Roadside Vegetation Management Research – 2017 Report

ANNUAL REPORT

June 30, 2017

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THE PENNSYLVANIA STATE UNIVERSITY

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION

Purchase Order No: 4300525794
Purchase Order Description:
Master Agreement # 4400015622

Technical Report Documentation Page

1. Report No. PA-2017-012-PSU RVM 4300525794	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle Roadside Vegetation Management Research – 2017 Report		**5. Report Date** June 30, 2017 **6. Performing Organization Code**
7. Author(s) Jon M. Johnson, David A. Despot, and James C. Sellmer.		**8. Performing Organization Report No.**
9. Performing Organization Name and Address The Pennsylvania State University College of Agricultural Sciences University Park, PA 16802		**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** Purchase Order No: 4300525794
12. Sponsoring Agency Name and Address The Pennsylvania Department of Transportation Bureau of Planning and Research Commonwealth Keystone Building 400 North Street, 6th Floor Harrisburg, PA 17120-0064		**13. Type of Report and Period Covered** Annual Report: July 1, 2016 – June 30, 2017 **14. Sponsoring Agency Code**
15. Supplementary Notes Project Management – Joseph S. Demko – Bureau of Maintenance and Operations, Office of Roadside Development		

16. Abstract

This report details a cooperative research project performed for the Pennsylvania Department of Transportation's Bureau of Maintenance and Operations by Penn State. The report includes the following: Evaluation of the Herbicides Streamline®, Viewpoint®, and Combinations of PennDOT Custom Blend or Milestone with 2,4-D and Escort XP for Control of Black Birch (*Betula lenta*) – Results Two Years After Treatment, The Effects of Commonly Used Herbicides on Common Milkweed (*Asclepias syriaca*), Comparing Spring Applied Herbicide Treatments for Control of Poison Hemlock (*Conium maculatum*) in a Crownvetch Groundcover, Control of Japanese Knotweed (*Fallopia japonica*) Using Aminocyclopyrachlor Alone or Blended, or Glyphosate with Foliar Applied Treatments, Comparing Summer Applied Herbicide Treatments for Control of Common Teasel (*Dipsacus fullonum*), Further Investigation of Alternatives to Embark 2S for Plant Growth Regulation of Roadside Turf, Seasonal Timing Effects on Warm-Season Grass Establishment Relative to Crownvetch and Annual Ryegrass – Year Seven, Comparing Spring Seeded Formula L Seed Mix at Two Rates and Sheep Fescue for Groundcover Establishment in a Roadside Application – Second Year Results, Investigating Grass Species, Seeding Rates, and Fertilizer plus Broadleaf Herbicide Application for Groundcover Establishment in Roadside Applications – Third Year Results, Testing Preemergence Herbicides Alone and in Combination with Esplanade for Season Long Bareground Weed Control.

17. Key Words Roadside vegetation management, herbicides, brush control, black birch, common milkweed, poison hemlock, Japanese knotweed, common teasel, plant growth regulators, native warm-season grasses, groundcovers, bareground, Esplanade, Embark		**18. Distribution Statement** No restrictions. This document is available from the National Technical Information Service, Springfield, VA 22161	
19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 67	**22. Price**

Form DOT F 1700.7 **(8-72)** **Reproduction of completed page authorized**

ACKNOWLEDGMENTS

This research was funded by the Pennsylvania Department of Transportation, Bureau of Maintenance and Operations, and conducted by the Department of Plant Science, of the College of Agricultural Sciences at Penn State. Personnel contributing to the production of this report include Jon M. Johnson, research support associate; David A. Despot, research support associate; and James C. Sellmer, professor of ornamental horticulture at Penn State.

The authors would like to begin by thanking the PennDOT District Roadside Specialists who have been instrumental in locating the field sites needed for this research. Specific mention is needed for Mike Heitzenrater, District 2-0 Roadside Specialist, and the Centre County maintenance personnel who coordinate and work around our many ongoing projects within the State College area. Our sincere appreciation also goes to Joseph S. Demko for his continued support of this research project.

We are grateful for the assistance of the representatives of the various manufacturers providing products for the vegetation management industry, who have lent their time, expertise, and material support on many occasions. The following manufacturers assisted this research project during the 2016 season: Dow AgroSciences, BASF Corporation, Bayer Environmental Science, NuFarm Specialty Products, and Wilbur-Ellis Company.

This work was sponsored by the Pennsylvania Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

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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

These reports are available by request from the authors, and are available online in portable document format (PDF) at http://vm.cas.psu.edu.

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
Arsenal Powerline	imazapyr	2 S	BASF Corporation
Cleantraxx, Pindar GT	oxyfluorfen + penoxsulam	40.31 + 0.85 SC	Dow AgroSciences LLC
DMA 4 IVM	2,4-D	3.8 S	Dow AgroSciences LLC
Embark	mefluidide	2 S	PBI/Gordon Corporation
Escort XP	metsulfuron	60 DF	Bayer Environmental Science
Esplanade	indaziflam	200 SC	Bayer Environmental Science
Freelexx	2,4-D Choline	3.8 S	Dow AgroSciences LLC
Garlon 3A	triclopyr amine	3 S	Dow AgroSciences LLC
Method 50SG	aminocyclopyrachlor	50 SG	Bayer Environmental Science
Method 240SL	aminocyclopyrachlor	2 SL	Bayer Environmental Science
Milestone VM	aminopyralid	2 S	Dow AgroSciences LLC
Overdrive	dicamba + diflufenzopyr	55 + 21.3 WDG	BASF Corporation
Pendulum AquaCap	pendimethalin	3.8 ME	BASF Corporation
PennDOT Blend (or PDT Custom Blend)	aminocyclopyrachlor + metsulfuron	47.9 + 2.5 DF	E.I. DuPont de Nemours & Co.
Perspective	aminocyclopyrachlor + chlorsulfuron	39.5 + 15.8 DF	Bayer Environmental Science
Plateau	imazapic	2 SL	BASF Corporation
Portfolio	sulfentrazone	4 F	Wilbur-Ellis Company
Matrix	rimsulfuron	25 SG	E.I. DuPont de Nemours
Roundup ProMax	glyphosate	5.5 S	Monsanto Company
Segment	sethoxydim	1 S	BASF Corporation
Streamline	aminocyclopyrachlor + metsulfuron	39.5 + 12.6 DF	Bayer Environmental Science
Telar XP	chlorsulfuron	75 DF	Bayer Environmental Science
Viewpoint	aminocyclopyrachlor + metsulfuron + imazapyr	22.8 + 7.3 + 31.6 DF	Bayer Environmental Science
Vanquish	dicamba	4 S	Nufarm Americas, Inc.
Vastlan	triclopyr choline	4 S	Dow AgroSciences, LLC.
Velpar DF	hexazinone	75 DF	E.I. DuPont de Nemours & Co.

EVALUATION OF THE HERBICIDES STREAMLINE®, VIEWPOINT®, AND COMBINATIONS OF PENNDOT CUSTOM BLEND OR MILESTONE WITH 2,4-D AND ESCORT XP FOR CONTROL OF BLACK BIRCH (BETULA LENTA) – RESULTS TWO YEARS AFTER TREATMENT

Herbicide trade and common names: DMA 4 IVM (*2,4-D*); Escort XP (*metsulfuron*); Garlon 3A (*triclopyr* amine); Method 50 SG (*aminocyclopyrachlor*); Milestone VM (*aminopyralid*); Streamline or Custom Blend (*aminocyclopyrachlor + metsulfuron*); Viewpoint (*aminocyclopyrachlor + metsulfuron + imazapyr*).

Plant common and scientific names: black birch (*Betula lenta,* BETLE), goldenrod (*Solidago* spp, SOLXX), sweetfern (*Comptonia peregrina*).

ABSTRACT

The weed and brush herbicide spray program is used to target a variety of unwanted woody species that invade the roadway corridor. Black birch is among the species commonly targeted within the right-of-way. The emphasis of this experiment was two-fold. First to evaluate three products containing the active ingredient, *aminocyclopyrachlor*, including Viewpoint and Streamline at various rates and the PennDOT Custom Blend (i.e., Custom Blend) for efficacy on this species. Secondarily, to determine the overall effectiveness of 2,4-D (i.e. DMA 4 IVM) in controlling brush species beyond honeysuckle when tank mixed with the Custom Blend product or Milestone, Escort XP, and, in one combination Garlon 3A for use on black birch. One year after treatment (1 YAT), excellent control of black birch was observed with all herbicide mixes tested and values ranged from 87 to 100 percent. By 2 YAT, all herbicide treatments produced statistically similar control, except Streamline at 7.5 oz/ac (68%), with values from 80 to 100 percent. Mortality values were consistently lower, but followed a similar pattern. All treatments were statistically similar with values from 68 to 97 percent, except Streamline at 7.5 oz/ac and DMA 4 IVM, Milestone VM, plus Escort XP (56 and 42%). Complete or nearly complete loss of both goldenrod and sweetfern occurred for all treatments by 1 YAT.

INTRODUCTION

Black birch is a perennial woody species capable of reaching 60 feet in height, found throughout the eastern U.S., and commonly encroaches on the roadside corridors of Pennsylvania. Due in part to the ability of black birch to produce large amounts of wind dispersed seed, this tree can quickly colonize an area. When it becomes established in close proximity to the travel lanes it must be controlled or removed. The weed and brush spray program is a cost-effective approach to target the unwanted trees that encroach upon the road. There are many options when selecting herbicide mixes for this program. Among possible herbicide candidates are products containing the active ingredient, *aminocyclopyrachlor* (ACP). This material has been used in Penn DOT's roadside weed and brush program in recent years, but is soil active and caution must be observed near the root zone of desirable trees. This active ingredient is found in three separate products promoted for brush control operations including Streamline, Viewpoint, or the PennDOT Custom Blend (5.33 oz product = 5.11 oz Method (50% ACP) + 0.22 oz Escort XP). Another challenging woody species on the roadside is exotic shrub honeysuckle. The active ingredient 2,4-D has shown promise at controlling this species and as a result is being suggested for addition to brush control mixes where exotic honeysuckle is among the targets. This experiment was established to evaluate the performance of Streamline and Viewpoint alone at various rates and Custom Blend or Milestone in combination with DMA 4 IVM and other commonly used products for control of black birch.

