Roadside Vegetation Management Research – 2019 Report

ANNUAL REPORT

June 30, 2019

By Jeffrey C. Jodon, 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: Comparison of Aminocyclopyrachlor, Aminopyralid, and Two Formulations of Triclopyr for Control of Autumn Olive (*Elaeagnus umbellata*) Using Low Volume Foliar Treatments, Second Year, Evaluation of Brush Control Herbicides on Control of Exotic Shrub Honeysuckle- First Year, The Effects of Commonly Used Herbicides on and Competitive Turfgrass Ground Cover for Long Term suppression of Spotted Knapweed (*Centurea stoebe var. microanthus*)- Second Year, Efficacy of Glufosinate, Glyphosate, and Combinations of Glufosinate plus Glyphosate, Evaluation of Seed Mixes and Seeding Methods for Overseeding Low Growing Turf Groundcover Around Cable Guiderail - Second Year, Conversion of Existing Roadside Turf to a Low Growing Fine Fescue Groundcover Around Cable Guiderails, Low Maintenance Turfgrass Species and Cultivar Comparison, Comparison of Plainview SC and Commonly Used Tank Mixes for Season-Long Bareground Control.

17. Key Words
Roadside vegetation management, herbicides, brush control, autumn olive, honeysuckle, spotted knapweed, glyphosate, glufosinate, fine fescue, groundcovers, bareground, Plainview SC

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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 http://plantscience.psu.edu/research/projects/vegetative-management.

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, EC=emulsifiable concentrate, ME=microencapsulated, RTU = ready to use, S=water soluble, SC = soluble concentrate, SG = soluble granule, SL = soluble liquid, WG, WDG=water-dispersible granules.

Trade Name	Active Ingredients	Formulation	Manufacturer
Accord XRT II	glyphosate	5.07 S	Dow AgroSciences LLC
DMA 4 IVM	2,4-D	3.8 S	Dow AgroSciences LLC
Escort XP	metsulfuron methyl	60 DF	Bayer Environmental Science
Esplanade	indaziflam	1.67 SC	Bayer Environmental Science
Finale	glufosinate	1 S	Bayer Environmental Science
Freelexx	2,4-D choline	3.8 S	Dow AgroSciences LLC
Garlon 3A	triclopyr amine	3 S	Dow AgroSciences LLC
IAF-RIS	indazflam + rimsulfuron	24.3 + 16.7 WDG	Bayer Environmental Science
Method 50 SG	aminocyclopyrachlor	50 SG	Bayer Environmental Science
Method 240 SL	aminocyclopyrachlor	2 SL	Bayer Environmental Science
Milestone VM	aminopyralid	2 S	Dow AgroSciences LLC
Oust XP	sulfmeturon	75 DG	Bayer Environmental Science
Plainview SC	indaziflam+aminocyclopyrachlor+imazapyr	0.18+0.5+1.51 SC	Bayer Environmental Science
Roundup Pro Concentrate	glyphosate	5 S	Monsanto Company
Triplet LO	2,4-D+mecoprop-p +dicamba	47.3 +8.2 + 2.3 S	Nufarm Americas, Inc.
Vastlan	triclopyr choline	4 S	Dow AgroSciences LLC

COMPARISON OF AMINOCYCLOPYRACHLOR, AMINOPYRALID, AND TWO FORMULATIONS OF TRICLOPYR FOR CONTROL OF AUTUMN OLIVE *(ELAEAGNUS UMBELLATA)* USING LOW VOLUME FOLIAR TREATMENTS, SECOND YEAR RESULTS

Herbicide trade and common names: Garlon 3A (*triclopyr amine*); Method 50 SG (*aminocyclopyrachlor*); Method 240 SL (*aminocyclopyrachlor*); Milestone VM (*aminopyralid*); Vastlan (triclopyr choline).

Plant common and scientific names: autumn olive (*Elaeagnus umbellata* ELGUM).

ABSTRACT

Autumn olive ranks among the most difficult to control brush species found along the roadside in Pennsylvania. 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 herbicides for control of autumn olive. The experiment evaluated the performance of Garlon 3A, Method 50 SG, Method 240 SL, Milestone VM, and Vastlan. Treatments included Method 240 SL at 4.8 oz/ac, 9.6 oz/ac, and 19.2 oz/ac; Milestone VM at 4.8 oz/ac and 9.6 oz/ac; Method 50 SG at 4.8 oz/ac; Garlon 3A at 128 oz/ac; Vastlan at 96 oz/ac; and an untreated check. Methylated seed oil, FS MSO Ultra, at 1% v/v was added to all herbicide treatments. The application was made at a carrier volume of 15 gallons per acre, GPA. The amount of herbicide applied to the shrubs was based on the calculated canopy area of the plants in that treatment. Initial control of autumn olive ranged from 18% to 98.3% at 34 DAT (days after treatment). At 729 DAT, Garlon 3A had the best control at 49.3% while Vastlan resulted in 48.1% control. The triclopyr formulations, Garlon 3A (amine) or Vastlan (choline), were the most effective treatments throughout the experiment.

INTRODUCTION

Autumn olive (Elaeagnus umbellata) is a problematic brush species on a roadside ROW. After mowing or cutting autumn olive, it will vigorously resprout, spreading and crowding out desirable vegetation which can reduce visibility for motorists and impede maintenance operations. Autumn olive has characteristics which make it a formidable pest. Plants can reach 11 feet in height and fruit prolifically with birds dispersing the seeds beyond the immediate area. Elaeagnus is a nitrogen fixing small tree or shrub species which aids its establishment and growth in poor soil conditions found along the roadside.

MATERIALS AND METHODS

An experiment was established at the Penn State Agronomy Farm located at the Russell E. Larson Agricultural Research Center near Rock Springs, PA. Treatments included Method 240 SL at 0.25% v/v (4.8 oz/ac), 0.5% v/v (9.6 oz/ac) and 1% v/v (19.2 oz/ac); Milestone VM at 0.25% v/v (4.8 oz/ac) and 0.5% v/v (9.6 oz/ac); Method 50 SG at 4.8 oz/ac; Garlon 3A at 6.67% v/v (128 oz/ac); Vastlan at 5.0% v/v (96 oz/ac); and an untreated check. Methylated seed oil, FS MSO Ultra, at 1% v/v was added to all herbicide treatments. The application was made at a carrier volume of 15 gallons per acre (GPA). The amount of herbicide applied to the shrubs was based on the calculated canopy area of the plants in that treatment. The canopy measurements can be found in Table 1. Autumn olive plants selected for the trial had a maximum height of 128 inches, a minimum height of 28 inches and averaged 64 inches tall. The experiment was established with 10 plants per treatment for a total of 90 plants arranged in a completely randomized design. Treatments were applied using a CO_2-powered sprayer equipped with an AA30 GunJet 30 spray gun, TeeJet adjustable ConeJet nozzle, and Y-2 tip operating at 36 psi. The autumn olive was treated on August 9, 2016.

Percent control (0 = no injury, 100 = complete necrosis) of autumn olive was visually rated on September 12, 2016, October 17, 2016, September 6, 2017, and August 8, 2018; 34, 69,393, and 729 DAT.

RESULTS AND DISCUSSION

Initial control of autumn olive ranged from 18% to 98.3% at 34 DAT (Table 2). Similar percent control (17.5% to 98.9%) was observed at 69 DAT. All treatments produced lower percent control (1.3% to 73%) by 393 DAT compared to the 69 DAT rating. By 729 DAT percent control continued to decrease, ranging from 0.6% to 49.3%, and differences between treatments were no longer significant. The triclopyr formulations, Garlon 3A (amine) or Vastlan (choline), were the most effective treatments throughout the experiment. At 729 DAT, Garlon 3A had the best control at 49.3% while Vastlan offered 48.1% control. The least effective treatment was Milestone VM at 9.6 oz/ac (0.5% v/v) with 0.6% control. Method 50 SG at 4.8 oz/ac consistently outperformed Method 240 SL at 9.6 oz/ac (0.5% v/v), even though they contained the same amount of active ingredient. Milestone VM at 4.8 oz/ac was consistently more effective than Milestone VM at 9.6 oz/ac. Overall trends for all herbicide treatments include: an increase in percent control from 34 DAT to 69 DAT and a decrease in percent control from 69 DAT to 729 DAT. In general, shrubs which were not completely killed appeared to be growing sprouts and foliage with normal appearance and vigor. Resprouting of autumn olive from lower branches and roots resulted in decreased control at 393 and 729 days.

CONCLUSIONS

Increasing Method 240 SL rates from 4.8 oz/ac to 19.6 oz/ac increased percent control of autumn olive. Milestone VM at 4.8 oz/ac was more effective than Milestone VM at 9.6 oz/ac. Garlon 3A at 128 oz/ac and Vastlan at 96 oz/ac were more effective than Method 240 SL, Milestone VM, and Method 50 SG at all rates tested. Across treatments, it appears that autumn olive plants which were not completely killed were able to resprout, resulting in a decrease in control over time.

MANAGEMENT IMPLICATIONS

Of the products tested, Garlon 3A at 128 oz/ac and Vastlan at 96 oz/ac were the best performers, although at 729 DAT they both achieved less than 50 % control. Both formulations of Method along with Milestone produced less than 40 percent control at 729 DAT. Utilizing tanks mixes of herbicides or higher carrier volumes could improve results. Caution should be used when using products that contain aminocyclopyrachlor due to soil activity and potential injure nearby desirable trees. Also, caution should be exercised when using aminopyralid due to the potential for injury to nearby leguminous trees and shrubs as well as other species listed on the label or supplemental literature from DOW AgroSciences.

Table 1. Stem canopy area and height of plant. Each plant is an individual treatment for a total of 9 treatments. Each treatment was replicated 10 times. Area = (average diameter/2)^2*3.14.

Stem No.	Treatment	Area (sq. ft.)	Height (ft.)	Stem No.	Treatment	Area (sq. ft.)	Height (ft.)
1	2	7	6	46	7	15	5.8
2	8	2	2.8	47	3	18	7.7
3	9	7	5.1	48	9	24	6
4	3	3	5.2	49	1	5	4.8
5	6	16	5.5	50	8	20	7.7
6	1	7	4.7	51	4	6	6.2
7	7	6	3.8	52	6	2	2.9
8	4	13	6	53	5	14	9.2
9	5	1	3.2	54	2	8	4.5
10	6	10	3.8	55	4	11	6
11	7	1	6.3	56	5	12	6.5
12	8	15	10.7	57	2	8	6.5
13	2	3	3.8	58	6	8	7.7
14	9	3	3.8	59	3	4	4.2
15	1	49	8.5	60	7	1	3.8
16	5	14	4.8	61	1	15	6.2
17	4	27	5.8	62	8	5	9
18	3	7	7.8	63	9	2	4
19	4	11	5	64	9	9	8.5
20	1	29	7.7	65	4	8	5.8
21	9	7	4.2	66	6	13	7.7
22	7	6	5.5	67	8	24	6
23	2	4	3.3	68	2	4	7.2
24	8	9	3.8	69	5	7	8.1
25	5	4	2.8	70	7	14	6
26	6	15	7.7	71	3	11	5.7
27	3	26	9.3	72	1	2	3.3
28	2	14	4.7	73	7	5	5.7
29	5	27	6.3	74	1	6	5.2
30	1	20	7	75	6	8	2.9
31	9	6	2.8	76	2	3	3
32	3	11	6.2	77	8	3	2.7
33	7	9	8.5	78	5	1	3.2
34	6	10	6.8	79	9	7	5.2
35	8	9	6.5	80	3	9	3.3
36	4	9	4.2	81	4	2	4.2
37	4	6	5	82	1	11	4.5
38	1	4	3	83	3	11	3.5
39	5	4	3.2	84	5	6	6.2
40	2	4	2.9	85	9	6	2.8
41	3	15	9	86	2	7	2.8
42	6	9	3.7	87	7	7	4.5
43	7	3	5	88	4	11	6.2
44	9	4	2.3	89	8	2	5.5
45	8	3	4.7	90	6	8	4.5

Table 2. Percent control of autumn olive (*Elaeagnus umbellata* ELGUM). Percent control was visually rated as percent defoliation of autumn olive. Treatments were applied August 9, 2016 at 15 gallons per acre. All treatments included methylated seed oil, FS MSO Ultra at 1 % v/v. Percent control of autumn olive was visually rated on September 12, 2016, October 17, 2016, September 6, 2017 and August 8, 2018; 34, 69, 393 and 729 DAT (days after treatment) respectively. Each value is the mean of ten replications. Means within columns followed by the same letter are not significantly different at $p \leq 0.05$.

