25 b	18.25 b	18.06 b	13.19 b	15.63 b
Piper Razor Xtreme	10 32	17.38	2.19 a	1.63 a	1.13 a	1.5 a	1.63 a
Piper Payload Razor Xtreme	10 3 32	21.69	1.13 a	0.63 a	1.69 a	1.31 a	2.63 a
Piper Depth Charge Razor Xtreme	10 32 32	20.06	1.5 a	0.5 a	1.06 a	1.13 a	2.75 a
Piper Payload NuFarm Imazapic Razor Xtreme	10 3 12 32	25.13	0.88 a	0.81 a	1.5 a	1.88 a	2.63 a
Piper Payload Polaris Razor Xtreme	10 3 24 32	20.44	0.63 a	0.19 a	0.25 a	0.81 a	2 a
Piper Payload Spyder Extra Razor Xtreme	10 3 4 32	22	0.25 a	0.06 a	0.25 a	1.38 a	3.63 a
Esplanade 200 SC Method 240SL Razor Xtreme	5 12 32	28.56	0.19 a	0.06 a	0 a	0 a	0.5 a
Milestone VM Esplanade 200 SC Razor Xtreme	7 5 32	19.06	0.94 a	0.44 a	0.38 a	0.44 a	0.5 a
		n.s.					

* Means from 2 replications (rep #3 & rep #4).

EVALUATION OF PLAINVIEW SC, ESPLANADE SURE, AND COMMONLY USED TANK MIXES FOR TOTAL VEGETATION CONTROL

Herbicide trade and common names: RoundUp Pro (*glyphosate*), Esplanade 200 SC (*indaziflam*), Method 240SL (*aminocyclopyrachlor*), Plainview SC (*indaziflam + aminocyclopyrachlor + imazapyr*), Krovar DF (*bromacil + diuron*), Oust XP (*sulfometuron-methyl*), Esplanade Sure (*indaziflam + rimsulfuron*), Pendulum Aquacap (*pendimethalin*), CleanTraxx (*penoxsulam + oxyfluorfen*), Esplanade EZ (*indaziflam + diquat + glyphosate*)

Plant common and scientific names: wild carrot *(Daucus carota),* common evening primrose *(Oenothera biennis),* spotted spurge *(Euphorbia maculata),* devils beggarticks *(Bidens frondosa),* spotted knapweed *(Centurea stoebe var. microanthus)*, marestail *(Conyza canadensis),* teasel *(Dipsacus fullonum),* goldenrod *(Solidago spp.)* white heath aster *(Aster pilosus),* tufted lovegrass *(Eragrostis pectinacea),* stinkgrass *(Eragrostis cilianensis),* poverty dropseed *(Sporobolus vaginiflorus),* foxtail *(Setaria spp.),* witchgrass *(Panicum capillare)*

ABSTRACT

Roadside areas that require season long bareground weed control include signs, guiderails and other fixed structures. This experiment evaluated various rates of Esplanade Sure and Plainview SC in combination with RoundUp Pro in comparison with commonly used bareground weed control tank mixes for season long total vegetation control. Treatments included RoundUp Pro at 51.2 oz/ac; Esplanade 200 SC at 5 oz/ac + RoundUp Pro at 51.2 oz/ac; Esplanade Sure at 3 oz/ac + RoundUp Pro at 51.2 oz/ac; Esplanade Sure at 4.5 oz/ac + RoundUp Pro at 51.2 oz/ac; Esplanade Sure at 6 oz/ac + RoundUp Pro at 51.2 oz/ac; Pendulum Aquacap at 10 oz/ac + RoundUp Pro at 51.2 oz/ac; CleanTraxx at 48 oz/ac + RoundUp Pro at 51.2 oz/ac; Esplanade EZ at 696.96 oz/ac; 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; Krovar DF at 128 oz/ac + RoundUp Pro at 64 oz/ac; Esplanade 200 SC at 5 oz/ac + Method 240SL at 12 oz/ac + RoundUp Pro at 64 oz/ac; Plainview SC at 48 oz/ac; Plainview SC at 48 oz/ac + Oust XP at 2 oz/ac + RoundUp Pro at 64 oz/ac; and an untreated check. The following herbicide mixes showed less than 10 percent total vegetative cover, by 148 DAT: Plainview SC at 64 oz/ac + RoundUp Pro at 64 oz/ac, Plainview SC at 48 oz/ac + Oust XP at 2 oz/ac + RoundUp Pro at 64 oz/ac, Plainview SC at 48 oz/ac + RoundUp Pro at 64 oz/ac; Esplanade 200 SC at 5 oz/ac + Method 240SL at 12 oz/ac + RoundUp Pro at 64 oz/ac; Plainview SC at 32 oz/ac + RoundUp Pro at 64 oz/ac; Plainview SC at 48 oz/ac; Esplanade EZ at 696.96 oz/ac; Krovar DF at 128 oz/ac + RoundUp Pro at 64 oz/ac; and Esplanade Sure at 3 oz/ac + RoundUp Pro at 51.2 oz/ac.