MATERIALS AND METHODS

An experiment was established within the right-of-way of I-99N near Port Matilda, PA. The herbicide treatments investigated are described in the following table:

product	rate	product	rate
	(oz/ac)		(oz/ac)
Streamline	7.5	Garlon 3A Escort XP	64 0.5
Streamline	9.5	PennDOT Custom Blend DMA 4 IVM Escort XP Garlon 3A	5.33 96 0.5 32
Streamline	11.5	PennDOT Custom Blend DMA 4 IVM Escort XP	5.33 96 0.5
Viewpoint	13	PennDOT Custom Blend DMA 4 IVM Escort XP	5.33 96 0.25
Viewpoint	16.5	DMA 4 IVM Milestone VM Escort XP	96 7 0.5
Viewpoint	20	untreated	---

Treatments of Streamline, Viewpoint, and the standard Garlon 3A plus Excort XP contained methylated seed oil (i.e., FS MSO Ultra[1]) at 1% v/v and were applied at a carrier volume of 25 gallons per acre, GPA. Other treatments containing the PennDOT Custom Blend and/or DMA 4 IVM included a non-ionic surfactant (i.e., CWC Surfactant 90[2]) at 0.25% v/v and were applied at 50 GPA. The experiment was established as a randomized complete block design with four replications. Plots were 10 by 25 ft. in size. Black birch had a maximum height of approximately 10 ft and averaged 6 ft tall. Treatments were applied using a CO_2-powered sprayer equipped with an AA30 GunJet spray gun, TeeJet adjustable ConeJet nozzle, and X-4 tip operating at 32 psi. The black birch was treated on June 13, 2014 and treatments were applied evenly across each 250 sq. ft. plot.

Percent injury to black birch was evaluated September 12, 2014, 91 days after treatment, DAT. Percent injury to black birch was a reflection of the percentage of defoliation. Percent

[1] FS MSO Ultra (100% proprietary blend of methylated soy oil, nonionic surfactants and emulsifiers), Growmark, Inc., Bloomington, IL.
[2] CWC Surfactant 90 (nonionic low foam wetter/spreader adjuvant), CWC Enterprises, Inc., Cloverdale, VA.

control and mortality of black birch was evaluated September 8, 2015 and July 11, 2016, 1 and 2 years after treatment, YAT. Percent control was a reflection of the percentage of defoliation, while mortality was the number of stems completely devoid of foliage divided by the total stems found within the plot x 100. Percent injury and control of goldenrod (*Solidago* spp.) and sweetfern (*Comptonia peregrina*) was also evaluated at 91 DAT and 1 YAT, respectively, but was inconsistently found across the site and not reported.

RESULTS AND DISCUSSION

Initial injury to black birch was statistically similar and ranged from 68 to 89 percent for all herbicide treatments (Table 1). PennDOT Custom Blend treatments applied at 50 gallons per acre resulted in the greatest injury with rating values from 84 to 89 percent. All other treatments including Streamline; Viewpoint; Garlon 3A plus Escort XP; and DMA 4IVM, Milestone VM, plus Escort XP resulted in injury values of 68 to 79 percent. One year later, excellent control of black birch was observed with all herbicide mixes tested with values from 87 to 100 percent.

By 2 YAT, all herbicide treatments produced statistically similar control, except Streamline at 7.5 oz/ac (68%), with values from 80 to 100 percent. Mortality values were consistently lower, but followed a similar pattern. All treatments were statistically similar with values from 68 to 97 percent, except Streamline at 7.5 oz/ac and DMA 4 IVM, Milestone VM, plus Escort XP (56 and 42%).

At 1 YAT, complete or nearly complete loss of both goldenrod and sweetfern occurred for all treatments. There was not sufficient quantity of either species to perform a statistical analysis. The only instance where complete elimination of goldenrod was not achieved by the herbicide treatment was DMA 4 IVM at 96 oz/ac, Escort XP at 0.5 oz/ac, plus either PennDOT Custom Blend at 5.33 oz/ac or Milestone VM at 7 oz/ac (99 and 95% control). Sweetfern was completely controlled by all herbicide treatments, except for Garlon 3A at 64 oz/ac plus Escort XP at 0.5 oz/ac (90% control).

CONCLUSIONS

Excellent long-term control of black birch was demonstrated with Streamline at 9.5 oz/ac or greater, Viewpoint, Garlon 3A plus Escort XP, or the PennDOT Custom Blend, DMA 4 IVM, and Escort XP rates and combinations tested in this experiment. At 2 YAT, control slightly diminished for all herbicide treatments, except one, Streamline at 11.5 oz/ac (94 to 95% control), but remained acceptable at 90 percent or greater. Only Streamline at 7.5 oz/ac and the DMA 4 IVM, Milestone VM, Escort XP treatment offered questionable control (68 and 80 percent), especially when considering mortality. The control of black birch observed with the Streamline, Viewpoint, and Garlon 3A plus Escort XP treatments was improved compared to results from a previous experiment established in 2013, but followed a similar trend.[3] Nearly permanent loss of the forb understory occurred with all treatments. This would be expected with herbicide treatments developed for broadleaf weed and brush control.

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[3] Johnson, J.M. et al 2016. Evaluation of the herbicides Streamline® and Viewpoint® for control of black birch (Betula lenta) – results two years after treatment. Roadside Vegetation Management Research – 2016 Report. p. 15-19.

MANAGEMENT IMPLICATIONS

The 64 oz/ac Garlon 3A plus 0.5 oz/ac Escort XP combination is effective at controlling black birch while causing less damage to the grass understory. Streamline, Viewpoint, or tank mixtures including PennDOT Custom Blend offer alternatives to control black birch; however, greater damage to the understory would be expected, especially using Viewpoint. In addition, caution should be exercised in using products that contain aminocyclopyrachlor due to the soil activity and potential to injure nearby desirable trees. Tank mixtures containing DMA 4 IVM have shown success in controlling exotic shrub honeysuckles, so the PennDOT Custom Blend plus DMA 4 IVM combinations do offer a broad spectrum of activity on brush. Damage to non target plants can be minimized if used within larger right-of-ways. In most instances; however, we do not recommend replacing the standard herbicide combination (Garlon 3A plus Escort XP) with these aminocyclopyrachlor products. DMA 4 IVM could be added to the Garlon 3A plus Escort XP mixture. This will broaden the spectrum of control to include exotic shrub honeysuckle while limiting the soil activity and concerns for off-target damage where the root zone of desirable trees is encountered.

Table 1: Percent injury, control, and mortality to black birch (*Betula lenta,* BETLE). The experiment was visually rated for percent injury on September 12, 2014, 91 days after treatment, DAT, percent control on September 8, 2015, 1 year after treatment (YAT) and percent control plus mortality on July 11, 2016, approximately 2 YAT. Treatments were applied on June 13, 2014. Treatments including Streamline, Viewpoint, and Garlon 3A plus Escort XP contained 1 percent v/v methylated seed oil, while other herbicide treatments included 0.25 percent v/v non-ionic surfactant. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

		Percent Injury	Percent Control	Percent Control	Percent Mortality
product	rate	BETLE 9/12/14	BETLE 9/8/15	BETLE 7/11/16	BETLE 7/11/16
	(oz/ac)				
Untreated	---	0 a	0 a	0 a	0 a
Streamline	7.5	68 b	87 b	68 b	56 bc
Streamline	9.5	79 b	93 b	90 bc	77 cd
Streamline	11.5	76 b	94 b	95 bc	87 d
Viewpoint	13	71 b	97 b	95 bc	84 cd
Viewpoint	16.5	74 b	98 b	95 bc	81 cd
Viewpoint	20	75 b	100 b	100 c	97 d
Garlon 3A Escort XP	64 0.5	68 b	94 b	90 bc	68 bcd
PennDOT Custom Blend DMA 4 IVM Escort XP Garlon 3A	5.33 96 0.5 32	89 b	97 b	91 bc	83 cd
PennDOT Custom Blend DMA 4 IVM Escort XP	5.33 96 0.5	84 b	93 b	91 bc	78 cd
PennDOT Custom Blend DMA 4 IVM Escort XP	5.33 96 0.25	84 b	98 b	97 c	84 cd
DMA 4 IVM Milestone VM Escort XP	96 7 0.5	74 b	90 b	80 bc	42 b

THE EFFECTS OF COMMONLY USED HERBICIDES ON COMMON MILKWEED (*ASCLEPIAS SYRIACA*)

Herbicide trade and common chemical names: Method 240SL (*aminocyclopyrachlor*), Escort XP (*metsulfuron*), Telar XP (*chlorsulfuron*), Accord XRT (*glyphosate*), Garlon 3A (*triclopyr amine*), DMA 4 IVM (*2,4-D*).

Plant common and scientific names: common milkweed (*Asclepias syriaca,* ASCSY), birdsfoot trefoil (*Lotus corniculatus*, LOTCO), Kentucky bluegrass (*Poa pratensis*, POPRA), K-31 tall fescue (*Festuca arundinacea*, FESAR).

ABSTRACT

Milkweed is recognized as an important contributor to the life cycle of the monarch butterfly. As a result, vegetation management practices that control roadside vegetation while allowing milkweed to survive are becoming a topic of interest. These practices often involve the use of herbicides or mowing to control unwanted weeds and brush in areas where milkweed is commonly found. This experiment compared various herbicides and a single mowing for their effects on milkweed. Treatments included Method 240SL alone at 4, 8, and 12 oz/ac; Escort XP at 1 oz/ac; Telar XP at 1 oz/ac; Accord XRT II at 10 oz/ac; Garlon 3A at 32 and 64 oz/ac; DMA 4 IVM at 128 oz/ac; mow only (approximate 4 inch height); and an untreated check. DMA 4 IVM at 128 oz/ac appeared to be the safest treatment to use around milkweed. To a lesser degree, Telar XP at 1 oz/ac, Accord XRT at 10 oz/ac, and Garlon 3A at 32oz/ac allowed milkweed stem counts to increase.

INTRODUCTION

Common milkweed is a clonal, perennial, herbaceous plant often found along less intensely managed areas of the roadside. These areas; however, still require some level of maintenance to reduce or eliminate unwanted weeds and brush to ensure a safe roadway corridor for the motoring public. To achieve the desired result, periodic herbicide or mowing treatments are employed. The monarch butterfly is dependent upon common milkweed for its survival. Adult monarch butterflies lay eggs on milkweed plants and the larva emerge and feed on the leaves. Chemicals found within the common milkweed foliage and consumed by actively feeding larvae make their taste unfavorable to predators and ensure their survival. The common milkweed plant is the sole plant species used by the monarch for depositing eggs, larvae food source, and pupation.[1] With the increasing awareness of the importance of common milkweed to the environment, identifying broadleaf herbicides that minimize harm to milkweed yet control common roadside weeds is important. This experiment investigated the effect of various weed and brush herbicides plus mowing on common milkweed survival.

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[1] United States Department of Agriculture Natural Resources Conservation Service, Plant Guide Common Milkweed *Asclepias syriaca* L., viewed May 29, 2017, < https://plants.usda.gov/plantguide/pdf/cs_assy.pdf>.

MATERIALS AND METHODS

The experiment was conducted along I-99 northbound just beyond the Shiloh Road exit near State College, PA. Plots were twelve by thirty feet in size and were arranged a randomized complete block design with four replications. Treatments included Method 240SL alone at 4, 8, and 12 oz/ac; Escort XP at 1 oz/ac; Telar XP at 1 oz/ac; Accord XRT II at 10 oz/ac; Garlon 3A at 32 and 64 oz/ac; DMA 4 IVM at 128 oz/ac; mow only (approximate 4 inch height); and an untreated check. Induce non-ionic surfactant (NIS) at 0.25% v/v was added to all herbicide treatments. Treatments were applied on September 17, 2015 at 35 gal/ac using a CO_2-powered backpack sprayer equipped with a six-foot boom and four 8004VS nozzles.