Treatment	Rate oz/ac	% v/v	Percent Control 34 DAT	Percent Control 69 DAT	Percent Control 393 DAT	Percent Control 729 DAT
Untreated	--	--	0 a	0 a	0.2 a	1.2
Method 240 SL	4.8	0.25	39.5 bc	47 bc	32.2 ab	24.3
Method 240 SL	9.6	0.5	19.5 ab	35 abc	28.9 ab	17.5
Method 240 SL	19.2	1.0	61 cd	63.5 cd	42 ab	39.3
Milestone VM	4.8	0.25	36.5 abc	41 bc	33.5 ab	27.1
Milestone VM	9.6	0.5	18 ab	17.5 ab	1.3 a	0.6
Method 50 SG	4.8	--	53 bc	64.5 cd	34.5 ab	34.4
Garlon 3A	128	6.67	98.3 e	98.9 d	60.5 b	49.3
Vastlan	96	5.0	92.5 de	94.8 d	73 b	48.1
						n.s.

EVALUATION OF BRUSH CONTROL HERBICIDES ON CONTROL OF EXOTIC SHRUB HONEYSUCKLE- FIRST YEAR

<u>Herbicide trade and common names:</u> DMA 4 IVM (*2,4-D*); Roundup (*glyphosate*); Garlon 3A (*triclopyr*)
<u>Plant common name and scientific name:</u> 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, Garlon 3A at increasing rates, and Garlon 3A tank mixed with DMA 4 IVM. After the first growing season, Roundup 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. 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 honeysuckles were introduced in the 1800's as an ornamental and were up until recently planted as a food and cover crop for wildlife. Even though the native shrub honeysuckle species were higher in nutritional value than the exotics[1]. The increase in planting of exotic shrub honeysuckles were further spread by birds feeding on the berries and spreading the seed, which remain viable for several years. One key identification characteristic used to separate native and non-native shrub honeysuckle species is that the pith is solid when a stem is broken among native species, whereas, the pith of non-native honeysuckle is hollow. Previous brush control research applying a combination of brush control herbicides through a side trimming application to mimic a typical truck spray pattern employed for brush control appeared partially effective on shrub honeysuckle; however, the results were inconclusive.[2,3] This experiment was designed to determine the effectiveness of Roundup, Garlon 3A, DMA4 IVM and a mix of Garlon 3A plus DMA 4 IVM when applied to the entire shrub.

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 at 128 oz/ac, 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

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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.

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 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 hand gun 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, 2018, and September 11, 2018, 31 and 65 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, 31 DAT. The untreated check plots averaged over 5 percent injury due to leaf spots. By 65 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 at 128 oz/ac, resulted in 99% injury by 65 DAT. The least effective treatment was Garlon 3A at 64 oz/ac. The most effective treatment was Roundup at 128 oz/ac. In comparison, the untreated check increased to 29.99 percent injury at 65 DAT. Suggesting that the wet conditions found during the summer of 2018 was also promoting foliar disease among the bush 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.

CONCLUSIONS

Roundup at 128 oz/ac, DMA 4 IVM at 128 oz/ac, and Garlon 3A at 384 oz/ac were effective treatments after the first growing season. However, Roundup is a total vegetation herbicide that will control desirable vegetation as well and creates bareground below shrubs when applied as a foliar application. Garlon 3A and DMA 4 IVM are grass safe broadleaf herbicides. Further data collection will determine the long term effectiveness of the treatments to control the shrub honeysuckle and prevent resprouting.

Table 1. Percent injury of honeysuckle (Lonicera spp.). The experiment was visually rated for percent injury on August 8, 2018, (31 days after treatment, DAT) and percent control on September 11, 2018, (65 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 $p \leq 0.005$.

Treatment	Rate (oz/ac)	% Injury 8/8/18 31 DAT	% Injury 9/11/18 65 DAT
Untreated	--	5.56 a	29.44 a
DMA 4 IVM	128	91.78 bc	99.78 b
Roundup	128	99.33 c	99.89 b
Garlon 3A	64	63.78 b	86.67 b
Garlon 3A	128	75.33 bc	93.67 b
Garlon 3A	384	97.33 c	99 b
Garlon 3A DMA 4 IVM	64 128	87 bc	98.78 b

THE EFFECTS OF COMMONLY USED HERBICIDES AND COMPETITIVE TURFGRASS GROUNDCOVER FOR LONG TERM SUPPRESSION OF SPOTTED KNAPWEED *(Centurea stoebe var. microanthus)* - SECOND YEAR

Herbicide trade and common names: Method 240 SL (*aminocyclopyrachlor*), Method 50 SG (*aminocyclopyrachlor*), Garlon 3A (*triclopyr amine*), Vastlan (*triclopyr choline*), DMA 4 IVM (*2,4-D*), Freelexx (*2,4-D choline*), Milestone VM (*aminopyralid*)

Plant common and scientific names: spotted knapweed (*Centaurea stoebe var. microanthos, synonym C. maculosa,* CETMA)

ABSTRACT

Spotted knapweed, an invasive biennial weed, can outcompete native plant species as well as desirable roadside vegetation. This experiment evaluated herbicides, herbicide combinations, and competitive turf cover for efficacy against spotted knapweed. The treatments were 64 oz/ac DMA 4 IVM plus 64 oz/ac Garlon 3A; 64 oz/ac Freelexx plus 64 oz/ac Garlon 3A; 64 oz/ac DMA 4 IVM plus 48 oz/ac Vastlan; 8 oz/ac Method 240 SL; 4 oz/ac Method 50 SG; and 7 oz/ac Milestone. Initially, spotted knapweed was found covering 45-68% of the treatment area. By 64 days after treatment, all treatments except DMA 4 IVM and Vastlan resulted in rosette coverage of 0.1 to 9% of the treatment plots representing a decrease in coverage from 59.9 to 36%, respectively among treatments. On September 19, 2017, each 20 foot by 6-foot plot was subdivided into two 10-foot by 6-foot subplots. The lower subplots were seeded to Formula L and the upper subplots were not seeded. By 369 days after treatment, percent spotted knapweed cover ranged from 0.13 to 66.25%. The 4 oz/ac Method 50 SG plus seeded Formula L treatment yielded the lowest percent cover (0.13%) of spotted knapweed, although not statistically different from other seeded treatments and two of the non-seeded treatments: 4 oz/ac Method 50 SG and 8 oz/ac Method 240 SL.

INTRODUCTION

Spotted knapweed is a Eurasian introduced invasive biennial or short-lived perennial plant found throughout the United States and Canada and is becoming increasingly common on the roadsides of Pennsylvania. Spotted knapweed is typically found in full sun on dry, gravelly, or sandy sites, especially following disturbance. Colonization is aided by long seed viability and heavy seed production averaging 1,000 to 5,000 seeds per plant.[4,5] Spotted knapweed has the potential to establish, spread, and reduce native plant populations. One of the reasons that spotted knapweed is able to compete so effectively with native vegetation is that it is reported to have allelopathic characteristics that include the ability to exude catechin, a phenolic secondary metabolite from its root system that will effectively act as an herbicide to native plants or

[4] Spotted Knapweed https://mdc.mo.gov/sites/default/downloads/9530_6467.pdf Viewed 2/13/2018
[5] Spotted Knapweed http://paflora.org/original/pdf/INV-Fact%20Sheets/Centaurea%20maculosa.pdf Viewed 2/1/18

existing groundcovers.[6] This experiment was initiated to evaluate herbicides and herbicide mixes for effectiveness in controlling spotted knapweed. The scope of the experiment expanded to include the effect of seeding a competitive turfgrass groundcover for long term suppression of spotted knapweed following herbicide treatment.

METHODS AND MATERIALS

The experiment was established on the shoulder of the entrance ramp to SR 322 W at Old Fort, just east of State College, PA. Six herbicide treatments were tested including: 64 oz/ac DMA 4 IVM plus 64 oz/ac Garlon 3A; 64 oz/ac Freelexx plus 64 oz/ac Garlon 3A; 64oz/ac DMA 4 IVM plus 48 oz/ac Vastlan; 8 oz/ac Method 240 SL; 4 oz/ac Method 50 SG; 7 oz/ac Milestone; and an untreated check. All herbicide treatments included a non-ionic surfactant at 0.25 percent v/v. Plots of 20-feet by 6-feet were arranged in a randomized complete block design with four replications. Herbicides were applied at 30 gallons per acre on July 7, 2017, using a CO_2 powered backpack sprayer with a 6-foot boom equipped with 4 8002 VS nozzles. Initial percent spotted knapweed cover was recorded on July 7, 2017, on day of treatment. The percent spotted knapweed injury was recorded on August 8, 2017, 32 days after treatment (DAT). The percent cover by spotted knapweed rosettes was recorded 64 DAT on September 9, 2017. All data were subject to analysis of variance, and when treatments effect F-tests were significant ($p \leq 0.05$), treatment means were compared using Tukey's HSD separation test.

On September 19, 2017, each 20-foot by 6-foot plot was subdivided into two 10-foot by 6-foot subplots. The lower subplots were seeded to Formula L and the upper subplots were not seeded to determine the effect of a competitive groundcover on controlling spotted knapweed. The soil on the lower subplots of each plot was loosened with a disc harrow pulled by a Kubota tractor, Formula L seed was broadcast seeded at 48 lbs./1000 sq. yd. The seeded plots were fertilized according to soil test recommendations at 1lb. N per 1000 sq. ft., and straw blankets were rolled out over the area and secured.

On July 11, 2018, 369 DAT, the seeded and non-seeded plots were visually rated for percent spotted knapweed cover. Additionally, two 2-foot by 2-foot sampling units were identified in each seeded and non-seeded plots and spotted knapweed stem counts were conducted.