INTRODUCTION

Many areas along roadsides such as under guiderails and around signposts are sprayed every spring to eliminate weeds, allow proper water flow from the roadway, and for ease of maintenance activities. Roadside specialists choose products based on site of action, current label, cost, and availability. A bareground treatment mix will include products to meet target goals of a broad-spectrum residual, preemergence, and postemergence herbicide. Some bareground mixes may use multiple herbicides to cover one goal in a successful bareground mix. While other mixes may use one herbicide to cover multiple goals in a bareground mix. In this experiment, several residual herbicide combinations were paired with RoundUp Pro to determine if combinations would provide season-long total vegetation control in bareground sites.

MATERIAL AND METHODS

The experiment was established as a randomized complete design with four replications on plots of 15 x 6 feet in size on a site located along I-99 south bound approximately ½ mile south of the SR 453 interchange near Tyrone, Pennsylvania. Treatments included RoundUp Pro at 51.2 oz/ac; Esplanade 200 SC at 5 oz/ac + RoundUp Pro at 51.2 oz/ac; Esplanade Sure at 3 oz/ac + RoundUp Pro at 51.2 oz/ac; Esplanade Sure at 4.5 oz/ac + RoundUp Pro at 51.2 oz/ac; Esplanade Sure at 6 oz/ac + RoundUp Pro at 51.2 oz/ac; Pendulum Aquacap at 10 oz/ac + RoundUp Pro at 51.2 oz/ac; CleanTraxx at 48 oz/ac + RoundUp Pro at 51.2 oz/ac; Esplanade EZ at 696.96 oz/ac; 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; Krovar DF at 128 oz/ac + RoundUp Pro at 64 oz/ac; Esplanade 200 SC at 5 oz/ac + Method 240SL at 12 oz/ac + RoundUp Pro at 64 oz/ac; Plainview SC at 48 oz/ac; Plainview SC at 48 oz/ac + Oust XP at 2 oz/ac + RoundUp Pro at 64 oz/ac; and an untreated check. Induce, a non-ionic surfactant, was added to all treatments at 0.25% v/v. Plots were 15 by 6 feet in size. Treatments were pre-measured, mixed, and applied on April 29, 2019 using a CO_2 powered backpack sprayer equipped with a six-foot boom and four 8004 VS nozzles, at 35 PSI, and delivered at 50 gallons per acre. Weather at the time of application consisted of mostly cloudy skies with some sun, wind speeds of 5-10 mph, 26% relative humidity, air temperatures of 66° F, average soil moisture and soil temperatures of 62° F, 64° F, 60° F, and 60° F at 0, 1, 3, and 6 inch depths, respectively. Local rain events occurred on April 29, 30, May 1, 3, 4, 5, and 6, 2019 with 0.01", 0.02", 0.02", 0.62", 0.32", 0.23", and 0.32" respectively, according to httpp://newa.cornell.edu. The nearest weather station was located in Rock Springs, Pennsylvania.

The experiment was visually rated for percent total vegetative cover and stem counts were conducted on April 26, May 29, June 26, July 29, August 29, and September 24, 2019, 0, 30, 58, 91, 122, and 148 DAT (days after treatment). A killing frost occurred on October 13, 2019, ending the growing season at the site. Four, 1-foot by 1-foot, subplots were established within each plot to conduct stem counts. All data were subjected 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