PennDOT in-house crews mowed the site earlier in 2015, but vegetative height returned to an average of 2 ft. with a maximum of 3 ft. by the time of treatment. Birdsfoot trefoil was in flower at the time of treatment while the grass canopy averaged 15 inches with some plants up to 21 inches tall. The grass species evaluated were composed primarily of Kentucky bluegrass and K-31 tall fescue. This experiment targeted common milkweed in a mixed stand of vegetation; however, it should be noted that the use rates of herbicides may differ when applied to areas during the establishment or maintenance of unimproved turf, for example the current label for Method 240SL limits use rates to a maximum of 4 oz/ac in unimproved turf settings[2]. More liberal use rates of Method 240SL for applications made to unimproved turfgrass have recently been approved by EPA[3]. So, in all cases read and follow label instructions prior to planning for and making applications.

The experiment was visually rated for total vegetative cover, percent cover by common milkweed (ASCSY), percent cover by birdsfoot trefoil (LOTCO), percent cover by turf grasses, and a count of common milkweed stems within each plot on September 15, 2015 (at the onset of the experiment), May 26, 2016, (235 DAT, days after treatment), and July 20, 2016 (308 DAT).

RESULTS AND DISCUSSION

At 308 DAT, plots treated with Method 240SL at 4 oz/ac experienced little change in the number of milkweed stems per plot; however, increasing the method to 8 or 12 oz/ac resulted in a greater than 50 percent decrease in the number of milkweed stems present (Table 1). The percent cover by milkweed rating, (Table 2) presents a harsher view of the effects of Method with a 33, 75, and 80 percent decrease in milkweed cover for the 4, 8, and 12 oz/ac rates, respectively. Treatment with Telar XP at 1 oz/ac, Accord XRT at 10 oz/ac, and Garlon 3A at 32 oz/ac allowed milkweed stem counts to increase slightly to moderately (24, 7, and 2 percent respectively), and had no effect on milkweed cover. Increased rates of Garlon 3A (i.e., 64 oz/ac) caused a decline in milkweed resulting in a reduction of stem numbers by 23 percent and cover by 40 percent. DMA 4 IVM at 128 oz/ac showed the greatest safety to milkweed, with a 34 percent increase in milkweed stems and a 40 percent increase in milkweed cover at 308 DAT. A single mowing treatment resulted in a slight decrease in milkweed stem count and a large decrease in milkweed cover, 6 and 50 percent decrease respectively. Birdsfoot trefoil, the only other broadleaf weed monitored, was well controlled (less than 1 percent cover at 308 DAT) in plots treated with all three rates of Method 240 SL, both rates of Garlon 3A, the Telar XP and the DMA 4 IVM treatments.

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[2] Bayer Environmental Science, Method 240SL, Internet, June 25, 2017.

[3] D. Spak, personal communication, June 21, 2017.

CONCLUSIONS

Of the herbicides tested, DMA 4 IVM provided good control of birdsfoot trefoil and allowed milkweed plant numbers to increase. Telar XP at 1 oz/ac, Accort XRT at 10 oz/ac, and Garlon 3A at 32 oz/ac also appeared to offer relative safety to milkweed growing in turf cover on the roadside environment. The increase in milkweed following treatment (where noted) may be due to the suppression of other broadleaf weeds allowing this species to reclaim open areas within the turf. This experiment targeted common milkweed in a mixed stand of vegetation; however, it should be noted that the use rates of herbicides may differ when applied to areas during the establishment or maintenance of unimproved turf, for example the current label for Method 240SL limits use rates to a maximum of 4 oz/ac in unimproved turf settings[2]. More liberal use rates of Method 240SL for applications made to unimproved turfgrass have recently been approved by EPA[3]. So, in all cases read and follow label instructions prior to planning for and making applications.

MANAGEMENT IMPLICATIONS

Based on this experiment, DMA IVM 4 seems to be the product with the lowest impact on milkweed while controlling birdsfoot trefoil in a turf environment. Additional testing should be done with these and other herbicides using a variety of rates to better understand the effects on milkweed. Perhaps, effective weed and brush mixes can be identified that would minimize negative impacts on milkweed stands.

Table 1. Number of milkweed (*Asclepias syriaca,* ASCSY) stems per 12 X 30 ft. plot. Each number is the mean of four replications. Treatments were applied on September 17, 2015. Stems were counted on September 15, 2015 and July 20, 2016 (0 and 308 DAT, days after treatment). Numbers in columns without letters are not significantly different from each other at $p \leq 0.05$ (n.s. = not significant).

treatment	rate	avg. number ASCSY stems 0 DAT	avg. number ASCSY stems 308 DAT	percent change
	(oz/ac)	(no. stems)	(no. stems)	(%)
Untreated	--	88	97	10
Mow Only	--	65	61	-6
Method 240SL	4	68	69	1
Method 240SL	8	45	20	-56
Method 240SL	12	53	25	-53
Escort XP	1	59	55	-7
Telar XP	1	37	46	24
Accord XRT	10	54	58	7
Garlon 3A	32	41	42	2
Garlon 3A	64	48	37	-23
DMA 4 IVM	128	50	67	34
Sign. Level ($p \leq 0.05$)		n.s.	n.s.	

Table 2. Percent cover by milkweed (*Asclepias syriaca,* ASCSY). Each number is the mean of four replications. Treatments were applied on September 17, 2015. Plots were rated on September 15, 2015 and July 20, 2016 (0 and 308 DAT, days after treatment). Numbers in columns without letters are not significantly different from each other at $p \leq 0.05$ (n.s. = not significant).

treatment	rate	percent cover by ASCSY 0 DAT	percent cover by ASCSY 308 DAT	percent change
	(oz/ac)	(%)	(%)	(%)
untreated	--	11	11	0
Mow Only	--	8	4	-50
Method 240SL	4	12	8	-33
Method 240SL	8	4	1	-75
Method 240SL	12	5	1	-80
Escort XP	1	4	3	-25
Telar XP	1	4	4	0
Accord XRT	10	4	4	0
Garlon 3A	32	4	4	0
Garlon 3A	64	5	3	-40
DMA 4 IVM	128	5	7	40
Sign. Level ($p \leq 0.05$)		n.s.	n.s.	

COMPARING SPRING APPLIED HERBICIDE TREATMENTS FOR CONTROL OF POISON HEMLOCK (*CONIUM MACULATUM*) IN A CROWNVETCH GROUNDCOVER

Herbicide trade and common names: Accord XRTII (*glyphosate*); 2,4-D choline (i.e., Freelexx), DMA 4 IVM (*2,4-dichlorophenoxyacetic acid*); Method 240SL, Method 50SG (*aminocyclopyrachlor*); Milestone (*aminopyralid*); Velpar DF (*hexazinone*).

Plant common and scientific names: crownvetch (*Coronilla varia*, CZRVA), poison hemlock (*Conium maculatum,* COIMA).

ABSTRACT

Poison hemlock presents a danger to livestock when consumed and is commonly found along Pennsylvania's roads in low maintenance areas. This species often develops and thrives in voids within declining stands of crownvetch where it is difficult to selectively remove using herbicides. Previous experiments have investigated spring-applied herbicide treatments targeting poison hemlock rosettes while the crownvetch was still dormant or just emerging from dormancy. At this stage of development, the crownvetch stand would possibly be less susceptible to the postemergence herbicide treatments. In previous work, it was discovered that a properly timed, early spring-applied treatment of 21 oz/ac Velpar DF might provide control of poison hemlock rosettes and offer a margin of safety to crownvetch.

This experiment compared several herbicides, rates, and formulations for efficacy on poison hemlock rosettes and long-term control of the seedbank along with safety to crownvetch using spring-applied treatments. Among the treatments tested were incremental rates of Method 240SL (i.e., 4 to 16 oz/ac), 8 oz/ac Method 50SG, 7 oz/ac Milestone VM, 32 oz/ac of two different 2,4-D salts (i.e., DMA 4 IVM and 2,4-D choline), plus 21 oz/ac Velpar DF alone and combined with 16 oz/ac Accord XRTII. Treatments that provided both control of the poison hemlock rosettes and offered a margin of safety to crownvetch using properly timed treatments included 21 oz/ac Velpar DF alone or combined with 16 oz/ac Accord XRTII. Other treatments failed to provide effective control of the poison hemlock rosettes or caused excessive injury to the crownvetch stand. None of the treatments prevented germination of poison hemlock from seed the following year.

INTRODUCTION

Poison hemlock (*Conium maculatum*, COIMA) is a biennial forb in the carrot family (*Apiaceae*) native to Eurasia. The species is particularly common in areas established to crownvetch where no routine mowing or herbicide treatments occur. Poison hemlock appears to reduce crownvetch cover and all of its parts are lethally poisonous to both humans and livestock.[1] Poison hemlock generally overwinters as a rosette of leaves, bolts the following spring, and then flowers. The poison hemlock plant can reach heights of 3 to 8 ft. when in flower. Investigations of herbicides or combinations that are both selective on crownvetch and

[1] Poisonous Plants of Pennsylvania. 1986. Robert J. Hill and Donna Folland. Pennsylvania Department of Agriculture. Pages 48-49.

provide control of poison hemlock have been investigated with encouraging results.[2] However, annual control strategies would likely have to be employed to control new poison hemlock plants in an attempt to deplete the seedbank.

This experiment was conducted to determine the efficacy of various chemistries not yet investigated by our team for control of poison hemlock and the margin of safety to crownvetch with spring-applied treatments. The timing of this treatment targeted the rosettes of the poison hemlock while the crownvetch was just emerging from dormancy. This early spring treatment was meant to target the poison hemlock when the plants were still small and most vulnerable. At the same time the crownvetch, with little developed foliage, would offer a lesser canopy for herbicides to intercept.

MATERIALS AND METHODS

The experiment was established along the on-ramp leading from SR26 to SR 322W, near State College, PA. Treatments included Method 240SL at 4, 8, 12, and 16 oz/ac; Method 50SG at 8 oz/ac; Milestone at 7 oz/ac; DMA 4 IVM at 32 oz/ac; 2,4-D choline[3] at 32 oz/ac; Velpar DF at 21 oz/ac; Velpar DF at 21 oz/ac plus Accord XRTII at 16 oz/ac; and an untreated check. A non-ionic surfactant (i.e., Induce) was added to all herbicide treatments at 0.25% v/v. The experiment was arranged in a randomized complete block design with four replications. Plots were 6 by 20 feet in size. Poison hemlock was at a vegetative stage and had not yet begun to bolt, averaging 9 inches tall when treatments were applied on April 27, 2016. Crownvetch plants were just coming out of dormancy and had begun to form a low-growing carpet of foliage with an average height of 3 inches. Treatments were applied using a CO_2-powered backpack sprayer equipped with a six foot boom and four (4) 8003VS tips operating at 38 psi for an application volume of 30 gallons per acre.