RESULTS AND DISCUSSION

The initial spotted knapweed percentage cover ranged from 45 to 68 percent with no significant difference between treatment plots (Table 1). The percent injury rating recorded on August 8, 2017, 32 DAT, ranged from 65 to 99 percent. Method 240 SL applied at 8 oz/ac and Method 50 SG applied at 4 oz/ac provided the highest level of injury to spotted knapweed at 99 and 96 percent, respectively. The September 9, 2017 (64 DAT) rating of the percent spotted knapweed rosette cover within each treatment plot showed the lowest cover among the Method treatments (Method 240 SL and 50 SG at 0.1%, 0.4%, respectively) followed by Milestone at 2%, and DMA4 IVM plus Garlon 3A and Freelexx plus Garlon 3A at 9% cover. The percent

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[6] Colorado State University. "Weed Takes Over by Triggering Other Plants to Self-Destruct". ScienceDaily. ScienceDaily, 9 September 2003. <www.sciencedaily.com/2003/09/030909071258.html>

reduction in spotted knapweed cover (Table 1) during the 2017-growing season is a comparison between the percent cover by mature flowering stems and rosettes at the start of the experiment and the percent cover by rosettes present on September 9, 2017. Method 240 SL at 8 oz/ac, DMA 4 IVM at 64 oz/ac plus Garlon 3A at 64 oz/ac and Milestone VM at 7 oz/ac treatments all showed a percent reduction in spotted knapweed cover ranging between 87 and 100. DMA 4 IVM at 64 oz/ac plus Vastlan at 48 oz/ac produced the smallest percent reduction in spotted knapweed cover (54) of all of the chemical treatments.

Data collected on July 11, 2018, 369 DAT, showed percent spotted knapweed cover in plots seeded with Formula L (64 DAT after the initial herbicide treatments, July 7, 2017) ranged from 0.13 to 21.25% (Table 2). The percent spotted knapweed cover in non-seeded plots ranged from 10% to 66.25%. Plots seeded to Formula L showed reduced percent spotted knapweed cover across all herbicide treatments when compared to the same herbicide treatments in non-seeded plots. Similarly, the average spotted knapweed stem counts in the plots seeded with Formula L yielded less stems (1 to 3.63) than the plots not seeded (1.8 to 38.38).

We evaluated the effect of seeding or non-seeding following the initial herbicide treatment for percent control of spotted knapweed (Table 3). By 369 DAT, percent spotted knapweed cover ranged from 0.13% to 66.25%. Method 50 SG at 4 oz/ac plus seeded Formula L yielded the lowest spotted knapweed cover (0.13%) but was statistically similar to the other herbicide plus Formula L seeding treatments and the untreated (no herbicide) plus Formula L seeded treatment. The untreated plus Formula L seeding was statistically similar to all the other treatments except the untreated and non-seeded treatment. Overall, the untreated, formula L seeded plots had less than 1/3 of the spotted knapweed cover compared to untreated, non-seeded plots at 369 DAT (21.25 and 66.25, respectively). The take away message being that seeding alone without herbicide applications provides a competitive advantage in growth over spotted knapweed and could be used to prevent spotted knapweed colonization.

CONCLUSIONS

All herbicide treatments were effective and reduced the amount of spotted knapweed cover. The greatest control was provided by Method 50 SG at 4 oz/ac plus seeded Formula L and Method 240 SL at 8 oz/ac plus seeded Formula L. Seeding a competitive turfgrass groundcover after herbicide applications appear to reduce spotted knapweed cover by limiting the number of germinating seedlings.

MANAGEMENT IMPLICATIONS

The herbicide treatments Method 240 SL, Method 50 SG, DMA 4 IVM plus Garlon 3A, and Milestone VM provided good control of spotted knapweed. We recommend that managers establish competitive turfgrass ground cover to limit seed germination and re-establishment of spotted knapweed. This experiment demonstrated that seeding two months after herbicide treatments didn't appear to affect turfgrass seed germination and establishment. Caution should be used when using Method 240 SL. The label recommends using rates, not to exceed, 4-8 oz/ac to avoid turfgrass damage. Spotted knapweed will not be controlled with one herbicide application. Successive applications with a turf safe herbicide will be needed to deplete the seedbank of spotted knapweed. Establishment of a competitive turfgrass ground cover will compete against spotted knapweed or other weeds for open space, reduce the number of germinating weed seedlings, and if the terrain permits allow for mowing and/or broadleaf weed applications without leaving the area void of vegetation.

Table 1. Percent cover and injury to spotted knapweed (*Centaurea stoebe var. micranthos* CETMA). The experiment was visually rated for initial cover and treatments were applied on July 7, 2017. Percent knapweed injury was visually rated August 8, 32 days after treatment, DAT. Percent cover by knapweed rosettes was visually rated September 9, 2017, 64 DAT. The % reduction spotted knapweed was calculated using the formula [(initial spotted knapweed cover (0 DAT)-cover spotted knapweed rosettes (64 DAT))/ initial spotted knapweed cover (0 DAT) x 100]. All treatments included 0.25% v/v non-ionic surfactant (i.e. Induce). Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

	Knapweed				
Treatment	Rate oz/ac	% Cover by Spotted Knapweed* 7/7/17 0 DAT	% Injury 8/8/17 32 DAT	% Cover by Spotted Knapweed Rosettes 9/19/17 64 DAT	% Reduction in Spotted Knapweed Cover**
Untreated		48	10 a	46 b	4.2
Milestone VM	7	59	65 b	2 a	97
DMA 4 IVM Vastlan	64 48	52	67 b	24 ab	54
DMA 4 IVM Garlon 3A	64 64	68	76 b	9 a	87
Freelexx Garlon 3A	64 64	45	80 b	9 a	80
Method 50 SG	4	48	96 b	0.4 a	99
Method 240 SL	8	60	99 b	0.1 a	100
		n.s.			

*The spotted knapweed population consisted of mature flowering plants and young rosettes.
**Change in cover from 0 DAT to 64 DAT.

Table 2. Percent spotted knapweed (*Centaurea stoebe var. microanthos* CETMA) cover seeded subplot, percent spotted knapweed cover non-seeded subplot, average stem count before treatments (0 DAT), average spotted knapweed stem count seeded subplot, average spotted knapweed stem count non-seeded subplot. The initial stem count were collected July 7, 2017 using three 2 foot by 2 foot sampling units per plot. The plots were divided in half on September 9, 2017 and the lower subplots were seeded to Formula L at 48 lb/1000 yd^2 and the upper subplots were not seeded. The experiment was visually rated for percent knapweed cover and knapweed stem counts were collected July 11, 2018, 369 DAT. Two 2 foot by 2 foot sampling units were identified in each seeded and non-seeded subplot. 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	Rate oz/ac	% Spotted Knapweed Cover Seeded 7/11/18 369 DAT	% Spotted Knapweed Cover Non Seeded 7/11/18 369 DAT	Spotted Knapweed Stem Count 7/7/17 0 DAT	Spotted Knapweed Stem Count Seeded 7/11/18 369 DAT	Spotted Knapweed Stem Count Non Seeded 7/11/18 369 DAT
Untreated	--	21.25 ab	66.25 b	56.42	15.25 b	38.38 c
Milestone VM	7	2.63 a	31.25 ab	36.08	0.75 a	7 ab
DMA 4 IVM Garlon 3A	64 64	4.75 a	38.25 ab	59.25	0.63 a	18 ab
DMA 4 IVM Vastlan	64 48	10.5 ab	42.50 ab	30.00	3.63 a	21.63 bc
Freelexx Garlon 3A	64 64	10.5 ab	41.25 ab	42.67	2.13 a	15.88 ab
Method 50 SG	4	0.13 a	17.5 a	29.00	0.0 a	5.13 ab
Method 240 SL	8	0.63 a	10.0 a	47.75	0.0 a	1.88 a
				n.s.		

Table 3. Percent spotted knapweed (*Centaurea stoebe var. microanthos* CETMA) cover and percent turfgrass cover following herbicide and seeding treatment. The herbicide treatments were applied on July 7, 2017. The plots were divided in half on September 9, 2017 and the lower plots were seeded to Formula L at 48 lb./1000 yd^2 and the upper plots were not seeded. The herbicide treatments were applied on July 7, 2017. The experiment was visually rated for percent knapweed cover and percent turfgrass cover on July 11, 2018, 369 days after treatment, DAT. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/ac	Formula L	% Spotted Knapweed Cover 7/11/18 369 DAT	% Turfgrass Cover 7/11/18 369 DAT
Untreated	--	Seeded	21.25 abcd	57.5 b
DMA 4 IVM Garlon 3A	64 64	Seeded	4.75 ab	67.5 b
Freelexx Garlon 3A	64 64	Seeded	10.5 abc	62.5 b
DMA 4 IVM Vastlan	64 48	Seeded	10.5 abc	61.25 b
Method 240 SL	8	Seeded	0.63 a	65 b
Method 50 SG	4	Seeded	0.13 a	52.5 b
Milestone	7	Seeded	2.63 ab	75 b
Untreated	--	Non-seeded	66.25 e	0a
DMA 4 IVM Garlon 3A	64 64	Non-seeded	38.25 cde	0a
Freelexx Garlon 3A	64 64	Non-seeded	41.25 de	0a
DMA 4 IVM Vastlan	64 48	Non-seeded	42.5 de	0a
Method 240 SL	8	Non-seeded	10 abc	0a
Method 50 SG	4	Non-seeded	17.5 abcd	0a
Milestone VM	7	Non-seeded	31.25 bcd	2.75 a

EFFICACY OF GLUFOSINATE, GLYPHOSATE, AND COMBINATIONS OF GLUFOSINATE PLUS GLYPHOSATE

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

Plant common and scientific names: fine fescues *(Festuca species,* 1FESG*),* tall fescue *(Schedonorus arundinaceum* synonym *Festuca arundinacea,* FESAR*)*, Kentucky bluegrass *(Poa pratensis,* POAPR*)*, buckhorn plantain *(Plantago lanceolate,* PLALA*)*, dandelion *(Taraxacum officinale,* TAROF*)*, yellow wood sorrel *(Oxalis strictata,* OXAST*)*, American burnweed *(Erechtites hieraciifolia,* EREHI*)*, and crabgrass species *(Digitalis spp.,* 1DIGG*),* henbit *(Lamium amplexicaule,* LAMAM*)*, yarrow *(Achillea millefolium,* ACHMI*)*, red clover *(Trifolium pretense,* TRFPR*)*, white clover *(Trifolium repens,* TRFRE*)*, and black medic *(Medicago lupulina,* MEDLU*)*

ABSTRACT

Evidence in row crops specifically in areas in Roundup ready no-till production systems are common, glyphosate resistant species have been reported from prolonged and repeated applications of glyphosate. To counteract the potential effect of glyphosate some are advocating the use of Finale (active ingredient glufosinate) as an alternative or in combination with glyphosate to reduce the development of resistance. Previous research has reported that Finale, a limited translocatable contact herbicide when added in a tank mix with glyphosate, the effectiveness of the glyphosate may be reduced because of antagonism The following experiment was designed to evaluate the efficacy of various rates of Finale (glufosinate) alone and combinations of various rates of Finale and Accord XRT II (glyphosate) at 48 oz/ac on a typical roadside stand of turfgrass and broadleaf weeds. One goal of the experiment was to determine if antagonism between the two products. The highest percent injury produced by Finale at 16 oz/ac was 38.33% at 3 days after treatment (DAT) and Finale at 32 oz/ac was 70% at 7 DAT. After the injury produced by both rates of Finale alone peaked, phytotoxicity gradually declined to the point where at 21 DAT the injury was statistically similar to the untreated check. By 21 DAT, all treatments that contained glyphosate produced statistically similar levels of injury.