The guiderail site was not treated in 2018 and offered a diverse weed population. Evaluations of total vegetative cover ranged from 12 to 36.75 percent on April 26, 2019 with no significant difference among the treatments (Table 1). Total vegetative cover ranged from 0.05 to 8.5 percent for the herbicide treatments and 50 percent for the untreated check plots on May 29, 30 DAT. By August, 122 DAT, the following treatments showed less than 1 percent total vegetative cover: 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; Esplanade 200 SC at 5 oz/ac + Method 240SL at 12 oz/ac + RoundUp Pro at 64 oz/ac; and Plainview SC at 48 oz/ac + Oust XP at 2 oz/ac + RoundUp Pro at 64 oz/ac. Treatments showing less than 10 percent total vegetative cover included: Esplanade EZ at 696.96 oz/ac, Krovar DF at 128 oz/ac + RoundUp Pro at 64 oz/ac, Plainview SC at 48 oz/ac, Esplanade Sure at 3 oz/ac + RoundUp Pro at 51.2 oz/ac, and Esplanade Sure at 6 oz/ac + RoundUp Pro at 51.2 oz/ac. Esplanade 200 SC at 5 oz/ac + RoundUp Pro at 64 oz/ac showed 10.31 percent total vegetative cover. While reviewing initial results of the treatments, it was determined that a mixing error was made with the amount of Pendulum Aquacap used for the experiment. The original protocol stated 70 oz/ac Pendulum Aquacap; however, mistakenly 10 oz/ac Pendulum Aquacap was used. Pendulum Aquacap treatments showed less than expected performance in the data. Total vegetative cover for the untreated check was 72.5 percent. On August 29, 2019, weed species information was collected for each plot. Common plants identified across the site included a mix of summer annual grasses, i.e. poverty dropseed and tufted lovegrass, wild carrot, common evening primrose, spotted spurge, devils beggartick, and occasionally spotted knapweed. The weeds listed were not in every plot but frequently identified across the site.

The last rating of the experiment occurred September 24, 2019. By 148 DAT, Plainview SC at 64 oz/ac + RoundUp Pro at 64 oz/ac and Plainview SC at 48 oz/ac + Oust XP at 2 oz/ac + RoundUp Pro at 64 oz/ac showed the lowest total vegetative cover at 0.15 percent. Total vegetative cover of less than 10 percent included: Plainview SC at 48 oz/ac + RoundUp Pro at 64 oz/ac; Esplanade 200 SC at 5 oz/ac + Method 240SL at 12 oz/ac + RoundUp Pro at 64 oz/ac; Plainview SC at 32 oz/ac + RoundUp Pro at 64 oz/ac; Plainview SC at 48 oz/ac; Esplanade EZ at 696.96 oz/ac; Krovar DF at 128 oz/ac + RoundUp Pro at 64 oz/ac; and Esplanade Sure at 3 oz/ac + RoundUp Pro at 51.2 oz/ac. Esplanade Sure at 6 oz/ac + RoundUp Pro at 51.2 oz/ac showed 10.75 percent total vegetative cover. The lowest percent total vegetative cover treatments, Plainview SC at 64 oz/ac + RoundUp Pro at 64 oz/ac and Plainview SC at 48 oz/ac + Oust XP at 2 oz/ac + RoundUp Pro at 64 oz/ac, were statistically similar at 148 DAT to Plainview SC at 48 oz/ac + RoundUp Pro at 64 oz/ac; Esplanade 200 SC at 5 oz/ac + Method 240SL at 12 oz/ac + RoundUp Pro at 64 oz/ac; Plainview SC at 32 oz/ac + RoundUp Pro at 64 oz/ac; Plainview SC at 48 oz/ac; Esplanade EZ at 696.96 oz/ac; Krovar DF at 128 oz/ac + RoundUp Pro at 64 oz/ac; Esplanade Sure at 3 oz/ac + RoundUp Pro at 51.2 oz/ac, Esplanade Sure at 6 oz/ac + RoundUp Pro at 51.2 oz/ac; Esplanade Sure at 4.5 oz/ac + RoundUp Pro at 51.2 oz/ac; Esplanade 200 SC at 5 oz/ac + RoundUp Pro at 51.2 oz/ac; and Cleantraxx at 48 oz/ac + RoundUp Pro at 51.2 oz/ac. The weed species present in the untreated check plots and plots treated with only RoundUp Pro at 51.2 oz/ac or 64 oz/ac at 148 DAT included: poverty dropseed, tufted lovegrass, and occasionally stinkgrass, foxtail, and witchgrass. Other weeds identified included common evening primrose, wild carrot, marestail, and occasionally teasel, common goldenrod, white heath aster, and spotted knapweed.

The effectiveness of herbicide treatments based on stem counts (Table 2) were conducted on April 26, May 29, June 36, July 29, August 29, and September 24, 2019 representing 0, 30, 58, 91, 122, and 148 DAT. On April 26 (0 DAT), stem counts were statistically similar among the treatments and ranged from 8.5 to 26.81 stems per square foot. By 148 DAT, all herbicide treatments were statistically different from the untreated check plots.