Visual evaluations of percent total vegetative cover, cover by crownvetch (CZRVA), and cover by poison hemlock (COIMA) were recorded on April 27, August 30, and September 27, 2016 and May 17, 2017, 0, 125, 153, and 385 days after treatment (DAT), respectively. Percent cover by crownvetch was additionally evaluated on July 27, 2016, 91 DAT. Percent control or injury to crownvetch and poison hemlock were evaluated on May 31 and June 30, 2016, 34 and 64 DAT. Plant counts were conducted for poison hemlock within each plot at the onset of the experiment (April 27) and end of season evaluation (September 27, 2016). Three fixed subplots, each four square feet in size, were located within each plot. Individual poison hemlock plants were counted and the mean number of plants was calculated from data gathered within the three subplots. 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

Crownvetch cover initially ranged from 8 to 29 percent with no significant difference among plots (Table 1). All herbicide treatments caused a decline in crownvetch cover by 91 DAT (July 27) ranging from 0 to 19 percent, except Velpar DF alone (26 percent). The crownvetch cover rebounded by 153 DAT (September 27) for treatments that included 2,4-D (i.e., DMA 4 IVM or

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[2] Gover, A.E. et al 2006. Selective Herbicide Mixtures for Control of Poison Hemlock in a Crownvetch Groundcover. Roadside Vegetation Management Research Report – Nineteenth Year Report. pp. 31-36.
[3] Dow AgroSciences LLC, Freelexx (*2,4-D choline*), Internet. February 22, 2017.

2,4-D choline), Velpar DF alone or combined with Accord XRTII, and 4 oz/ac Method 240SL. These treatments averaged 42 to 56 percent cover by crownvetch and were comparable to the untreated check at 40 percent. Increased rates of 8 to 16 oz/ac Method 240SL, 8 oz/ac Method 50SG, and 7 oz/ac Milestone caused significant and long-term reduction to the crownvetch stand with percent cover values from 1 to 14 percent. This trend continued into the spring of 2017 with treatments containing 2,4-D, Velpar DF, or 4 oz/ac Method 240SL having crownvetch cover from 40 to 58 percent. In contrast, plots treated with 8 to 16 oz/ac Method 240SL, 8 oz/ac Method 50SG, and 7 oz/ac Milestone had crownvetch cover ranging from 0 to 22 percent.

The site had a significant stand of poison hemlock at the onset of the experiment with cover ranging from 13 to 29 percent (Table 2). At 64 DAT (June 30), the existing poison hemlock plants displayed substantial injury symptoms and stand reduction by treatments containing Method or Velpar DF with control values of 90 to 100 percent, whereas 2,4-D or Milestone resulted in lower control (18 to 38 percent). A substantial reduction in poison hemlock was observed for all treatments, including the untreated check, as the plants senesced and neared the end of the season at 153 DAT (September 27). The decrease in poison hemlock was evident in evaluations for both cover ranging from 0 to 2.6 percent and reduction in poison hemlock plant numbers from 11 to 100 percent (Table 3). There was a sharp increase in poison hemlock by the following spring at 385 DAT (May 17, 2017) with no statistical differences among treatments and poison hemlock plants accounting for 14 to 41 percent cover (Table 2).

CONCLUSIONS

Treatments that included Method, Velpar DF, and Velpar DF plus Accord XRTII provided excellent control of the existing poison hemlock plants. Among those treatments the Velpar DF with or without Accord XRTII offered safety to the crownvetch stand. The lowest rate of Method 240SL (4 oz/ac) caused initial setback to the crownvetch, but it recovered by late-season. However, Method 240SL at use rates of 8 oz/ac or greater and Method 50SG at 8 oz/ac caused substantial injury to crownvetch. Milestone offered little control of existing poison hemlock plants and was destructive to the crownvetch; whereas crownvetch rebounded following treatment with either formulation of 2,4-D, although 2,4-D had little impact on the poison hemlock present during the application. None of the herbicides at rates tested in this experiment provided enough soil activity to prevent poison hemlock from developing the following spring.

MANAGEMENT IMPLICATIONS

This experiment once again demonstrated that 21 oz/ac Velpar DF is both safe to crownvetch and provides excellent control of poison hemlock rosettes with a spring-applied treatment as crownvetch is just emerging from dormancy. An alternative mix might include 21 oz/ac Velpar DF plus 16 oz/ac Accord XRTII; however, Accord XRTII is non-selective chemistry and may cause unintended injury to crownvetch. So, further investigation of these mixes should occur before recommending for use in this application. No treatment offered long-term, preemergence control of the poison hemlock seed bank into the following season. So, annual herbicide or mowing treatments would be necessary to attempt to deplete the seedbank. Perhaps, a better option but one that would require a greater, short-term investment would be conversion of the infested area to a grass stand. A grass groundcover offers greater competition and flexibility in management options. Once established in turf, the area can be maintained through mowing or selective herbicide treatments.

Table 1: Percent cover by crownvetch (*Coronilla varia*, CZRVA). The experiment was visually rated for percent cover by crownvetch on April 27, July 27, September 27, 2016 and May 17, 2017 (0, 91, 153, and 385 days after treatment, DAT, respectively). Treatments were applied on April 27, 2016. 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 $p \leq 0.05$.

		CZRVA Cover			
product	rate	4/27/16	7/27/16	9/27/16	5/17/17
	(oz/ac)	(----------------------------	%---------------------------)		
Untreated	---	11 a	14 ab	40 a	49 a
Method 240SL	4	22 a	11 ab	56 a	58 a
Method 240SL	8	23 a	3 ab	14 a	22 a
Method 240SL	12	26 a	1 ab	7 a	9 a
Method 240SL	16	14 a	0 a	1 a	1 a
Method 50SG	8	15 a	0 a	13 a	3 a
Milestone	7	8 a	0 a	1 a	0 a
DMA 4 IVM	32	29 a	8 ab	43 a	44 a
2,4-D choline	32	28 a	12 ab	45 a	47 a
Velpar DF	21	17 a	26 b	43 a	40 a
Velpar DF Accord XRTII	21 16	22 a	19 ab	42 a	49 a
Significance Level ($p \leq 0.05$)		0.875	0.012	0.044	0.048

Table 2: Percent control of and cover by poison hemlock (*Conium maculatum*, COIMA). The experiment was visually rated for percent control of poison hemlock on June 30, 2016 (64 days after treatment, DAT). Cover by poison hemlock was visually rated on April 27, September 27, 2016, and May 17, 2017 (0, 153, and 385 DAT, respectively). Treatments were applied on April 27, 2016. 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≤0.05.

product	rate	COIMA Control 6/30/16	COIMA Cover 4/27/16	9/27/16	5/17/17
	(oz/ac)	(----------------------------	%		----------------------------)
Untreated	---	0 a	29 a	0 a	34 a
Method 240SL	4	90 c	22 a	0 a	18 a
Method 240SL	8	100 c	13 a	0.2 a	33 a
Method 240SL	12	100 c	16 a	0.3 a	28 a
Method 240SL	16	100 c	22 a	0.1 a	34 a
Method 50SG	8	100 c	22 a	0.2 a	24 a
Milestone	7	25 ab	26 a	2.6 a	41 a
DMA 4 IVM	32	38 b	25 a	0.2 a	14 a
2,4-D choline	32	18 ab	16 a	0.6 a	22 a
Velpar DF	21	100 c	21 a	0.2 a	17 a
Velpar DF Accord XRTII	21 16	95 c	22 a	0 a	30 a
Significance Level (p≤0.05)		0.000	0.931	0.486	0.933

Table 3: Average number and reduction of poison hemlock (*Conium maculatum*, COIMA) plants. Poison hemlock plants were counted within three fixed, 4 sq ft. subplots located within each plots on April 27 and September 27, 2016 (0 and 153 days after treatment, DAT). The percent reduction in poison hemlock plants was found by comparing initial plant numbers (recorded 4/27/16) to current plant numbers (recorded 9/27/16) within each subplot. (i.e., initial plant count - current plant count/initial plant count *100). Treatments were applied on April 27, 2016. 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 $p \le 0.05$.

product	rate	Average Number of COIMA Plants		Reduction in COIMA Plants
		4/27/16	9/27/16	9/27/16
	(oz/ac)	(number)	(number)	(%)
Untreated	---	6.2 a	3.8 a	66 a
Method 240SL	4	4.8 a	0.5 a	88 a
Method 240SL	8	5.8 a	0 a	100 a
Method 240SL	12	3.8 a	1.8 a	65 a
Method 240SL	16	5.8 a	1.5 a	78 a
Method 50SG	8	4.5 a	3.8 a	51 a
Milestone	7	5.0 a	8.8 a	11 a
DMA 4 IVM	32	3.5 a	1.2 a	61 a
2,4-D choline	32	4.2 a	0.2 a	94 a
Velpar DF	21	4.8 a	0 a	99 a
Velpar DF Accord XRTII	21 16	3.8 a	0 a	100 a
Significance Level ($p \le 0.05$)		0.881	0.616	0.688

CONTROL OF JAPANESE KNOTWEED (*FALLOPIA JAPONICA*) USING AMINOCYCLOPYRACHLOR ALONE OR BLENDED, OR GLYPHOSATE WITH FOLIAR APPLIED TREATMENTS

<u>Herbicide trade and common chemical names:</u> Arsenal (*Imazapyr*), Garlon 3A (*triclopyr amine*), MAT28, Method 50SG (*aminocyclopyrachlor*), Perspective (*aminocyclopyrachlor + chlorsulfuron*), Accord XRTII (*glyphosate*), Telar XP (*chlorsulfuron*), Vanquish (*dicamba*).

<u>Plant common and scientific names:</u> Japanese knotweed (*Fallopia japonica,* POLCU).

ABSTRACT

Japanese knotweed is an invasive herbaceous perennial weed found in low maintenance areas throughout much of the United States. It is widely spread by both root fragments and seed. However, most new populations develop from root fragments that are transported downstream with eroded soils or as soil is moved by machinery such as mowers or excavators during routine maintenance activities. Many commonly used brush herbicides such as Garlon 3A and Escort XP are not particularly effective at controlling knotweed. Method 50SG (*aminocyclopyrachlor*) is a soil active broadleaf herbicide that is currently used in bareground, broadleaf weed, and brush control programs on the roadside. This experiment tested Method 50SG alone at 3 and 3.75 oz/ac, Perspective (*aminocyclopyrachlor + chlorsulfuron*) at 3.75 and 4.75 oz/ac and Accord XRTII at 96 oz/ac using a low carrier volume of 25 gal/ac. For comparison, the Accord XRTII at 96 oz/ac was also tested at a high volume application rate using 100 gal/ac of carrier. Accord XRTII at 96 oz/ac at either carrier volume provided the highest level of control at all 3 rating dates extending over a period of two years after treatment.