INTRODUCTION

Along with the development and adoption of Roundup ready field crops in no-till farming, there has been an increase in reports of glyphosate resistance weeds due to the prolonged, repeated use of glyphosate (http://wssa.net/wssa/weed/resistance/). As of publication there have been no confirmed cases of glyphosate resistant weeds found in roadside right-of-way (ROW). Glyphosate is a key component of a successful bareground program. Bareground programs consist of three components: a pre emergence herbicide, a broad spectrum residual herbicide, and a post emergence herbicide. To counteract the potential effect of glyphosate some are advocating the use of Finale (active ingredient glufosinate) as an alternative or in combination with glyphosate to reduce the development of resistance.[7,8] Previous research has reported that Finale added in a tank mix with glyphosate has been antagonistic to effective weed control by limiting the translocation of glyphosate into the root system of the weed (Besancon et. al. 2018)[9]. Glyphosate is a systemic non-selective herbicide. Once applied, the chemical is absorbed by the leaves and translocated throughout the plant including the roots. Glufosinate, described as locally systemic or limited translocatable product is absorbed by the leaf and moves only within the leaf contacted by the spray. Therefore, glufosinate does not move into the root system. The question is whether glufosinate will inhibit glyphosate movement into the root system and to what extent? This report describes the results of an experiment designed to evaluate the efficacy and antagonism of various rates of Finale (glufosinate) alone and in combination with Accord XRT II (glyphosate).

MATERIALS AND METHODS

The experiment was established at the Penn State Horticulture Research Farm located within the Russell E. Larson Agricultural Center in Rock Springs, PA. Treatments included Finale at 16 oz/ac, Finale at 32 oz/ac, Finale at 16 oz/ac plus Accord XRT II at 48 oz/ac, Finale 32 oz/ac plus Accord XRT II at 48 oz/ac, Finale at 48 oz/ac plus Accord XRT II at 48 oz/ac, Finale at 64 oz/ac plus Accord XRT II at 48 oz/ac, and Accord XRT II at 48 oz/ac. A non-ionic surfactant (i.e. Induce) was added to all herbicide treatments at 0.25% v/v. Treatments were applied at an application volume of 50 gallons per acre to plots measuring 6 by 3 foot. The experiment was established as a randomized complete block design with three replications. Treatments were applied on May 29, 2018 using a CO_2 powered sprayer equipped with a six foot boom and four 8004 VS tips. At application, the sky was partly cloudy, temperature 84° F, with 60% relative humidity. The soil moisture was average and the soil temperature at 0" was 82°F, at 1" was 76°F, at 3" was 72°F, and at 6" was 69°F. The plant species present at the time of application included: tall fescue, Kentucky bluegrass, fine fescues species, buckhorn plantain, broadleaf plantain, dandelion, henbit, yarrow, red clover, white clover, and black medic.

The site was visually rated for percent injury or control on June 1, 3 days after treatment (DAT); June 5, 7 DAT; June 11, 13 DAT; June 19, 21 DAT; June 26, 28 DAT; July 3, 35 DAT; July 10 42 DAT; and July 17, 49 DAT. All data were subject to analysis of variance, and when treatment effects F-tests were significant ($p \leq 0.05$) treatment means were compared using Tukey's HSD separation test.

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[7] https://agriculture.basf.com/en/Crop-Protection/Innovation-Herbicides/Glufosinate-Ammonium/Benefits-Glufosinate-Ammonium/Fighting-weed-resistance.html BASF. Fighting weed resistance. Viewed April 9, 2019

[8] https://nam01.safelinks.protection.outlook.com/?url=http%3A%2F%2Fgrounds-mag.com%2Fmag%2Fgrounds_maintenance_finale_vs_roundup%2F&data=02%7C01%7Cjcj107%40psu.edu%7C7ef7ac0148b54e71a57608d6b9f0a18e%7C7cf48d453ddb4389a9c1c115526eb52e%7C0%7C0%7C636900840479873930&sdata=AHIpLmZWRTUEsnLxBr19NOWxZS5CVXHPmjoK9%2BaXCvQ%3D&reserved=0 Grounds Maintenance. Viewed April 9, 2019

[9] Thierry E. Besançon, DONALD PENNER, and Wesley J. Everman
Source: Weed Science, 66(2) : 159-167 https://bioone.org/journals/Weed-Science/volume-66/issue-2/wsc.2017.72/Reduced-Translocation-is-Associated-with-Antagonism-of-Glyphosate-by-Glufosinate/10.1017/wsc.2017.72.full

RESULTS AND DISCUSSION

Initial percent injury rating at 3 DAT ranged from 26.67% (Accord XRT II at 48 oz/ac) to 71.67% (Finale at 64 oz/ac + Accord XRT II at 48 oz/ac). Finale at 16 oz/ac produced a peak percent injury of 38.33% 3 DAT. Finale at 32 oz/ac peak percent injury was 70% 7 DAT. After 7 DAT percent injury from both rates of Finale gradually declined to the point where at 21 DAT both Finale rates were statistically similar to the untreated check. At 35 DAT, both treatments had 0.5 % injury.

In comparing treatment results of Finale plus Accord XRT II at 48 oz/ac and comparing it to Accord XRT II at 48 oz/ac alone 7 DAT the percent injury ranged from 16.67 (Finale at 16 oz/ac) to 90 (Finale 64 oz/ac + Accord XRT II at 48 oz/ac). Finale at 16 oz/ac was similar to the untreated check. Finale at 32 oz/ac was similar to all treatments except Finale at 16 oz/ac. By 21 DAT, there was no statistical difference between the various rates of Finale (16 oz/ac, 32 oz/ac, 48 oz/ac, and 64 oz/ac) + Accord XRT II when compared to Accord XRT II alone. From 35 DAT to 49 DAT, percent control reduced due regrowth of some grass not completely killed by the treatments and germination of summer annual grasses and broadleaf weed seedlings.

Species remaining in the plots on August 13, 2018, 76 DAT based on treatment were fine fescue, tall fescue, Kentucky bluegrass, buckhorn plantain, and dandelion in the Finale at 32 oz/ac. The Finale at 32 oz/ac + Accord XRT at 48 oz/ac treatment plots contained, fine fescue species, tall fescue, Kentucky bluegrass, buckhorn plantain, dandelion, yellow wood sorrel, American burnweed, and crabgrass species. Finale at 48 oz/ac + Accord XRT at 48 oz/ac treatment plots consisted of fine fescue species, tall fescue, buckhorn plantain, yellow wood sorrel and crabgrass species and Accord XRT at 48 oz/ac plots included yellow wood sorrel, crabgrass species, and dandelion remaining after treatment.

CONCLUSIONS

Treatments of Finale alone burned down plant top growth but did not kill the plant. Both Finale treatments resulted in injury within 7 DAT and by 49 DAT there was nearly no injury to the treated area. Although statically similar, the percent injury/control by Finale (16, 32, 48, 64 oz/ac) + Accord XRT II was lower than Accord XRT II alone suggesting that antagonism between the herbicides may have made the mixture less effective than glyphosate alone.

MANAGEMENT IMPLICATIONS

Based on this experiment we do not recommend tank mixing glufosinate and glyphosate due to the limited long-term effectiveness of glufosinate and the antagonistic potential of glufosinate in glyphosate effectiveness. In addition, glufosinate additions, increases the cost of the control program by its price and its antagonism to glyphosate. In our view it is not cost effective to add glufosinate into the PennDOT bareground program. We do believe that judicious use of glyphosate and rotating the bareground mixes may be a more effective approach to preventing resistance along the roadside.

Table 1. Percent injury or control was visually rated as percent necrosis. Treatments were applied May 29, 2018 at 50 gallons per acre. All treatments included 0.25% v/v non-ionic surfactant. Treatments were visually rated for percent injury or control on June 1, 3 DAT (days after treatment); June 5, 7 DAT; June 11, 13 DAT; June 19, 21 DAT; June 26, 28 DAT; July 3, 35 DAT; July 10, 42 DAT; and July 17, 49 DAT. Each value is the mean of three replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product Rate	Percent Injury/ Control 6/1/18 3DAT	Percent Injury/ Control 6/5/18 7 DAT	Percent Injury/ Control 6/11/18 13 DAT	Percent Injury/ Control 6/19/18 21 DAT	Percent Injury/ Control 6/26/18 28 DAT	Percent Injury/ Control 7/3/18 35 DAT	Percent Injury/ Control 7/10/18 42 DAT	Percent Injury/ Control 7/17/18 49 DAT
Untreated	0.0 a	0.0 a	0.0 a	0.33 a	0.0 a	0.17 a	0.0 a	0.0 a
Finale 16 oz/ac	38.33 bc	16.67 a	8.33 a	4 a	2.67 a	0.5 a	0.23 a	0.1 a
Finale 32 oz/ac	65 cd	70 bc	22.5 ab	10 a	6 a	0.5 a	0.3 a	0.1 a
Finale 16 oz/ac + Accord 48 oz/ac	38.33 bc	51.67 b	45 b	70 b	66.67 b	80 b	78.33 b	75 b
Finale 32 oz/ac + Accord 48 oz/ac	68.33 cd	86.67 c	81.67 c	78.33 b	81.67 b	86.67 b	78.33 b	61.67 ab
Finale 48 oz/ac + Accord 48 oz/ac	68.33 cd	88.33 c	88.33 c	83.33 b	88.67 b	87.67 b	77.67 b	71.67 b
Finale 64 oz/ac + Accord 48 oz/ac	71.67 d	90 c	86.67 c	81.67 b	76.67 b	76 b	76 b	61.67 ab
Accord 48 oz/ac	26.67 ab	71.67 bc	85 c	93.33 b	97.33 b	98.33 b	97.67 b	89 b

EVALUATION OF SEED MIXES AND SEEDING METHODS FOR OVERSEEDING LOW GROWING TURF GROUNDCOVER AROUND CABLE GUIDERAILS - SECOND YEAR

Herbicide trade and common names: Triplet L.O.: 2,4-D + Mecoprop-p + Dicamba

Plant common and scientific names: annual ryegrass *(Lolium multiflorum,* LOLMU*),* creeping red fescue *(Festuca rubra L.,* FESRU*),* hard fescue *(Festuca brevipila,* FESBR*)*, sheep fescue *(Festuca ovina L.,* FESOV*)*

Seed Mixes: Formula L: 35% creeping red fescue, 55% hard fescue, 10% annual ryegrass
Modified Formula L: 35% creeping red fescue, 55% sheep fescue, 10% annual ryegrass
Sheep fescue: 100% sheep fescue

ABSTRACT

Vegetation management under cable guiderails is challenging because mowing around these structures may require high levels of labor or specialized equipment, while the traditional approach of applying herbicides to create bareground as under traditional shoulder guiderails often leads to erosion when applied to the newer cable guiderail system in turf in medians. One solution would be to convert the vegetation under the cable guiderails to low growing turf to reduce mowing cycles. Creeping red fescue and hard fescue, found in PennDOT Formula L are reliable, low maintenance turf species. Sheep fescue has shown promise as a low growing groundcover in previous research[10]. The goal of this study was to test three seed mixes and three seeding methods for successful establishment of low maintenance turf near cable guiderails. The seed mixes tested included PennDOT Formula L, modified Formula L (hard fescue replaced with sheep fescue), and sheep fescue alone. The seeding methods included broadcast seeding, slice seeding with a slice seeder attached to a tractor and soil preparation with a disc harrow attached to a tractor followed by broadcast seeding. At the end of the first growing season, modified Formula L was the most successful seed mix and disc/ broadcast was the most successful seeding method. At the end of the second growing season there was no significant difference between seed mix or seeding method.