CONCLUSION

Increasing the rate of Esplanade Sure in a mix with RoundUp Pro did not increase percent control. Evaluation of Esplanade Sure at 4.5 oz/ac + RoundUp Pro 51.2 oz/ac and Esplanade 200 SC at 5 oz/ac + RoundUp Pro at 51.2 oz/ac allows for comparison of similar indaziflam active ingredient rates in Esplanade 200 SC and Esplanade Sure and to determine the effect of rimsulfuron, in Esplanade Sure. By 148 DAT, Esplanade Sure at 4.5 oz/ac + RoundUp Pro 51.2 oz/ac showed slightly higher control compared to Esplanade 200 SC at 5 oz/ac + RoundUp Pro at 51.2 oz/ac. The increased control may be the result of the addition of rimsulfuron in Esplanade Sure. It was apparent from this initial experiment that further experiments comparing varying rates of Esplanade Sure as a total vegetation control product component is needed.

Plainview SC alone and at various rates was similar to the commonly used bareground mix Esplanade 200 SC at 5 oz/ac + Method 240SL at 12 oz/ac + RoundUp Pro at 64 oz/ac. Increasing the rate of Plainview SC increased control. The addition of Oust XP at 2 oz/ac to Plainview SC at 48 oz/ac + RoundUp Pro at 64 oz/ac increased control compared to Plainview SC at 48 oz/ac + RoundUp Pro at 64 oz/ac.

MANAGEMENT IMPLICATIONS

None of the herbicide treatments provided season long total vegetation control. The following herbicide mixes showed generally acceptable control at less than 10 percent total vegetative cover: Plainview SC at 64 oz/ac + RoundUp Pro at 64 oz/ac, Plainview SC at 48 oz/ac + Oust XP at 2 oz/ac + RoundUp Pro at 64 oz/ac, Plainview SC at 48 oz/ac + RoundUp Pro at 64 oz/ac; Esplanade 200 SC at 5 oz/ac + Method 240SL at 12 oz/ac + RoundUp Pro at 64 oz/ac; Plainview SC at 32 oz/ac + RoundUp Pro at 64 oz/ac; Plainview SC at 48 oz/ac; Esplanade EZ at 696.96 oz/ac; Krovar DF at 128 oz/ac + RoundUp Pro at 64 oz/ac; and Esplanade Sure at 3 oz/ac + RoundUp Pro at 51.2 oz/ac.

One caution to using CleanTraxx is that the label requires a 25-foot buffer between treated areas and bodies of water during ground applications[34]. Products containing aminocyclopyrachlor or imazapyr require judicious use due to potential tree or desirable plant injury caused from the root system extending into treated areas[35]. Krovar DF label warns applying the product on or near desirable trees and plants where their roots may extend into treated areas[36].

[34] Corteva agriscience. CleanTraxx. Internet February 5, 2020
[35] Bayer CropScience LP. Method 240 SL, Plainview SC. Internet February 5, 2020
[36] Bayer CropScience LP. Krovar I DF. Internet February 5, 2020