INTRODUCTION

Japanese knotweed is an invasive herbaceous perennial weed that proliferates in low maintenance areas such as roadsides, railroad right-of-ways, and riverbanks and is capable of forming a monoculture that crowds out existing plants. Knotweed is a formidable pest with a large clonal root system that allows it to recover from mowing and herbicide treatments. Past experiments have shown that control is best achieved with a properly timed cutting or herbicide treatment in mid summer to exhaust the energy reserves in the plant followed by a late season application of glyphosate[1]. Herbicides commonly used for brush control such as Garlon 3A and Escort XP are not particularly effective at controlling knotweed. This experiment was designed to test the efficacy of Method and Perspective using a low volume application (i.e., 25 gal/ac) typically associated with a backpack sprayer treatment compared to a glyphosate treatment at both low and high volumes, (i.e., 25 versus 100 gal/ac).

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[1] Johnson, J.M. et al. 2011. Japanese Knotweed Control: Comparison of Garlon 3A/Escort Efficacy to Standard Sequential Cutting and Glyphosate Application. Roadside Vegetation Management Research – 2011 Report. pp. 9-12.

MATERIALS AND METHODS

The experimental site was located along I-80 East near Clarion, PA. Plots were ten by twenty feet in size and were arranged a randomized complete block design with three replications. MAT28, an experimental form of aminocyclopyrachlor was used in this experiment and is identical to Method 50SG which is made reference to throughout this document. Treatments included Method 50SG at 3 and 3.75 oz/ac; Perspective at 3.75 and 4.75 oz/ac; Accord XRTII at 96 oz/ac in both 25 gal/ac and 100 gal/ac carrier volume; and an untreated check. Methylated seed oil (MSO) was added to all treatments at 1.0% v/v, except Accord XRTII (surfactant loaded). Herbicide treatments were applied on August 28, 2014 at 25 gal/ac with the exception of one Accord XRTII treatment that was applied using a carrier volume of 100 gal/ac. The application equipment used included a CO_2-powered backpack sprayer equipped with GunJet 30, adjustable conejet nozzle, and X-6 tip. An evaluation of percent control of Japanese knotweed (POLCU) was conducted on September 29, 2014, 32 days after treatment, DAT; September 1, 2015, 369 DAT; and September 16, 2016, 749 DAT.

RESULTS AND DISCUSSION

Method 50SG or Perspective, at either rate, did not achieve more than 30 percent control of Japanese knotweed in this experiment (Table 1). The best control attained by either of these herbicides was observed on September 1, 2015, 369 DAT, when plots treated with Method 50SG at 3.75 oz/ac and Perspective at 4.75 oz/ac were rated at 30 and 25 percent control, respectively. Among herbicides tested, Accord XRTII produced the highest level of control at all three observation dates. At 369 DAT, Accord XRTII at 96 oz/ac using 25 and 100 gal/ac carrier volume produced 89 and 82 percent control, respectively. By September 16, 2016, 749 DAT, Accord XRTII was the only herbicide treatment that produced any visible control, with carrier volumes of 25 and 100 gal/ac producing 58 and 40 percent control, respectively.

CONCLUSIONS

The poor control exhibited by Method and Perspective is not unexpected because most herbicide mixes commonly used for broadleaf weed or brush control have not demonstrated effectiveness against Japanese knotweed. The exceptions are glyphosate, Arsenal, and Vanquish[2]. Glyphosate is the most common herbicide choice for treating Japanese knotweed in a roadside setting where the use of soil active herbicides can be problematic.

MANAGEMENT IMPLICATIONS

Glyphosate, applied in late summer prior to frost is the most effective herbicide for control of Japanese knotweed. An early summer cutting or burn down with an herbicide (i.e., targeting June 1 in Pennsylvania) will limit the height of the canopy making the late summer glyphosate application less challenging to apply, help to exhaust the stored energy reserves within the root system, and help to regain sight distance along the roadway. Some concerns may exist with using

[2] Gover, A.E., et al. 2005. Roadside Vegetation Management Factsheet 5a - Managing Japanese Knotweed and Giant Knotweed on Roadsides. (http://plantscience.psu.edu/research/projects/vegetative-management/publications/roadside-vegetative-mangement-factsheets/5a-managing-knotweed-on-roadsides)

a non-selective herbicide such as glyphosate; however, there is often very little desirable vegetation growing under or near Japanese knotweed because of the dense plant canopy.

Table 1. Percent control of Japanese knotweed (*Fallopia japonica*). Each number is the mean of three replications. Treatments were applied on August 28, 2014. Plots were rated on September 29, 2014, 32 days after treatment, DAT; September 1, 2015, 369 DAT; and September 16, 2016, 749 DAT. Numbers in columns without letters are not significantly different from each other at $p \leq 0.05$. N.S. indicates not significantly different.

		Control of Japanese knotweed		
treatment	rate	9/29/14 (32 DAT)	9/1/15 369 DAT	9/16/16 749 DAT
	(oz/ac)	(%)	(%)	(%)
Method 50SG	3	8 ab	12 a	0
Method 50SG	3.75	8 ab	30 ab	0
Perspective	3.75	12 ab	0 a	0
Perspective	4.75	13 ab	25 a	0
Accord XRT II @ 25 gpa	96	42 ab	89 c	58
Accord XRT II @ 100 gpa	96	23 ab	82 bc	40
untreated	--	0 a	0 a	0
Significance level (p≤0.05)		0.014	0.000	N.S.

COMPARING SUMMER APPLIED HERBICIDE TREATMENTS FOR CONTROL OF COMMON TEASEL (*DIPSACUS FULLONUM*)

<u>Herbicide trade and common names</u>: 2,4-D choline (i.e., Freelexx), DMA 4 IVM (*2,4-dichlorophenoxyacetic acid*); Garlon 3A (*triclopyr amine*); Method 240SL, Method 50SG (*aminocyclopyrachlor*); Milestone (*aminopyralid*).

<u>Plant common and scientific names</u>: birdsfoot trefoil (*Lotus corniculatus*, LOTCO), common teasel (*Dipsacus fullonum,* DIWSI).

ABSTRACT

Infestations of common teasel are increasing along the roadways of Pennsylvania. Disturbed roadside sites with thinning groundcover offer the ideal setting for common teasel to become established and thrive. Mowing operations contribute to the spread of common teasel by moving seed into areas where new populations then develop. This species can displace desirable vegetation by forming a mass of rosettes that later produce seed stalks with an abundance of seed. This plant also forms flower stalks up to 6 feet in height that can create sight distance issues and diminish the aesthetic quality of the roadside. Another species, birdsfoot trefoil, was also present in sufficient quantity to evaluate the effect of the herbicide treatments. This species serves as a desirable, low growing, perennial groundcover in many areas of Pennsylvania's roadside where grasses or other forbs are not as well adapted.

This experiment compared several herbicides, rates, and formulations for efficacy on common teasel and long-term control of the teasel seedbank along with safety to birdsfoot trefoil using foliar treatments. Among the treatments tested were incremental rates of Method 240SL (i.e., 4 to 16 oz/ac), 8 oz/ac Method 50SG, 7 oz/ac Milestone VM, 32 oz/ac of two different 2,4-D salts (i.e., DMA 4 IVM and 2,4-D choline), plus 32 oz/ac Garlon 3A alone and combined with 32 oz/ac DMA 4 IVM. All herbicide treatments tested were injurious and reduced cover by common teasel. However, the greatest control was provided by 8 or 16 oz/ac Method 240SL, 8 oz/ac Method 50SG, and 7 oz/ac Milestone. These same treatments also eliminated or nearly eliminated the birdsfoot trefoil that existed within the treated areas.

INTRODUCTION

Common teasel (*Dipsacus fullonum,* DIWSI) was introduced to the U.S. with European settlement where, over time, it has naturalized throughout much of the country. Over the last several decades this species has become more widespread and abundant along Pennsylvania's roadways. As a biennial, it begins life as a rosette that later flowers and sets seed the following year. This plant takes advantage of disturbed, open spaces typically found in roadside settings. The seed stalks can attain heights of 6 feet, possibly hindering sight distance and altering the aesthetic quality of the roadside. Additionally, the rosettes displace and compete with desirable vegetation that may establish in the site. Targeting common teasel with properly timed cutting or herbicide treatments may help in efforts to manage established populations. However, in most cases reestablishing a permanent groundcover will also be necessary for effective long-term control. This experiment investigated the efficacy of ten herbicide treatments for control of common teasel and injury to birdsfoot trefoil (*Lotus corniculatus*, LOTCO). Birdsfoot trefoil is a desirable herbaceous legume used as a groundcover planting in certain roadside settings.

MATERIALS AND METHODS

The experiment was conducted at two separate locations each containing two replicate experimental blocks totaling four replications of each treatment. The first experiment was located on a cut slope along the SR 322E on ramp from I-99 southbound near University Park, PA (i.e., University Park). The second experimental site was located along the I-99 northbound shoulder near State College, PA (i.e., State College). Plots were six by twenty feet in size and were arranged a randomized complete block design. Treatments included Method 240SL alone at 4, 8, 12, and 16 oz/ac; Method 50SG at 8 oz/ac; Milestone at 7 oz/ac; DMA 4 IVM at 32 oz/ac; 2,4-D choline[1] (i.e., Freelexx) at 32 oz/ac; Garlon 3A at 32 oz/ac; DMA 4 IVM at 32 oz/ac plus Garlon 3A at 32 oz/ac; and an untreated check. Induce non-ionic surfactant (NIS) was added at 0.25% v/v to all herbicide treatments. Treatments were applied on June 15, 2016 at 30 gal/ac using a CO_2-powered backpack sprayer equipped with a GunJet 30 handgun and BoomJet 10R nozzle (University Park) or six-foot boom and four 8002VS nozzles (State College).

At the time of treatment, common teasel (DIWSI) was vegetative with heights from 6 to 50 inches and averaging 30 inches tall. Birdsfoot trefoil (LOTCO) was in flower at the time of application, ranging in size from 9 to 26 inches tall, while averaging 18 inches in height.

The trial was visually rated for total vegetative cover, percent cover by common teasel (DIWSI) and birdsfoot trefoil (LOTCO) on June 14, September 15, October 14, and November 15, 2016 plus May 19, 2017 (0, 3, 4, 5, and 11 months after treatment, MAT). Percent injury to common teasel (DIWSI) and birdsfoot trefoil (LOTCO) were evaluated July 15 and August 15, 2016 (1 and 2 MAT). All data were subjected to analysis of variance and when treatment effect F-tests were significant ($p \leq 0.05$), treatment means were compared using Tukey's HSD separation test.

RESULTS AND DISCUSSION

Initial cover by common teasel ranged from 38 to 59 percent with no significant differences among plots at the time of treatment (Table 1). There was no statistical significance for common teasel cover at any of the reported dates for the treatments; however, there were trends. At 3 and 5 months after treatment, MAT, 4 to 16 oz/ac Method 240SL (exception 12 oz/ac), 8 oz/ac Method 50SG, and 7 oz/ac Milestone produced a notable decrease in common teasel cover. At these evaluation dates, the treatments averaged from 1 to 12 percent cover by common teasel. The impact using other treatments was not as great with cover by common teasel averaging 20 to 52 percent. Cover by common teasel decreased for all herbicide treatments from June 2016 (0 MAT) to May 2017 (11 MAT). The highest rate of 16 oz/ac Method 240SL and 8 oz/ac Method 50SG, with equivalent rates of the active ingredient, resulted in the greatest reduction of common teasel cover the following season compared to initial populations from 38 to 8 percent and 41 to 7 percent, respectively. Plots treated with 8 oz/ac Method 240SL and 7 oz/ac Milestone also resulted in dramatic decreases in common teasel cover the following season compared to initial populations from 59 to 18 percent and 50 to 16 percent, respectively. All other herbicides or rates resulted in 25 to 48 percent cover by common teasel at 11 MAT.