INTRODUCTION

Cable guiderails are being constructed in the medians of limited access roadways across Pennsylvania as a means of preventing vehicles from crossing into the path of oncoming traffic. Vegetation management under cable guiderails is challenging because the traditional approach of creating and maintaining bareground under the shoulder guiderail is often not suitable for these structures. The placement of the cable guiderails in the median is often on sloped and easily erodible ground, so disturbing the vegetation can result in severe loss of soil. Mowing under the rail requires specialized equipment or large amounts of labor. One possible solution is to convert the vegetation under the guiderails to a low growing competitive turf species such as creeping red fescue and hard fescue found in PennDOT Formula L. Sheep fescue, another low

[10] Johnson, J. M. et al 2016. Comparing Spring Seeded Formula L Seed Mix at Two Rates and Sheep Fescue for Groundcover Establishment in a Roadside Application – First Year Results. Roadside Vegetation Management Research – 2016 Report. pp 42-44.

growing grass species, has shown promise as a competitive ground cover in previous research. To avoid the potential for soil erosion while the new turf is being established, seed was applied as an overseeding process to existing turf. The purpose of this experiment was to test seeding methods and seed mixes for potential to establish under cable guiderail in the presence of existing turf cover. This paper presents first and second year results following spring seeding.

MATERIALS AND METHODS

The experiment was initiated at two sites in central Pennsylvania in 2017. One is approximately one mile north of State College, in the median of I-99 near the Shiloh Road exit (hereafter called Shiloh Road). The second site, also in the median of I-99 is located 12 miles south of State College near the Port Matilda exit (hereafter called Port Matilda). Both sites had cable guiderails in the median that had been installed for three or more years. The three seeding methods tested were broadcast seeding with no soil preparation, overseeding with an Olathe model 93 slice seeder attached to a Kubota 2500 tractor, and soil preparation with a disc harrow attached to a Kubota 2500 tractor followed by broadcast seeding. Plots at Port Matilda were 12 by 42 feet while plots at Shiloh Road were 12 by 20 feet. Three seed mixes were also tested: PennDOT Formula L, modified Formula L (sheep fescue replaced the hard fescue component), and sheep fescue alone. The Shiloh Road and Port Matilda sites were seeded the week of April 17, and April 24, respectively. Formula L and modified Formula L were seeded at 48 lb per 1000 sq. yd. Sheep fescue was seeded at 54 lb per 1000 sq. yd. Complete fertilizer was applied to all plots according to soil test recommendations at 1 lb. nitrogen per 1000 sq. ft. Fall ratings were conducted on September 21 and September 28 for Port Matilda and Shiloh Road, respectively. Triplet L.O. was applied at 2 quarts per acre on July 25 and July 27 at the Shiloh Road and Port Matilda sites, respectively. Ratings were performed using a sampling method. At Port Matilda, each plot was visually rated using four fixed sub-plots, one square meter in size, while at Shiloh Road, three, one square meter fixed sub-plots were rated. In 2018, spring ratings occurred on June 8 at Shiloh Road and June 12 at Port Matilda. The fall ratings occurred on October 23 at Shiloh Road and October 22 at Port Matilda. The Port Matilda site received a Triplet L/O application at a rate of 2 quarts per acre to control broadleaf weeds on August 7, 2018. All data were subject 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 interaction between seed mix and seeding method was not statistically significant. In other words, the effect of the type of seed mix used did not depend on the seeding method and correspondingly, the effect of the seeding method did not depend on the seed mix used. The main effects are described as follows. At the Shiloh Road site, disc / broadcast seeding produced the best results with a 11.3% increase in fine fescue turf cover followed by slice seeder (8.4%), and broadcast (5.6%) (Table 1). Modified Formula L produced the largest increase in fine fescue cover (12.8%), followed by Formula L (6.4%), and sheep fescue (6%) (Table 2).

At the Port Matilda site, the disc/ broadcast seeding method produced the greatest increase (18.2%) in fine fescue turf cover, followed by broadcast seeding (8.1%), and slice seeding (6.4%) (Table 3). An anomaly showing that the turf cover in the untreated check plots increased slightly more than the disc/broadcast seeded plots was likely due to inaccuracy in the visual rating of the turf cover. The modified Formula L seed mix produced the greatest increase in fine fescue cover (12.7%), followed by Formula L (10.3%), and sheep fescue (9.6%) at the Port Matilda site (Table 4). Sheep fescue has been reported to perform better in seed mixes than when used alone[11]. This may help explain why plots seeded to modified Formula L had the largest increase in fine fescue cover at both sites (12.8 and 12.7 percent), but plots seeded to sheep fescue alone showed the smallest increase (6 and 9.6 percent).

Soil preparation with a disc harrow followed by broadcast seeding proved to be the most effective seeding method of the three methods tested in this experiment. The disc harrow opened up cuts in the sod so that seed could come in contact with bare soil. Slice seeding is designed to achieve the same goal with less soil disturbance as it deposits seed in the slits created as the machine moves forward. The slice seeder may have been set to cut and deposit seed too deeply for optimum germination. Recommendations suggest seeding sheep fescue to a depth of ¼ inch or less and hard fescue to a depth of ½ inch or less and advise that sheep fescue seedlings may be difficult to find until the second year of establishment.[12] Broadcast seeding requires little or no special equipment. The biggest drawback to broadcast seeding into an existing turf cover is placing the seed in good contact with the soil. Mowing prior to seeding to reduce the canopy cover and leaf surface area along with using a leaf blower to remove clippings can help expose soil and encourage better seed soil contact and seed germination. Pulling a cultipacker or roller over the site after seeding may aid in germination and establishment by pressing the seed into the soil.

Conditions and soils at the two sites were quite different. The Port Matilda site was much more exposed to wind and weather and had coarse textured soil that appeared to have originated from shale which was visible on a nearby embankment. Shiloh Road, on the other hand was situated on a median with a drainage swale down the middle and was protected from wind because much of the median was below the level of the roadway. Soil was heavier and drained more slowly than that of the Port Matilda site. Even with these differences, overall, across three seed types and all seeding methods, there was no significant difference between the two sites in terms of increase in fine fescue cover at season end, with Port Matilda and Shiloh Road showing increases of 10.5 and 9.0 percent, respectively.

In 2018 during the second growing season after the seeding treatments, the Shiloh Road and Port Matilda sites were visually rated for percent fine fescue cover. The Shiloh Road site (Table 5) 560 DAT showed an overall increase in the percent fine fescue cover for all treatments compared to the initial rating at 0 DAT. There appears to be an anomaly in fine fescue cover ratings between 560 DAT and 423 DAT in that the cover ratings dropped after 423 DAT. This change in cover may be attributed to incorrectly identifying Kentucky bluegrass as a fine fescue. Since this was a mixed stand of Kentucky bluegrass, tall fescue, and fine fescue and in early growth in late spring Kentucky bluegrass can be confused with fine fescue it is presumed that during rating the differences were not readily observed. In addition, the check (control untreated) plots at the Shiloh Road site were away from the guiderail due to limited available space on the

[11] http://www.roads.maryland.gov/OPR_Research/MD-16-SHA-UMCES-6-3_Turfgrass_Report.pdf
[12] USDA Natural Resource Conservation Service Plant Guide. http://www.wwccd.net/wp-content/uploads/2015/08/Sheep-Fescue.pdf

guide rail and only one of the four control replicates were found and rated in 2018. . The fine fescue cover at the Port Matilda site (Table 6) 545 DAT also showed an increase for all treatments compared to the initial (0 DAT) percent fine fescue cover.

CONCLUSIONS

After the first season, modified Formula L has proven to establish the best among the seed mixes tested. Cover ratings will continue to determine how the seed mixes fill-in over time. This experiment represents the first step and first year in defining a suitable planting method for use under median cable guiderails where overseeding fine fescue into a tall fescue bluegrass mix has been attempted. This was a chance to look at low maintenance fine fescue seed types for establishment, cover, maintenance quality and aesthetic value near cable guiderails.

After the second growing season, there was no difference in seed mix or seeding method. All treatments increased the percent of fine fescue cover compared to the initial percent fine fescue cover.

MANAGEMENT IMPLICATIONS

The modified Formula L and the standard Formula L both performed well enough to be considered for use as a low growing groundcover under cable guiderails. After the first year, cutting the sod with a disc harrow followed by broadcast seeding was the best method for seeding into existing turf tested in this experiment. However, after the second year the seeding method was not significant, meaning there was no difference from the different seeding methods in this experiment. The importance of some type of soil preparation cannot be overstated. Seed soil contact is essential for successful germination and establishment of any type of turfgrass.

Table 1. Turf cover based on seeding method for the Shiloh Road site. Plots were visually rated for cover. The initial rating was done on April 12 and the fall rating was conducted on September 28. Seeding occurred the week of April 17. Each value is the mean of 4 replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$

Seeding Method	Percent Total Turf Cover 4/12/17	Percent Fine Fescue Cover 4/12/17	Percent Fine Fescue Cover 9/28/17	Change in Cover 2017 Growing Season
Broadcast	53.2 a	18.1 a	23.7 a	5.6
Slice Seeder	58.1 a	23.1 a	31.5 a	8.4
Disc/Broadcast	60.4 a	21.4 a	32.7 a	11.3
Unseeded Check	75 b	40 b	57.7 b	17.7
				n.s.

Table 2. Turf cover based on seed mix for the Shiloh Road site. Plots were visually rated for cover. The initial rating was done on April 12 and the fall rating was conducted on September 28. Seeding occurred the week of April 17. Each value is the mean of 4 replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Seed Type	Percent Total Turf Cover 4/12/17	Percent Fine Fescue Cover 4/12/17	Percent Fine Fescue Cover 9/28/17	Change in Cover 2017 Growing Season
Formula L	60.3 a	22.7 a	29.1 a	6.4
Modified Formula L	53.6 a	17 a	29.8 a	12.8
Sheep Fescue	57.8 a	23.1 a	29.1 a	6.0
				n.s.

Table 3. Turf cover based on seeding method for the Port Matilda site. Plots were visually rated for cover. The initial rating was done on April 24 and the fall rating was conducted on September 21. Seeding occurred the week of April 24. Each value is the mean of 4 replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$

Seeding Method	Percent Total Turf Cover 4/26/17	Percent Fine Fescue Cover 4/24/17	Percent Fine Fescue Cover 9/21/17	Change in Cover 2017 Growing Season
Broadcast	38.8 ab	16.4 a	24.4 ab	8.1 a
Slice Seeder	34.3 a	15.9 a	22.2 a	6.4 a
Disc/Broadcast	46.1 b	32.9 b	51.1 c	18.2 b
Unseeded Check	34.1 a	23 ab	42.6 bc	19.6 b

Table 4. Turf cover based on seed mix for the Port Matilda site. Plots were visually rated for cover. The initial rating was done on April 24 and the fall rating was conducted on September 21. Seeding occurred the week of April 24. Each value is the mean of 4 replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$

Seed Type	Percent Total Turf Cover 4/26/17	Percent Fine Fescue Cover 4/26/17	Percent Fine Fescue Cover 9/21/17	Change in Cover 2017 Growing Season
Formula L	36.1	23.4	33.8	10.3
Modified Formula L	39.9	17.5	30.2	12.7
Sheep fescue	43.1	24.2	33.8	9.6
	n.s.	n.s.	n.s.	n.s.