Table 1. Effectiveness of herbicide treatments based on percent total vegetative cover at 0, 30, 58, 91, 122, and 148 DAT (days after treatment). The site was visually rated on April 26, May 29, June 26, July 29, August 29, and September 24, 2019. Treatments were applied April 29, 2019. Induce, a non-ionic surfactant, 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/acre	% Total Cover 4/26/19 0 DAT	% Total Cover 5/29/19 30 DAT	% Total Cover 6/26/19 58 DAT	% Total Cover 7/29/19 91 DAT	% Total Cover 8/29/19 122 DAT	% Total Cover 9/24/19 148 DAT
Untreated	---	24.25	50 b	58.75 c	60 e	72.5 e	76.25 e
RoundUp Pro	51.2	24	8.25 a	20 b	23.5 cd	28.75 cd	33.75 cd
Esplanade 200 SC RoundUp Pro	5 51.2	20.5	5.13 a	10.75 ab	6.38 abc	10.31 abc	13.75 abc
Esplanade Sure RoundUp Pro	3 51.2	26.25	5.38 a	8 ab	6.13 abc	6 ab	7.75 ab
Esplanade Sure RoundUp Pro	4.5 51.2	20.5	7.0 a	7.63 ab	7.75 abc	11.38 abc	11.5 abc
Esplanade Sure RoundUp Pro	6 51.2	30	6.75 a	7 ab	3.63 ab	8.25 abc	10.75 ab
Pendulum Aquacap RoundUp Pro	10 51.2	24	7.88 a	20.5 b	20 bcd	25.5 bcd	28.25 bcd
CleanTraxx RoundUp Pro	48 51.2	25	1.75 a	9.5 ab	9 abc	12.75abc	20 abc
Esplanade EZ	696.96	26.5	1.15 a	1.56 a	0.59 a	1.5 a	3.63 a
RoundUp Pro	64	27.5	8.5 a	20.75 b	28.75 d	38.75 d	46.25 d
Plainview SC RoundUp Pro	32 64	28.75	0.43 a	0.53 a	0.24 a	0.88 a	1.75 a
Plainview SC RoundUp Pro	48 64	36.75	0.05 a	0.18 a	0.14 a	0.36 a	1 a
Plainview SC RoundUp Pro	64 64	12	0.08 a	0 a	0 a	0.03 a	0.15 a
Krovar DF RoundUp Pro	128 64	22.5	0.14 a	0 a	0.43 a	2.63 a	5.5 ab
Esplanade 200 SC Method 240SL RoundUp Pro	5 12 64	33.75	0.3 a	0.28 a	0.3 a	0.71 a	1.15 a
Plainview SC	48	26.25	2.13 a	1.75 a	1.25 a	3.13 a	2.88 a
Plainview SC Oust XP RoundUp Pro	48 2 64	21.25	0.05 a	0 a	0.05 a	0.11 a	0.15 a
		n.s.					

Table 2. Effectiveness of herbicide treatments based on stem counts at 0, 30, 58, 91, 122, and 148 DAT (days after treatment). The stem counts were conducted on April 26, May 29, June 26, July 29, August 29, and September 24, 2019. Treatments were applied April 29, 2019. Induce, a non-ionic surfactant, 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/acre	Stem Count 4/26/19 0 DAT	Stem Count 5/29/19 30 DAT	Stem Count 6/26/19 58 DAT	Stem Count 7/29/19 91 DAT	Stem Count 8/29/19 122 DAT	Stem Count 9/24/19 148 DAT
Untreated	---	16.63	48.25 d	58.38 c	38.38 d	74.13 b	39.25 c
RoundUp Pro	51.2	22	10.69 bc	10.75 b	14.56 c	12.44 a	10 b
Esplanade 200 SC RoundUp Pro	5 51.2	11.94	3 abc	2.19 ab	2.25 ab	1.81 a	1.63 a
Esplanade Sure RoundUp Pro	3 51.2	12.19	2.0 a	1.69 ab	2.06 ab	1.56 a	1.5 a
Esplanade Sure RoundUp Pro	4.5 51.2	17.25	2.13 a	1.81 ab	1.75 a	1.19 a	1 a
Esplanade Sure RoundUp Pro	6 51.2	14.44	0.69a	0.75 a	0.63 a	0.5 a	0.5 a
Pendulum Aquacap RoundUp Pro	10 51.2	13.69	5.88 abc	4.88 ab	5.31 ab	5.31 a	5.63 ab
CleanTraxx RoundUp Pro	48 51.2	17.38	2.44 ab	3.25 ab	3.5 ab	3.69 a	3.31 ab
Esplanade EZ	696.96	26.81	0.5 a	0.13 a	0.38 a	0.63 a	0.63 a
RoundUp Pro	64	20	11.31 c	9.69 ab	11 bc	10.31 a	9.38 b
Plainview SC RoundUp Pro	32 64	16.31	0.38 a	0 a	0.06 a	0.88 a	0.69 a
Plainview SC RoundUp Pro	48 64	13.25	0 a	0 a	0.06 a	0.13 a	0.31 a
Plainview SC RoundUp Pro	64 64	8.5	0 a	0 a	0 a	0 a	0a
Krovar DF RoundUp Pro	128 64	16.63	0.13 a	0 a	0.38 a	1.75 a	2.31 a
Esplanade 200 SC Method 240SL RoundUp Pro	5 12 64	18.06	0.06 a	0 a	0 a	0 a	0a
Plainview SC	48	16.06	0.56 a	0.06 a	0 a	0.19 a	0.38 a
Plainview SC Oust XP RoundUp Pro	48 2 64	16.75	0 a	0 a	0 a	0 a	0 a
		n.s.					