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[1] Dow AgroSciences LLC, Freelexx (*2,4-D choline*), Internet. June 11, 2017.

Injury to common teasel was similar at 1 MAT and significantly different from the untreated check for all herbicide treatments ranging from 32 to 60 percent, except 12 oz/ac Method 240SL with 28 percent injury (Table 2). This trend continued at 2 MAT for many of the treatments, including 8 and 16 oz/ac Method 240SL, 8 oz/ac Method 50SG, 7 oz/ac Milestone, and 32 oz/ac 2,4-D choline (i.e., Freelexx) with injury values from 55 to 85 percent. All other herbicide treatments were statistically similar to the untreated check for injury to common teasel and ranged from 28 to 50 percent.

Birdsfoot trefoil was affected by all herbicide treatments. The initial cover by birdsfoot trefoil ranged from 4 to 36 percent with no significant differences among plots at the time of treatment (Table 3). All herbicide treatments reduced cover by birdsfoot trefoil at 3, 5, and 11 MAT from 0 to 8 percent. During this time, cover by birdsfoot trefoil within the untreated check remained the same or increased, fluctuating from 4 to 9 percent. Injury to birdsfoot trefoil occurred with all herbicide treatments (Table 2). The most notable and severe injury of 100 percent resulted from treatments of 16 oz/ac Method 240SL and 32 oz/ac DMA 4 IVM plus 32 oz/ac Garlon 3A at 2 MAT. All other herbicides produced injury symptoms that ranged from 20 to 92 percent by this date.

CONCLUSIONS

All herbicide treatments tested were injurious and reduced cover by common teasel. However, the greatest control was provided by 8 or 16 oz/ac Method 240SL, 8 oz/ac Method 50SG, and 7 oz/ac Milestone. These same treatments also eliminated or nearly eliminated the birdsfoot trefoil that existed within the treated areas.

MANAGEMENT IMPLICATIONS

For control of common teasel, the Method 240SL label suggests use rates of 12 to 18 oz/ac[2], the Method 50SG label suggests 6 to 9 oz/ac[3], and Milestone suggests 4 to 7 oz/ac[4]. These herbicides and use rates were proven to effectively reduce common teasel populations including 16 oz/ac Method 240SL, 8 oz/ac Method 50SG, or 7 oz/ac Milestone. While they are effective at controlling common teasel, they are also detrimental to desirable herbaceous groundcovers. Use of these herbicides can be an effective tool to eliminate stands of common teasel. However, it is likely that little desirable groundcover exists among the teasel and any forbs that do exist will be eliminated. In this case, the area should be converted to grasses using Method, Milestone, or non-selective chemistry (i.e., glyphosate). The site can later be managed with mowing and/or subsequent selective herbicide treatments of Method or Milestone according to rates labeled for established roadside turf. The use rates of herbicides may differ when applied to areas during the establishment or maintenance of unimproved turf, for example the current label for both Method 50SG and 240SL limits use rates to a maximum of 4 oz/ac in unimproved turf settings[2,3]. More liberal use rates of Method 240SL for applications made to unimproved turfgrass have recently been approved by EPA[5]. So, in all cases read and follow label instructions prior to planning for and making applications.

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[2] Bayer Environmental Science, Method 240SL, Internet, June 11, 2017.
[3] Bayer Environmental Science, Method 50SG, Internent, June 11, 2017.
[4] Dow AgroSciences LLC, Milestone, Internet, June 11, 2017.
[5] D. Spak, personal communication, June 21, 2017

Table 1: Percent cover by common teasel (*Dipsacus fullonum*, DIWSI). The experiment was visually rated for percent cover by common teasel on June 14, September 15, November 15, 2016 and May 19, 2017 (0, 3, 5, and 11 months after treatment, MAT, respectively). Treatments were applied on June 15, 2016. 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 $p \leq 0.05$.

product	rate	DIWSI Cover 0 MAT	DIWSI Cover 3 MAT	DIWSI Cover 5 MAT	DIWSI Cover 11 MAT
	(oz/ac)	(---------------------------	%	------------------------	)
Untreated	---	46 a	43 a	46 a	37 a
Method 240SL	4	40 a	6 a	7 a	25 a
Method 240SL	8	59 a	12 a	6 a	18 a
Method 240SL	12	46 a	38 a	34 a	37 a
Method 240SL	16	38 a	1 a	0 a	8 a
Method 50SG	8	41 a	2 a	2 a	7 a
Milestone	7	50 a	6 a	6 a	16 a
DMA 4 IVM	32	45 a	20 a	26 a	26 a
2,4-D choline	32	46 a	29 a	24 a	36 a
Garlon 3A	32	51 a	45 a	52 a	48 a
DMA 4 IVM Garlon 3A	32 32	45 a	25 a	20 a	28 a
Significance Level ($p \leq 0.05$)		1.000	0.192	0.085	0.608

Table 2: Percent injury to common teasel ((*Dipsacus fullonum*, DIWSI) and birdsfoot trefoil (*Lotus corniculatus*, LOTCO). The experiment was visually rated for percent injury to common teasel and birdsfoot trefoil on July 15 and August 15, 2016 (1 and 2 months after treatment, MAT, respectively). Treatments were applied on June 15, 2016. 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 $p \leq 0.05$.

		DIWSI Injury		LOTCO Injury	
product	rate	1 MAT	2 MAT	1 MAT	2 MAT
	(oz/ac)	(----------------------------	---%	---	-------------------------)
Untreated	---	0 a	0 a	0 a	0 a
Method 240SL	4	46 bc	50 abc	38 a	55 ab
Method 240SL	8	48 bc	55 bc	77 a	85 ab
Method 240SL	12	28 ab	42 abc	47 a	65 ab
Method 240SL	16	50 bc	79 bc	92 a	100 b
Method 50SG	8	50 bc	79 bc	90 a	83 ab
Milestone	7	60 c	85 c	55 a	88 ab
DMA 4 IVM	32	38 bc	47 abc	70 a	48 ab
2,4-D choline	32	42 bc	61 bc	52 a	20 ab
Garlon 3A	32	32 bc	28 ab	93 a	92 ab
DMA 4 IVM Garlon 3A	32 32	36 bc	44 abc	72 a	100 b
Significance Level ($p \leq 0.05$)		0.000	0.000	0.110	0.017

Table 3: Percent cover by birdsfoot trefoil (*Lotus corniculatus*, LOTCO). The experiment was visually rated for percent cover by birdsfoot trefoil on June 14, September 15, November 15, 2016 and May 19, 2017 (0, 3, 5, and 11 months after treatment, MAT, respectively). Treatments were applied on June 15, 2016. 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 ≤ 0.05.

		LOTCO Cover			
product	rate	0 MAT	3 MAT	5 MAT	11 MAT
	(oz/ac)	(-----------------------------	------%	-------------------------	)
Untreated	---	4 a	9 a	4 a	5 a
Method 240SL	4	22 a	7 a	3 a	2 a
Method 240SL	8	16 a	5 a	3 a	2 a
Method 240SL	12	27 a	2 a	1 a	1 a
Method 240SL	16	13 a	0 a	0 a	0 a
Method 50SG	8	24 a	4 a	1 a	2 a
Milestone	7	32 a	1 a	1 a	0 a
DMA 4 IVM	32	22 a	8 a	2 a	8 a
2,4-D choline	32	27 a	7 a	2 a	2 a
Garlon 3A	32	36 a	1 a	0 a	0 a
DMA 4 IVM Garlon 3A	32 32	29 a	1 a	1 a	1 a
Significance Level (p≤0.05)		0.954	0.568	0.376	0.462

FURTHER INVESTIGATION OF ALTERNATIVES TO EMBARK 2S FOR PLANT GROWTH REGULATION OF ROADSIDE TURF

Herbicide trade and common names: 2,4-D choline, Freelexx (choline salt of 2,4 dichlorophenoxyacetic acid), Embark 2S (*mefluidide*), Escort XP (*metsulfuron*), Method 240SL (*aminocyclopyrachlor*), Overdrive (*dicamba + diflufenzopyr*), Plateau (*imazapic*), Segment (*sethoxydim*).

Plant common and scientific names: birdsfoot trefoil (*Lotus corniculatus* L., LOTCO), chicory (*Cichorium intybus*, CHIIN), dandelion (*Taraxacum officinale*, TAROF), Kentucky blue grass (*Poa pratensis*, POAPR), tall fescue (*Festuca arundinacea*, FESAR).

ABSTRACT

Using a spring application of plant growth regulators combined with a broadleaf herbicide is one management strategy for reducing mowing cycles along the roadside. With the proper tank mix, timing, and application, the growth of cool-season grasses can be slowed and seedhead development inhibited. The addition of a broadleaf herbicide helps to eliminate other unwanted and potentially tall growing weed species that might develop. Embark 2S, the standard growth regulator for this application, combined with Escort XP and a broadleaf component, has performed well in low maintenance turf areas. In April 2015, PBI-Gordon announced Embark would no longer be available due to the inability to locate a producer to supply the active ingredient, mefluidide. Alternative plant growth regulators were tested in combination with broadleaf herbicides for turf suppression and broadleaf weed control at two separate locations in Pennsylvania. The goal of this work was to build upon experiments conducted in 2015 to identify an acceptable substitute for Embark 2S. A total of fifteen product combinations were tested. Four potential individual or combination plant growth regulators were evaluated for seedhead suppression and reduced blade growth on tall fescue (*Festuca arundinacea*, FESAR) and Kentucky bluegrass (*Poa pratensis* L., POAPR). The treatments included: Plateau at 2, 3, or 4 oz/ac; Plateau at 2, 3, or 4 oz/ac plus Escort XP at 0.2 oz/ac; Escort XP at 0.33 oz/ac; Embark at 6 oz/ac plus Escort XP at 0.2 oz/ac; and Segment at 8, 16, and 24 oz/ac (FESAR only). These treatments were combined with Method 240 SL at 10 oz/ac. Additionally, Plateau at 2 oz/ac, Escort XP at 0.33 oz/ac, or Plateau at 2 oz/ac plus Escort XP at 0.2 oz/ac combined with Overdrive at 8 oz/ac plus 2,4-D choline at 64 oz/ac were evaluated. The experiment also included an untreated check. All herbicide treatments included Induce, non-ionic surfactant at 0.25 percent v/v. It should be noted that the current label for Method 240SL limits use rates to a maximum of 4 oz/ac in unimproved turf settings[1]. More liberal use rates of Method 240SL for applications made to unimproved turfgrass have recently been approved by EPA[2]. So, in all cases read and follow label instructions prior to planning for and making applications.