Table 5. Fine fescue cover at the Shiloh Road site. The site was initially visually rated for percent fine fescue cover April 12, 2017. The plots were seeded the week of April 17, 2017. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Method	Seed Mix	% Fine fescue cover 4/12/17 0 DAT	% Fine fescue cover 9/28/17 170 DAT	% Fine fescue cover 6/8/18 423 DAT	% Fine fescue cover 10/23/18 560 DAT
Broadcast	Formula L	20.25 ab	25.67 a	44.17 a	47.5 b
Broadcast	Modified L	15 a	20.02 a	40.83 a	40.84 b
Broadcast	Sheep fescue	19.17 a	25.42 a	59.17 ab	43.75 b
Slice Seed	Formula L	23.17 ab	31.25 ab	59.42 ab	40.83 b
Slice Seed	Modified L	20.83 ab	30.58 ab	58 ab	37.5 b
Slice Seed	Sheep fescue	25.42 ab	32.75 ab	56 ab	42.08 b
Disc, Broadcast	Formula L	24.58 ab	30.42 ab	55.58 ab	45.67 b
Disc, Broadcast	Modified L	15.08 a	38.75 ab	50.83 a	38.75 b
Disc, Broadcast	Sheep fescue	24.58 ab	29 ab	51.42 a	37.08 b
Untreated	--	40 b	57.67 b	73.25 b	1.25 a

Table 6. Fine fescue cover at the Port Matilda site. The plots were initially visually rated April 26, 2017. The plots were seeded by April 28, 2017. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Method	Seed Mix	% Fine fescue cover 4/26/17 0 DAT	% Fine fescue cover 9/21/17 149 DAT	% Fine fescue cover 6/12/18 413 DAT	% Fine fescue cover 10/22/18 545 DAT
Broadcast	Formula L	15.44 ab	24.97 ab	35.75	26.88 ab
Broadcast	Modified L	12.63 a	23.38 ab	29.25	20.19 a
Broadcast	Sheep fescue	21 ab	24.88 ab	37.19	29.47 ab
Slice Seed	Formula L	16.75 ab	21.38 a	38.06	36.88 ab
Slice Seed	Modified L	14.51 ab	19.88 a	37.06	24.38 ab
Slice Seed	Sheep fescue	16.32 ab	25.47 ab	37.88	30.94 ab
Disc, Broadcast	Formula L	38.06 b	54.94 b	54.25	52.38 b
Disc, Broadcast	Modified L	25.31 ab	47.31 ab	44.63	44.75 ab
Disc, Broadcast	Sheep fescue	35.38 ab	51.13 ab	52.25	50.16 ab
Untreated	--	23 ab	42.56 ab	41.31	38.47 ab
				n.s.	

CONVERSION OF EXISTING ROADSIDE TURF TO A LOW GROWING FINE FESCUE GROUNDCOVER AROUND CABLE GUIDERAILS

Plant common and scientific names: tall fescue (*Schedonorus arundinaceus*, FESAR), Kentucky bluegrass (*Poa pratensis*, POAPR), creeping red fescue (*Festuca rubra*, FESRU), bentgrass (*Agrostis spp*, 1AGR), hard fescue (*Festuca brevipilia*, FESBR), annual ryegrass (*Lolliom multiflorum*, LOLMG)

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 seeding 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 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. The fall seeded fine fescue showed initial establishment rates were similar to spring seeded plots. Further data will be collected in subsequent years.

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 seeding timing (i.e. spring versus fall seeding) into established turf cover under cable guiderail with the intention to convert the ground cover under the guiderail. The goal of this experiment is to establish a permanent, sustainable low growing fine fescue ground cover near cable guiderails. This paper summarizes the first year results of the spring seeded plots and the establishment of the fall seeded plots.

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[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

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.

In addition, the time of year for seeding was evaluated. The spring seeding was completed May 11, 2018 and the 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/seed 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 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. 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.

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 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 evaluated on October 30, 2018, 26 DAT. Plots were 20 feet by 6 feet. 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

The percent turfgrass cover before treatment (0 DAT) ranged from 55% to 65.67% and the percent fine fescue cover ranged from 0% to 2.33% with no statistical significance between treatments for the spring seeded plots (Table 1). By 63 DAT, percent turfgrass cover ranged from 89.42% to 94.83%. The percent fine fescue cover ranged from 0% to 8.33%. There was no statistical significance between the seeded treatments based on percent fine fescue 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% with no significance between treatments and percent fine fescue cover ranged from 0.06% to 2.33%. By the end of the first growing season, the spring seeded plots revealed the effects of seeding a slow to establish turf 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.

For the fall seeded plots, the percent turfgrass cover before treatment (0 DAT) ranged from 65.42% to 72.5% and the percent fine fescue cover ranged from 0 to 0.02%. By 26 DAT, the percent turfgrass cover ranged from 70.83% and 87.5%. The fine fescue cover ranged from 0% (untreated check) to 9.83% (disc/broadcast modified formula L). Fine fescue cover for the two highest treatments (disc/broadcast modified formula L and disc/broadcast formula L) were significantly different from all other treatments. All other treatments were statistically similar to the untreated check based on percent fine fescue cover.

CONCLUSIONS

At the start of this experiment, the expectation was fine fescue would establish into the existing turf by the end of the growing season. Even though there was initial establishment of spring seeded fine fescue, by the end of the season, very little fine fescue survived in the plots. The experimental site has a competitive stand of tall fescue and Kentucky bluegrass. Successful seedling establishment requires good seed to soil contact, light, and adequate rainfall. It appears that the spring seeded fine fescue simply could not compete with the established turf. The fine fescue seeding methods that were most successful in this experiment were no-till drill and disc/broadcast. The fall seeded plots once again demonstrated adequate initial germination and establishment of fine fescue . Further evaluations in spring 2019 will look at second year results for all plots. More frequent mowing may allow the fine fescue to successfully compete with existing turf. Future experiments may include evaluating the effect of more frequent mowing during the establishment period and treating plots with herbicides to suppress or eliminate the existing turf prior to seeding .

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. 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 DAT and September 27, 2018, 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 check	--	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. Fall seeded percent turf and fine fescue cover. 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 check	--	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.		

LOW MAINTENANCE TURFGRASS SPECIES AND CULTIVAR COMPARISON

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

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

ABSTRACT

Low maintenance turfgrass species are used along roadsides to provide dense vegetation which helps to control erosion and limit weed invasion. This experiment compared 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'; two forage tall fescues: 'K-31' and 'Fawn'; as well as buffalograss 'Bowie', as potential low maintenance turfgrass groundcovers. At the end of the first growing season, for all characteristics that were evaluated, except for turfgrass color, K-31 was the best performer; however, K-31 was not significantly different from the turf-type tall fescue cultivars tested in this experiment. 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.

INTRODUCTION

Roadside soils are often compacted, consisting of nonuniform 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. 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 list; 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) [17,18] 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. 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 buffalograss 'Bowie'. 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 Round*up* Pro at 64 ounces per acre (oz/ac) in a carrier volume of 50 gallons per acre (GPA) with a pressure of 36 psi (pounds per square inch) using a CO_2 powered backpack sprayer with a six foot boom equipped with four 8004VS nozzles. The plots were retreated with Round*up* 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 conditions at the time of seeding were slightly above average soil moisture and 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. The first mowing of the experimental site occurred October 16, 2018 with a zero turn rotary mower, 5 inch height of cut.

The plots were visually rated for percent turfgrass cover, percent weed cover, and turfgrass density on July 10, August 6, September 5, and October 10, 2018; 34, 61, 91, and 126 days after seeding (DAS). 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). Additionally, 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). Color reflects the

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[17] 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.

[18] 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.

inherent genetic color of the entry, not yellowing or browning due to mowing, drought stress, disease, etc. 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) 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, buffalograss 'Bowie' 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) was rated 34 and 61 DAS. By 34 DAS seedling vigor ranged from 1.5 to 7.3; buffalograss 'Bowie' 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.

Percent turfgrass cover, of cultivars seeded per plot, was rated 34, 61, 91, and 126 DAS (Table 3). All entries, except unnamed sheep fescue cultivar, increased in percent turfgrass cover between 34 and 126 DAS. At every rating, 'K-31' tall fescue was the top performer. By 126 DAS, percent turfgrass cover ranged from 37.5 ('Marco Polo' sheep fescue) to 87 ('K-31' tall fescue). 'Marco Polo' sheep fescue was statistically similar to the other two sheep fescue and buffalograss 'Bowie'. 'K-31' tall fescue was statistically similar to all other tall fescue entries.

The percent weed cover 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%. On August 7, 2018 (62 DAS), Triplet L/O at 64 oz/ac with Induce at 0.25% was applied to all plots to control broadleaf weeds. By 126 DAS, weed cover ranged between 2.75-17%. Buffalograss 'Bowie' had the highest weed cover at 17% and was statistically similar to the sheep fescues. 'K-31' tall fescue had the lowest weed cover at 2.75% and was significantly better than buffalograss 'Bowie'.

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 during the growing season allowing the cultivars to germinate and establish under above average soil moisture conditions. In fact, the rainfall for 2018 registered as the wettest year on record for Pennsylvania[19].

[19] https://www.weather.gov/ctp/RecordPrecip2018 February 14, 2019

All tall fescue entries germinated best among the species evaluated and provided acceptable turfgrass cover 126 days after seeding. The turf-type tall fescues were similar to 'K-31' tall fescue; however, 'K-31' tall fescue remained the best overall in density, vigor, and turf cover.

The three sheep fescue entries were slow to establish and did not provide greater than 50% 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.[20]

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.

MANAGEMENT IMPLICATIONS

After the establishment phase of this experiment, turf-type tall fescue shows promise as a turfgrass groundcover; however, more work needs to be done. Considering that the sheep fescues are slow to establish, their performance was acceptable during the first growing season. Over the next several years, additional data will be collected to determine the differences between the turfgrass species and cultivars to provide the basis for recommendations.

[20] 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.

Table 1. Turfgrass color and seedling vigor. The experiment was visually rated for turfgrass color on July 10, 2018, 34 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). 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	Cultivar	Turfgrass Color 7/10/18 34 DAS	Seedling Vigor 7/10/18 34 DAS	Seedling Vigor 8/6/18 61 DAS
Sheep fescue	Quatro	8.5 b	4.8 ab	4.8 ab
Sheep fescue		8.8 b	5.3 b	4.5 ab
Sheep fescue	Marco Polo	8.3 b	3.8 ab	3.3 a
Tall fescue	K-31	8.3 b	7.3 b	8.5 b
Tall fescue Turf type	Arid 3	9 b	6 b	7 ab
Tall fescue Turf type	No-Net	9 b	6.3 b	7 ab
Tall fescue	Fawn	8.3 b	6.8 b	8.3 b
Tall fescue Turf type	Technique	9 b	6.3 b	8 b
Tall fescue Turf type	Patagonia	8.8 b	6.3 b	8 b
Buffalograss	Bowie	6.5 a	1.5 a	4.3 ab

Table 2. Turfgrass density. The experiment was visually rated for turfgrass density, on a scale from 1-10 (1=minimum turfgrass plants or tillers/ft^2-10=maximum turfgrass plants or tillers/ft^2), on July 10, August 6, September 5, and October 10, 2018; 34, 61, 91, and 126 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. Percent turfgrass cover. The experiment was visually rated for percent turfgrass, on July 10, August 6, September 5, and October 10, 2018; 34, 61, 91, and 126 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, 62 DAS, 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 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 4. Percent 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, and 126 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, 62 DAS, 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	% 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.	

COMPARISON OF PLAINVIEW SC AND COMMONLY USED TANK MIXES FOR SEASON-LONG BAREGROUND CONTROL

Herbicide trade and common names: Plainview SC *(indaziflam, aminocyclopyrachlor, imazapyr)*, Esplanade 200 SC *(indaziflam)*, Method 240 SL (*aminocyclopyrachlor)*, Cleantraxx *(penoxsulam, oxyfluorfen)*, Milestone VM *(aminopyralid)* Oust XP *(sulfometuron-mehtyl)*, IAF-RIS *(indaziflam, rimsulfuron)*, Roundup Pro Concentrate *(glyphosate)*

Plant common and scientific names: foxtail (*Setaria* spp, 1SETG); spotted knapweed (*Centaurea stoebe var. micranthos*, CENBB); witchgrass (*Panicum capillare*, PANCA); quackgrass (*Elytrigia repens*, AGRRE); birdsfoot trefoil (*Lotus corniculatus*, LOTCU); Canada thistle (*Cirsium arvense*, CIRAR); crownvetch (*Coronilla varia*, CRZVA); common mullein (*Verbascum thapsus*, VESTH); tall fescue (*Lolium arundinaceum*, FESAR); poison hemlock (*Conium maculatum*, COIMA); wild carrot (*Daucus carota*, DAUCA); wild parsnip (*Pastinaca sativa*, PAVSA)

ABSTRACT

Bareground weed control, an essential program within roadside vegetation management, relies on herbicides to provide season-long weed control. This experiment evaluated a variety of commonly used tank mixes for bareground weed control as well as various rates of Plainview SC alone and in combination with Roundup Pro. Treatments included Roundup Pro at 51.2 oz/ac; Plainview SC at 32 oz/ac + Roundup Pro at 51.2 oz/ac; Plainview SC at 48 oz/ac + Roundup Pro at 51.2 oz/ac; Plainview SC at 64 oz/ac + Roundup Pro at 51.2 oz/ac; Esplanade 200 SC at 5 oz/ac + Roundup Pro at 32 oz/ac; Esplanade 200 SC at 5 oz/ac + Method 240 SL at 12 oz/ac + Roundup Pro at 51.2 oz/ac; Esplanade 200 SC at 5 oz/ac + Method 240 SL at 12 oz/ac + Oust XP at 3 oz/ac + Roundup Pro at 51.2 oz/ac; CleanTraxx at 48 oz/ac + Milestone VM at 7 oz/ac + Roundup Pro at 51.2 oz/ac; Esplanade 200 SC at 5 oz/ac + Oust XP at 3 oz/ac + Roundup Pro at 51.2 oz/ac; Plainview SC at 32 oz/ac; Plainview SC at 48 oz/ac; IAF-RIS at 4.5 oz/ac + Roundup Pro at 51.2 oz/ac; and an untreated check. The following herbicide treatments yielded less than 10% total vegetative cover at the end of the growing season (150 DAT, days after treatment): Plainview SC at 48 oz/ac; Plainview SC at 64 oz/ac + Roundup Pro at 51.2 oz/ac; Plainview SC at 32 oz/ac + Roundup Pro at 51.2 oz/ac Esplanade 200 SC at 5 oz/ac + Method 240 SL at 12 oz/ac + Roundup Pro at 51.2 oz/ac; and Esplanade 200 SC at 5 oz/ac + Method 240 SL at 12 oz/ac + Oust XP at 3 oz/ac + Roundup Pro at 51.2 oz/ac.

INTRODUCTION

Roadside areas that require season-long bareground weed control include signs, guiderails, and other fixed structures. Those areas maintained free of vegetation will allow for ease of maintenance operations, proper surface water movement from the roadway, aesthetics, and increased sight distance. Bareground herbicide mixes consist of three components: post emergence, broad spectrum residual, and pre emergence herbicides. Roadside specialist's select herbicides based on effectiveness, site of action, current label restriction, cost, and availability. This experiment evaluated the efficacy of a variety of commonly used tank mixes for bareground weed control. The tank mix partners which contained Roundup Pro in the treatment included: Esplanade 200 SC, Esplanade 200 SC-Method 240 SL, Esplanade 200 SC-Method 240 SL-Oust XP, CleanTraxx-Milestone VM, Esplanade 200 SC-Oust XP, and IAF-RIS. Two treatments consisted of Plainview SC alone. Plainview SC is a combination product containing 2% *indaziflam*, 5.6% *aminocyclopyrachlor*, 20.4% *imazapyr isopropylamine salt*, and 71.9% inert material. IAF-RIS is a combination product containing 24.3% *indaziflam*, 16.7% *rimsulfuron,* and 59% inert material. CleanTraxx is a combination product containing 0.85% *penoxsulam*, 40.31% *oxyfluorfen,* and 58.84% inert material.

Both Plainview SC and IAF-RIS were experimental herbicides and will be available soon in the market[21]. The trade name for IAF-RIS will be Esplanade Sure[22].

MATERIALS AND METHODS

This experiment was established along a roadside guiderail setting to evaluate various herbicide products effectiveness for season long bareground weed control. The experiment was established as a randomized complete block design with four replications. Plots were 20-feet by 4-feet in size. The site was located on a ramp, SR 8012, between SR 3040 and SR 3042 near Port Matilda, PA. Treatments included Roundup Pro at 51.2 oz/ac; Plainview SC at 32 oz/ac + Roundup Pro at 51.2 oz/ac; Plainview SC at 48 oz/ac + Roundup Pro at 51.2 oz/ac; Plainview SC at 64 oz/ac + Roundup Pro at 51.2 oz/ac; Esplanade 200 SC at 5 oz/ac + Roundup Pro at 32 oz/ac; Esplanade 200 SC at 5 oz/ac + Method 240 SL at 12 oz/ac + Roundup Pro at 51.2 oz/ac; Esplanade 200 SC at 5 oz/ac + Method 240 SL at 12 oz/ac + Oust XP at 3 oz/ac + Roundup Pro at 51.2 oz/ac; CleanTraxx at 48 oz/ac + Milestone VM at 7 oz/ac + Roundup Pro at 51.2 oz/ac; Esplanade 200 SC at 5 oz/ac + Oust XP at 3 oz/ac + Roundup Pro at 51.2 oz/ac; Plainview SC at 32 oz/ac; Plainview SC at 48 oz/ac; IAF-RIS at 4.5 oz/ac + Roundup Pro at 51.2 oz/ac; and an untreated check. Induce, a non-ionic surfactant, was added to all treatments at 0.25% v/v. Treatments were premeasured, mixed for each plot, and applied on April 23, 2018 using a CO_2 powered backpack sprayer equipped with one OC-08 nozzle at 36 PSI and delivered at 50 gallons per acre. Weather at the time of application consisted of mostly clear skies, air speed 5-10 mph, 17 percent relative humidity, air temperature of 75° F, moderate soil moisture, and soil temperatures of 76° F, 63° F, 52° F, and 48° F at 0, 1, 3, and 6 inch depths. Local rain events occurred on April 24, 25, 27, and 28, 2018 with 0.16, 0.01, 0.23, and 0.01 inches, respectively, according to http//newa.cornell.edu. The nearest weather station was located at Rock Springs, PA. Additionally, the year was extremely wet as evidenced by the monthly rain fall totals: May 4.52 inches, June 5.01 inches, July 8.89 inches, August 7.07 inches and September 8.02 inches.

The experiment was visually rated for percent total vegetative cover and stem counts were conducted on April 18, May 23, June 21, July 26, August 28, and September 20, 2018, 0, 30, 59, 94, 127, and 150 days after treatment, DAT. Four, 1-foot by 1-foot, subplots were established within each plot to conduct stem counts. A killing frost occurred on October 19, 2018 ending the growing season for this site. Percent grass cover and percent spotted knapweed cover were

[21] Dave Spak, personnel communication, January 19, 2019
[22] Dave Spak, personnel communication, January 21, 2019

evaluated 59, 94, 127, and 150 DAT. Percent cover by witchgrass and percent cover by foxtail species were evaluated 127 and 150 DAT. Weed species observed on April 18, 2018 in the experimental site included: spotted knapweed, tall fescue, Canada thistle, wild carrot, birdsfoot trefoil, crownvetch, poison hemlock, quackgrass, and common mullein. Weed species present on June 21, 2018 (59 DAT) within the untreated check plots included: spotted knapweed, crownvetch, quackgrass, summer annual grass seedlings, wild parsnip, and birdsfoot trefoil.

RESULTS AND DISCUSSIONS

The roadside guiderail site near Port Matilda, PA offered a diverse weed population. Evaluations of the total vegetative cover (Table 1) at the onset of the experiment ranged from 2.63% to 8.75% with no significant differences among plots. By July 26 (94 DAT), percent total vegetative cover ranged from 1.5 to 55.75%. The untreated check recorded the highest total vegetative cover at 55.75% and Plainview SC at 48 oz/ac was the lowest recorded treatment for total vegetative cover control at 1.5%. However, Plainview SC at 48 oz/ac was statistically similar to the other treatments except the untreated check, Roundup Pro 51.2 oz/ac, and Esplanade at 5 oz/ac + Roundup Pro at 32 oz/ac. By September 20 (150 DAT), total vegetative cover ranged from 2.65-61.25%. Plainview SC at 48 oz/ac, resulted in the least total vegetative cover (2.65%) and the untreated check resulted in the highest total vegetative cover (61.25%). Based on percent total vegetative cover, all of the treatments except Roundup Pro at 51.2 oz/ac and Esplanade at 5 oz/ac + Roundup Pro at 32 oz/ac performed statistically better than the untreated check. The following herbicide treatments resulted in less than 10% total vegetative cover by September 20 (150 DAT) included: Plainview SC at 48 oz/ac (2.65%); Plainview SC at 64 oz/ac + Roundup Pro at 51.2 oz/ac (5.13%); Plainview SC at 32 oz/ac + Roundup Pro at 51.2 oz/ac (5.31%); Esplanade 200 SC at 5 oz/ac + Method 240 SL at 12 oz/ac + Roundup Pro at 51.2 oz/ac (5.5%); and Esplanade 200 SC at 5 oz/ac + Method 240 SL at 12 oz/ac + Oust XP at 3 oz/ac + Roundup Pro at 51.2 oz/ac (7.31%).

The effectiveness of herbicide treatments based on stem counts (Table 2) were conducted on April 18, May 23, June 21, July 26, August 28, and September 20, 2018, 0, 30, 59, 94, 127, and 150 DAT, respectively. On April 18 (0 DAT), the stem counts were statistically similar ranging from 10.81 stem per square foot to 32.38 stems per square foot. By August 28 (127 DAT), the untreated check was statistically similar to the Roundup Pro at 51.2 oz/ac. All other treatments were statistically different from the untreated check.

Percent spotted knapweed cover (Table 3) was collected June 21 (59 DAT), July 26 (94 DAT), August 28 (127 DAT), and September 20 (150 DAT). By September 20 (150 DAT), the following treatments performed significantly better than the untreated check were the seven treatments containing Plainview SC or combinations of Esplanade and Method 240 SL.

Percent grass cover (Table 4) was collected June 21 (59 DAT), July 26 (94 DAT), August 28 (127 DAT), and September 20 (150 DAT). Percent witchgrass cover and foxtail species cover were collected on August 28 (127 DAT), and September 20 (150 DAT). By August 28 (127 DAT), all herbicide treatments performed significantly better than Roundup Pro alone at 51.2 oz/ac. This occurred again at the September 20 (150 DAT) rating date. By 150 DAT, grass cover for the most statistically effective herbicide treatments ranged from 0.37% to 2.62%.

Overall there was little foxtail in all treatments including the untreated check. The untreated check was statistically similar to all herbicide treatments. No conclusive evidence from statistical analysis support effectiveness of herbicide treatment based on percent witchgrass and foxtail cover.

CONCLUSIONS

Plainview SC at different rates alone and combined with Roundup Pro provided similar bareground weed control when compared to the other herbicide mixes tested in this trial. Herbicide treatments containing indaziflam and aminocyclopyrachlor, performed particularly well against spotted knapweed. Plainview SC, along with many of the other tank mixes tested, proved to be effective at providing season-long bareground control for this experiment.