The height of tall fescue was statistically similar for all treatments and significantly lower than the untreated plots through 6 weeks after treatment, WAT, with few exceptions. By 8 WAT tall fescue began to rebound for many treatments, but Plateau tank mixes inhibited growth of tall fescue equal to the standard Embark plus Escort XP treatment. At the conclusion of the experiment, 10 WAT, tall fescue recovered and was similar in height to untreated plots for all treatments with only one anomaly. Average height of Kentucky bluegrass was largely

[1] Bayer Environmental Science, Method 240SL, Internet, June 25, 2017.
[2] D. Spak, personal communication, June 21, 2017.

unaffected by the treatments and only found significantly different from untreated plots in a few cases. Treatments that included Plateau or Segment at 16 and 24 oz/ac offered excellent seedhead suppression and were not significantly different from the standard Embark 2S plus Escort XP treatment. However, Escort XP and Segment at 8 oz/ac consistently provided less seedhead suppression than the standard treatment. In some instances, turf phytotoxicity was greater for Embark 2S plus Escort XP compared to Plateau, Segment, or Escort XP alone. Treatments containing Plateau at 3 or 4 oz/ac combined with Escort XP and Segment at 16 or 24 oz/ac initially caused unacceptable damage and significant discoloration of the turf, but by 10 WAT symptoms had diminished and turf cover was fully restored. All mixes provided similar and effective control of chicory (*Cichorium intybus* L.), dandelion (*Taraxacum officinale*), and birdsfoot trefoil (*Lotus corniculatus* L.) by 8 WAT, although Method demonstrated quicker activity than Overdrive plus 2,4-D choline. Plateau, at the rates tested in these experiments, combined with Method appeared to provide acceptable turf growth suppression of cool-season roadside turf and broadleaf weed control. Further experiments are necessary to ensure the safety of the preferred treatments on a range of turf species and environmental conditions before adopting these treatments.

INTRODUCTION

Plant growth regulators, PGRs, combined with broadleaf herbicides is one strategy used by the Pennsylvania Department of Transportation, PennDOT, to reduce spring mowing cycles by suppressing the development of turfgrass and control broadleaf weeds. PGR applications are particularly useful where mechanical mowing operations are difficult to conduct due to traffic hazards or obstacles. These applications are generally employed to eliminate added mowing cycles and offer an alternative to complete reliance on mechanical operations.

The standard PGR mix contains Embark, Escort XP, plus a broadleaf weed control component. In April 2015, PBI-Gordon announced the discontinuation of Embark due to the inability to locate a producer to supply the active ingredient mefluidide. In an effort to find an alternative PGR, Plateau, Panoramic, Escort XP, Anuew, and Segment were compared against the standard in testing done during the 2015 season.[3,4] This experiment, conducted in 2016, was refined by those results and focused on only three PGRs, including Plateau, Escort XP, and Segment. Plateau is labeled for the growth regulation of cool-season roadside grasses (e.g., K-31 tall fescue and "wildtype common" Kentucky bluegrass) at rates of 2 to 4 oz/ac.[5] Precautions on the label limit the use of surfactants and offer a very short list of turf species to treat with the product. Escort XP is labeled for the suppression and seedhead inhibition of certain industrial turf species at rates of 0.25 to 0.5 oz/ac with several precautions listed.[6] Segment is older chemistry labeled for turf growth suppression on roadsides, rights-of-way, or tree farms.[7] This experiment, conducted at two locations, compares these alternative PGR products alone and in combination while tank mixed with a broadleaf herbicide component. Method 240SL was chosen as the broadleaf herbicide in the experiment with the exception of three treatments

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[3] Cleary Chemicals LLC. Anuew. Internet. February 20, 2017.
[4] Johnson, J.M. et al. 2016. Alternatives to Embark for plant growth regulation of roadside turf. Roadside Vegetation Management Research – 2016 Report. P. 20-32.
[5] BASF Corporation. Plateau. Internet. February 20, 2017.
[6] Bayer Environmental Science. Escort XP. Internet. February 20, 2017.
[7] BASF Corporation. Segment. Internet. February 20, 2017.

containing Overdrive plus 2,4-D choline. The 2,4-D choline component is currently sold as Freelexx.[8]

GENERAL SUMMARY OF MATERIALS AND METHODS

The experiments were conducted at two separate locations within central Pennsylvania. The first site was located along the Old Fort exit ramp from SR322E (Old Fort). The second site was located along the shoulder of SR322W just beyond the Flat Rock exit, near Port Matilda, PA (Port Matilda). Plots were six by twenty feet in size and were arranged as a randomized complete block design with four replications. Treatments included Plateau at 2, 3, or 4 oz/ac; Plateau at 2, 3, or 4 oz/ac plus Escort XP at 0.2 oz/ac; Escort XP alone at 0.33 oz/ac; Embark at 6 oz/ac plus Escort XP at 0.2 oz/ac; and an untreated check. All treatments were combined with Method 240SL at 10 oz/ac. Other treatments tested at only one of two locations include: Segment at 8, 16, or 24 oz/ac plus Method 240SL at 10 oz/ac (Port Matilda site only) or Plateau at 2 oz/ac, Plateau at 2 oz/ac plus Escort XP at 0.2 oz/ac, or Escort XP at 0.33 oz/ac each combined with Overdrive at 8 oz/ac and 2,4-D choline at 64 oz/ac (Old Fort site only). It should be noted that the current label for Method 240SL limits use rates to a maximum of 4 oz/ac in unimproved turf settings[1]. More liberal use rates of Method 240SL for applications made to unimproved turfgrass have recently been approved by EPA[2]. So, in all cases read and follow label instructions prior to planning for and making applications. Induce, a non-ionic surfactant (NIS) at 0.25% v/v, was added to all treatments. Treatments were applied either April 27 or May 6, 2016, at Old Fort and Port Matilda, respectively, at 35 gal/ac using a CO_2-powered backpack sprayer equipped with a six-foot boom and four 8004VS nozzles.

Trials were evaluated at two-week intervals for percent seedhead reduction of tall fescue, average height of tall fescue and Kentucky bluegrass, phytotoxicity of the turf, and percent injury and control of chicory, dandelion, or birdsfoot trefoil. Percent total turf cover was evaluated at the onset and conclusion of the experiment. Past research and use of plant growth regulators in seed head suppression and turf height for roadside application has revealed that Kentucky bluegrass seed heads do not raise to heights that warrant concern and are a less likely target for control whereas, tall fescue seed heads are deemed necessary targets for control. To simplify the presentation to the most salient points of the results and discussion below, the tables representing seed head suppression on tall fescue and phytotoxicity effects on turf are presented here. Tables representing results relative to tall fescue and Kentucky bluegrass blade height, total cover of turf stands after treatment, and weed control of chicory, dandelion, and birdsfoot trefoil are presented in the appendix. 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.

OLD FORT, SITE #1

Treatments were applied April 27, 2016. The trial was measured for average height of tall fescue and Kentucky bluegrass on May 11, May 25, June 9, June 22, and July 6, 2016 (2, 4, 6, 8, and 10 weeks after treatment, WAT). Percent seedhead reduction of tall fescue was visually rated on May 11, May 25, June 9, June 22, and July 6, 2016 (2, 4, 6, 8, and 10 WAT). Percent

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[8] Dow AgrowSciences LLC. Freelexx. Internet. February 20, 2017.

seedhead reduction reflects the decrease of tall fescue seedheads compared to the untreated check with consideration for the amount of the species present within the plot. Phytotoxicity of the turfgrass was visually rated on May 11, May 25, June 9, and June 22, 2016 (2, 4, 6, and 8 WAT). Turf phytotoxicity was rated on a scale of 0 to 10 where "0" = healthy, green; "5" = moderate discoloration; and "10" = completely necrotic, brown. Percent total turf cover was visually estimated at the onset and conclusion of the experiment on April 26 and July 6, 2016 (0 and 10 WAT). The percent change in turf cover was mathematically derived using the formula [(% ending turf cover-% initial turf cover)/% initial turf cover x 100]. Percent injury of chicory and dandelion was evaluated on May 11, May 25, June 9, and June 22, 2016 (2, 4, 6, and 8 WAT), while percent injury of chicory was also evaluated on July 6, 2016 (10 WAT).

RESULTS AND DISCUSSION

All treatments demonstrated a short-term effect at inhibiting tall fescue growth (Table 1, appendix). At 6 WAT, all herbicide mixes remained statistically shorter than the untreated check and measured from 9.8 to 11.9 inches in height compared to 16 inches for the untreated plots, except Escort XP at 0.33 oz/ac combined with Overdrive and 2,4-D choline (13.2 inches). By 8 WAT, only Plateau used at the highest rate of 4 oz/ac alone or combined with Escort XP at 0.2 oz/ac was statistically shorter than the untreated check (10.1 and 11.4 inches versus 15.7 inches). All other treatments measured in height from 11.9 to 15.2 inches. This trend continued at 10 WAT, with Plateau at 4 oz/ac alone or combined with Escort XP at 0.2 oz/ac maintaining the shortest height and measuring 9.9 and 9.7 inches compared to the untreated check (14.1 inches). Treatments using Escort XP as the sole plant growth regulator component were numerically taller at 15.2 inches.

The average height of Kentucky bluegrass was not greatly impacted by the treatments at any rating date (Table 2, appendix). Plateau at 3 or 4 oz/ac and Plateau at 3 oz/ac plus Escort XP at 0.2 oz/ac offered short-lived growth inhibition of this species and at 2 WAT resulted in heights of 7.5 to 7.7 inches compared to the untreated check at 10.6 inches. Plateau at 4 oz/ac provided the only other instance a treatment was found statistically shorter than the untreated plots (10.8 versus 15.2 inches at 6 WAT).

All treatments, except Escort XP, provided acceptable seedhead reduction of tall fescue and ranged from 88 to 100 percent (Table 3). In fact, the treatments under investigation ranged from 96 to 100 percent seedhead reduction at all rating dates, whereas the standard Embark plus Escort XP treatment ranged from 88 to 94 percent at 6 to 10 WAT. The performance of Escort XP at 0.33 oz/ac was less effective at seedhead reduction of tall fescue, ranging from 71 to 72 percent or 49 to 50 percent at 6 to 10 WAT depending on the broadleaf herbicide component added.

Turf phytotoxicity was occasionally significant but acceptable for all treatments (Table 4). Most treatments had elevated phytotoxicity values from 1.8 to 2.8 compared to the untreated plots (0) at 2 WAT. Plateau at 2 oz/ac plus Method 240SL at 10 oz/ac and Escort XP at 0.33 oz/ac plus Overdrive and 2,4-D choline were the exceptions with values of 1.2. In future ratings, all treatments ranged from 0.5 to 3.2 and only Plateau at 3 oz/ac combined with Escort XP at 0.2 oz/ac and Method 240SL at 10 oz/ac or Plateau at 4 oz/ac plus Method 240SL at 10 oz/ac with or without Escort XP at 0.2 oz/ac statistically exceeded values of the untreated check from 2.5 to 3.2.