MANAGEMENT IMPLICATIONS

None of the herbicide treatments provided complete season-long bareground weed control. The following herbicide treatments provided less than 10% vegetative cover at the end of the growing season: Plainview SC at 48 oz/ac; Plainview SC at 64 oz/ac + Roundup Pro at 51.2 oz/ac; Plainview SC at 32 oz/ac + Roundup Pro at 51.2 oz/ac; Esplanade 200 SC at 5 oz/ac + Method 240 SL at 12 oz/ac + Roundup Pro at 51.2 oz/ac; and Esplanade 200 SC at 5 oz/ac + Method 240 SL at 12 oz/ac + Oust XP at 3 oz/ac + Roundup Pro at 51.2 oz/ac.

The CleanTraxx label requires a 25 foot buffer between treated areas and bodies of water during ground applications[23]. Milestone VM contains statements warning of potential injury to trees with root systems extending into the treated area. Caution should be used by the Roadside specialist when selecting and using combinations containing Milestone VM, to avoid off-site damage especially along secondary roads[24]. Also, products containing aminocyclopyrachlor require judicious use due to potential tree or desirable plant injury caused from root systems extending into treated areas[25].

When considering herbicide rotations and using differing site of action to reduce herbicide resistance, Plainview SC used alone in bareground applications may eliminate the need of glyphosate. Plainview SC offers an herbicide rotation for bareground weed control not containing glyphosate.

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[23] Dow Agro Sciences LLC. Cleantraxx. Internet January 23, 2019.
[24] Dow Agro Sciences LLC. Milestone VM. Internet January 23, 2019.
[25] Bayer CropScience LP. Method 240 SL. Internet January 23, 2019.

Table 1. Effectiveness of herbicide treatments based on percent total vegetative cover at 0, 30, 59, 94 127, and 150 days after treatment (DAT). The site was visually rated for percent total cover on April 18, May 23, June 21, July 26, August 28, and September 20, 2018. Treatments were applied on April 23, 2018. A non-ionic surfactant (i.e. Induce) was added to all treatments at 0.25% v/v. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/acre	% Total Cover 4/18/18 0 DAT	% Total Cover 5/23/18 30 DAT	% Total Cover 6/21/18 59 DAT	% Total Cover 7/26/18 94 DAT	% Total Cover 8/28/18 127 DAT	% Total Cover 9/20/18 150 DAT
Untreated	---	5.38	43.25 b	48.75 d	58.75 d	72.5 d	61.25 b
Roundup Pro	51.2	6.25	4.88 a	24.5 bc	34.25 cd	47.5 cd	42.5 ab
Plainview SC Roundup Pro	32 51.2	3.38	0.71 a	1.53 a	3.38 ab	6.03 ab	5.31 a
Plainview SC Roundup Pro	48 51.2	8.75	0.8 a	2.03 a	5.06 abc	10.13 abc	12.5 a
Plainview SC Roundup Pro	64 51.2	3.25	0.2 a	0.8 a	2.61 ab	5.13 ab	5.13 a
Esplanade 200 SC Roundup Pro	5 32	4.25	8.5 a	27 c	33 bcd	42 bcd	37.75 ab
Esplanade 200 SC Method 240 SL Roundup Pro	5 12 51.2	4.75	0.32 a	0.4 a	2.28 a	6.08 ab	5.5 a
Esplanade 200 SC Method 240 SL Oust XP Roundup Pro	5 12 3 51.2	5.75	0.53 a	0.82 a	2.88 ab	6.31 ab	7.31 a
CleanTraxx Milestone VM Roundup Pro	48 7 51.2	3.25	0.65 a	1.5 a	6 abc	13 abc	11.5 a
Esplanade 200 SC Oust XP Roundup Pro	5 3 51.2	6.25	1.56 a	3.31 a	14 abc	18.25 abc	17.12 a
Plainview SC	32	6.00	1.75 a	1.28 a	5.31 abc	13.5 abc	11.5 a
Plainview SC	48	2.88	0.36 a	0.69 a	1.5 a	2.53 a	2.65 a
IAF-RIS Roundup Pro	4.5 51.2	2.63	2.88 a	4.75 ab	11.75 abc	15.5 abc	10.25 a
		n.s.					

Table 2. Effectiveness of herbicide treatments based on stem counts per square foot at 0, 30, 59, 94 127, and 150 days after treatment (DAT). Stem counts were conducted on April 18, May 23, June 21, July 26, August 28, and September 20, 2018. Treatments were applied on April 23, 2018. A non-ionic surfactant (i.e. Induce) was added to all treatments at 0.25% v/v. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/acre	Stem Count 4/18/18 0 DAT	Stem Count 5/23/18 30 DAT	Stem Count 6/21/18 59 DAT	Stem Count 7/26/18 94 DAT	Stem Count 8/28/18 127 DAT	Stem Count 9/20/18 150 DAT
Untreated	---	29.06	50.13 c	41.75 c	37.69 c	29.06 c	43.88 e
Round Up Pro	51.2	12.75	15.63 b	20.13 b	21.13 b	27.69 c	25.88 d
Plainview SC Round Up Pro	32 51.2	10.81	0.56 a	0 a	0.13 a	0.63 a	5.13 abc
Plainview SC Roundup Pro	48 51.2	21.50	0.69 a	1.5 a	3 a	1.56 a	4.56 ab
Plainview SC Roundup Pro	64 51.2	13.38	0.06 a	0.5 a	0.69 a	2.44 a	5.63 abc
Esplanade 200 SC Roundup Pro	5 32	24.75	9.94 ab	9.13 ab	10.75 ab	12.75 b	18.38 cd
Esplanade 200 SC Method 240 SL Roundup Pro	5 12 51.2	15.56	0.56 a	0 a	0.44 a	1 a	3.13 ab
Esplanade 200 SC Method 240 SL Oust XP Roundup Pro	5 12 3 51.2	13.44	0.19 a	0 a	0.13 a	0.81 a	3.38 ab
CleanTraxx Milestone VM Round Up Pro	48 7 51.2	25.06	1.5 ab	1.63 a	4 a	9.13 ab	7.94 abc
Esplanade 200 SC Oust XP Roundup Pro	5 3 51.2	32.38	6.13 ab	5.13 a	8.19 ab	8.38 ab	15.31 bcd
Plainview SC	32	19.88	4 ab	2.13 a	4.44 a	4.25 ab	9.69 abc
Plainview SC	48	21.75	0.19 a	0 a	0.13 a	0.38 a	1.13 a
IAF-RIS Roundup Pro	4.5 51.2	16.06	1.69 a	1.13 a	3.56 a	7.94 ab	10.44 abc
		n.s.					

Table 3. Effectiveness of herbicide treatments based on percent spotted knapweed, CENBB, cover at 59, 94, 127, and 150 days after treatment (DAT). The site was visually rated for % spotted knapweed on June 21, July 26, August 28, and September 20, 2018. Treatments were applied on April 23, 2018. A non-ionic surfactant (i.e. Induce) was added to all treatments at 0.25% v/v. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/acre	% Spotted knapweed cover 6/21/18 59 DAT	% Spotted knapweed cover 7/26/18 94 DAT	% Spotted knapweed cover 8/28/18 127 DAT	% Spotted knapweed cover 9/20/18 150 DAT
Untreated	---	22.5 b	24 b	28.75 b	14 b
Roundup Pro	51.2	6.13 ab	10.75 a	11.25 a	7.13 ab
Plainview SC Roundup Pro	32 51.2	0.01 a	0.44 a	1.125 a	1.13 a
Plainview SC Roundup Pro	48 51.2	0.28 a	0.69 a	1.73 a	1.81a
Plainview SC Round Up Pro	64 51.2	0.19 a	0.56 a	1.5 a	0.75 a
Esplanade 200 SC Roundup Pro	5 32	15.25 ab	11.25 a	14.5 ab	9.03 ab
Esplanade 200 SC Method 240 SL Roundup Pro	5 12 51.2	0.01 a	0.4 a	1.19 a	1.03 a
Esplanade 200 SC Method 240 SL Oust XP Roundup Pro	5 12 3 51.2	0.06 a	0.26 a	0.46 a	0.5 a
CleanTraxx Milestone VM Roundup Pro	48 7 51.2	0.71 a	2.63 a	5.38 a	5.13 ab
Esplanade 200 SC Oust XP Round Up Pro	5 3 51.2	1.63 a	5 a	7.88 a	5.38 ab
Plainview SC	32	0.4 a	1.25 a	3 a	1.5 a
Plainview SC	48	0.06 a	0.28 a	0.5 a	0.5 a
IAF-RIS Roundup Pro	4.5 51.2	3.5 a	8.75 a	11 a	6.88 ab

Table 4. Effectiveness of herbicide treatments based on percent grass cover at 59, 94, 127, and 150 days after treatment (DAT). The site was visually rated for percent foxtail spp, 1SETG and witchgrass, PANCA cover on June 21, July 26, August 28, and September 20, 2018. Treatments were applied on April 23, 2018. A non-ionic surfactant (i.e. Induce) was added to all treatments at 0.25% v/v. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/acre	% Grass cover 6/21/18 59 DAT	% Grass cover 7/26/18 94 DAT	% Grass cover 8/28/18 127 DAT	% Grass cover 9/20/18 150 DAT	% Witchgrass cover 8/28/18 127 DAT	% Foxtail cover 8/28/18 127 DAT	% Witchgrass cover 9/20/18 150 DAT	% Foxtail cover 9/20/18 150 DAT
Untreated	---	2.56	5.75 ab	10 ab	5.25 ab	8 ab	0.25	4.25 ab	0.25 a
Roundup Pro	51.2	2.43	10.88 b	27.63 b	18 b	13.5 b	6.75	9.75 b	4.75 b
Plainview SC Roundup Pro	32 51.2	0	0.44 a	1.84 a	1.53 a	1.4 a	0.25	1.4 a	0.13 a
Plainview SC Roundup Pro	48 51.2	0.07	1.13 ab	2.63 a	2 a	1.88 a	0.63	1.75 a	0.25 a
Plainview SC Roundup Pro	64 51.2	0.01	0.15 a	1.3 a	0.78 a	1.05 a	0	0.53 a	0 a
Esplanade Roundup Pro	5 32	0.13	1.36 ab	2.5 a	2.31 a	1.5 a	0.03	1.38 a	0 a
Esplanade Method 240 SL Roundup Pro	5 12 51.2	0.10	1.63 ab	4.25 a	3.63 a	1.03 a	0	1.03 a	0 a
Esplanade Method 240 SL Oust XP Roundup Pro	5 12 3 51.2	0.01	0.14 a	1.65 a	1.28 a	0.75 a	0.38	0.75 a	0.4 ab
CleanTraxx Milestone Roundup Pro	48 7 51.2	0.05	1.78 ab	4 a	2.63 a	0.9 a	1.75	0.65	1 ab
Esplanade Oust XP Roundup Pro	5 3 51.2	0.01	0.28 a	1.13 a	0.75 a	1 a	0	0.75 a	0 a
Plainview SC	32	0.01	0.5 a	5.81 a	2.88 a	1.31 a	3	1.38 a	0.75 ab
Plainview SC	48	0.01	0.05 a	0.19 a	0.38 a	0.05 a	0.03	0.19 a	0.03 a
IAF-RIS Roundup Pro	4.5 51.2	0.01	0.13 a	1.25 a	0.75 a	1.25 a	0	0.75 a	0 a
		n.s.					n.s.		