One concern with the use of PGRs is the potential for thinning of the turfgrass stand. An overall evaluation of the turf cover suggested that none of the treatments were detrimental to the turf density (Table 5, appendix). At the onset of the experiment, turf cover was similar and ranged from 70 to 76 percent for all treatments, including the untreated check. By the final evaluation, 10 WAT, turf cover was similar and increased in percentage for all treatments ranging from 74 to 80 percent, except a minor decrease using Escort XP at 0.33 oz/ac plus Overdrive at 8 oz/ac and 2,4-D choline at 64 oz/ac (71 versus 70 percent).

All herbicide treatments provided equivalent and excellent control of chicory and dandelion from 98 to 100 percent, although control was delayed using Overdrive plus 2,4-D choline (Tables 6 & 7, appendix).

PORT MATILDA, SITE #2

Treatments were applied on May 6, 2016. The trial was measured for average height of tall fescue on May 20, June 3, June 17, July 1, and July 15, 2015 (2, 4, 6, 8, and 10 weeks after treatment, WAT). Percent seedhead reduction of tall fescue was visually rated on May 20, June 3, June 17, July 1, and July 15, 2016 (2, 4, 6, 8, and 10 WAT). Percent seedhead reduction reflects the decrease of tall fescue seedheads compared to the untreated check with consideration for the amount of that species present within the plot. Phytotoxicity of the turfgrass was visually evaluated on May 20, June 3, June 17, and July 1, 2016 (2, 4, 6, and 8 WAT). Turf phytotoxicity was rated on a scale of 0 to 10 where "0" = healthy, green; "5" = moderate discoloration; and "10" = completely necrotic, brown. Percent total turf cover was visually estimated at the onset and conclusion of the experiment on May 5 and July 15, 2016 (0 and 10 WAT). The percent change in turf cover was mathematically derived using the formula [(% ending turf cover-% initial turf cover)/% initial turf cover x 100]. Percent injury of birdsfoot trefoil was evaluated on May 20, June 3, June 17, and July 1, 2016 (2, 4, 6, and 8 WAT).

RESULTS AND DISCUSSION

Tall fescue height was reduced for all treatments compared to the untreated check from 4 to 6 WAT (Table 8, appendix). At 4 WAT, treatments ranged from 9.3 to 11.1 inches in height compared to 14.2 inches for untreated plots. Measurements taken at 6 WAT resulted in heights from 8 to 11.5 inches for the treated plots compared to 15.2 inches for untreated plots. By 8 WAT, all treatments containing Plateau and the standard Embark plus Escort XP treatment remained significantly shorter than the untreated check (10.5 to 11.5 inches compared to 13.9 inches), except Plateau at 3 oz/ac plus Escort XP at 0.2 oz/ac and Method 240SL at 10 oz/ac (11.7 inches). Treatments containing Segment or Escort XP alone as the PGR were similar in height to the untreated check by this date (11.9 to 13.9 inches). By 10 WAT the herbicides were no longer offering growth inhibition and were similar to untreated plots from 11.2 to 14.2 inches.

All treatments, except Escort XP, provided acceptable seedhead reduction of tall fescue and ranged from 92 to 100 percent (Table 9). Escort XP resulted in tall fescue seedhead inhibition that fluctuated from 50 to 90 percent at 4 to 10 WAT.

Turf phytotoxicity was significant and unacceptable for treatments that included Segment at rates of 16 or 24 oz/ac with values of 6 and 8 at 4 WAT (Table 10). Other treatments that had elevated phytotoxicity on at least one occasion included Plateau at 3 or 4 oz/ac plus Escort XP at 0.2 oz/ac and Method 240SL at 10 oz/ac (4 or greater, 6 WAT). All other treatments resulted in acceptable injury to the turf with values of 0 to 3. By 8 WAT, the symptoms had diminished and no treatment exhibited unacceptable injury (1 to 2.5).

An overall evaluation of the turf cover suggested that none of the treatments were detrimental to the turf density (Table 11, appendix). At the onset of the experiment, turf cover was similar and ranged from 38 to 45 percent for all treatments, including the untreated check. By the final evaluation, 10 WAT, turf cover was similar and increased in percentage for all treatments, including the untreated control, ranging from 66 to 72 percent. The increase in turf cover that occurred during the 10-week rating period was likely the result of normal development of the grass stand as the season progressed.

All herbicide treatments provided equivalent and excellent control of birdsfoot trefoil from 86 to 94 percent (Table 12, appendix).

GENERAL CONCLUSIONS

Plateau combined with Method offered the most encouraging results throughout the experiment. These combinations used at the rates tested in this experiment performed equally to the standard Embark plus Escort XP treatment. Plateau plus Escort XP was also effective, but the addition of Escort XP could increase the potential for turf injury with no added benefit. Phytotoxicity was elevated and unacceptable with increased rates of Plateau when used in combination with Escort XP. Escort XP or Segment alone did not provide the results needed to serve as a replacement in roadside turf applications. Escort XP used alone did not offer adequate seedhead suppression of tall fescue. Segment at rates of 16 or 24 oz/ac was injurious and caused unacceptable discoloration of the turf while Segment at 8 oz/ac began to demonstrate a weakness in suppressing tall fescue growth. Ultimately, the combination of Overdrive plus 2,4-D choline provided weed control comparable to Method, but was slower to exhibit symptoms.

OVERALL MANAGEMENT IMPLICATIONS

Plateau at rates of 2 or 3 oz/ac combined with Method offers an alternative tank mix to PennDOT's plant growth regulation (7711-03) program and the standard Embark plus Escort XP plus broadleaf herbicide treatment. Plateau is labeled for suppression of cool-season roadside turf. A spring application, just prior to seedhead emergence, appears to prevent seedhead development of tall fescue without reducing overall turfgrass cover and manages undesirable broadleaf weeds. With a properly timed application the number of mowing cycles can be reduced in areas where mechanical operations are difficult or dangerous. Caution should be used when adding Method as this product is soil active and has the potential to injure some desirable tree species. It should also be noted that the current label for Method 240SL limits use rates to a maximum of 4 oz/ac in unimproved turf settings[1]. More liberal use rates of Method 240SL for applications made to unimproved turfgrass have recently been approved by EPA[2]. So, in all cases read and follow label instructions prior to planning for and making applications.

Table 3: Percent seedhead suppression of the tall fescue stand at Old Fort. The experiment was visually rated for seedhead reduction of tall fescue on May 11, May 25, June 9, June 22, and July 6, 2016 (2, 4, 6, 8, and 10 weeks after treatment, WAT). Treatments were applied on April 27, 2016. All treatments included 0.25% v/v non-ionic surfactant. 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	tall fescue percent seedhead reduction				
		2 WAT	4 WAT	6 WAT	8 WAT	10 WAT
	(oz/ac)					
Untreated	----	0 a	0 a	0 a	0 a	0 a
Plateau Method 240SL	2 10	100 b	100 b	100 c	98 d	98 d
Plateau Method 240SL	3 10	100 b	100 b	100 c	100 d	100 d
Plateau Method 240SL	4 10	100 b	100 b	100 c	100 d	100 d
Plateau Escort XP Method 240SL	2 0.2 10	100 b	100 b	98 c	94 d	100 d
Plateau Escort XP Method 240SL	3 0.2 10	99 b	100 b	100 c	99 d	100 d
Plateau Escort XP Method 240SL	4 0.2 10	100 b	99 b	99 c	100 d	100 d
Escort XP Method 240SL	0.33 10	100 b	95 b	71 bc	72 c	72 c
Embark Escort XP Method 240SL	6 0.2 10	100 b	100 b	88 c	88 cd	94 d
Plateau Overdrive 2,4-D choline	2 8 64	100 b	100 b	100 c	96 d	100 d
Plateau Escort XP Overdrive 2,4-D choline	2 0.2 8 64	100 b	100 b	100 c	99 d	99 d
Escort XP Overdrive 2,4-D choline	0.33 8 64	98 b	22 a	49 b	50 b	50 b
Sign. Level ($p \leq 0.05$)		0.000	0.000	0.000	0.000	0.000

Table 4: Phytotoxicity of the turfgrass stand at Old Fort. The experiment was visually rated for turf phytotoxicity using a scale of 0-10 where "0" = healthy, green; "5" = moderate discoloration; "10"= completely necrotic, brown. Evaluations were made on May 11, May 25, June 9, and June 22, 2016 (2, 4, 6, and 8 weeks after treatment, WAT). Treatments were applied on April 27, 2016. All treatments included 0.25% v/v non-ionic surfactant. 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	turf phytotoxicity (0-10 scale)			
		2 WAT	4 WAT	6 WAT	8 WAT
	(oz/ac)				
Untreated	----	0 a	0.2 a	0 a	0 a
Plateau Method 240SL	2 10	1.2 ab	2.5 a	2 abc	1.8 ab
Plateau Method 240SL	3 10	1.8 b	1.8 a	1.8 abc	2 ab
Plateau Method 240SL	4 10	2 b	2.5 a	2.5 bc	2.2 ab
Plateau Escort XP Method 240SL	2 0.2 10	2.2 b	1.8 a	1 ab	2.2 ab
Plateau Escort XP Method 240SL	3 0.2 10	2.2 b	2.8 a	2.5 bc	2.2 ab
Plateau Escort XP Method 240SL	4 0.2 10	2.8 b	2.5 a	3.2 c	2.5 b
Escort XP Method 240SL	0.33 10	2.2 b	2.2 a	1.5 abc	1 ab
Embark Escort XP Method 240SL	6 0.2 10	2.2 b	2.2 a	1.5 abc	2 ab
Plateau Overdrive 2,4-D choline	2 8 64	2.2 b	2 a	0.8 ab	1.5 ab
Plateau Escort XP Overdrive 2,4-D choline	2 0.2 8 64	2.5 b	2.5 a	1.8 abc	1.8 ab
Escort XP Overdrive 2,4-D choline	0.33 8 64	1.2 ab	2.2 a	0.5 ab	1.5 ab
Sign. Level ($p \leq 0.05$)		0.000	0.165	0.000	0.037

Table 9: Percent seedhead suppression of the tall fescue stand at Port Matilda. The experiment was visually rated for seedhead reduction of tall fescue on May 20, June 3, June 17, July 1, and July 15, 2016 (2, 4, 6, 8, and 10 weeks after treatment, WAT). Treatments were applied on May 6, 2016. All treatments included 0.25% v/v non-ionic surfactant. 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	tall fescue percent seedhead reduction				
		2 WAT	4 WAT	6 WAT	8 WAT	10 WAT
	(oz/ac)					
Untreated	----	0 a	0 a	0 a	0 a	0 a
Plateau Method 240SL	2 10	98 b	100 d	100 d	97 c	98 c
Plateau Method 240SL	3 10	98 b	100 d	100 d	100 c	100 c
Plateau Method 240SL	4 10	100 b	100 d	100 d	100 c	100 c
Plateau Escort XP Method 240SL	2 0.2 10	100 b	100 d	100 d	98 c	100 c
Plateau Escort XP Method 240SL	3 0.2 10	100 b	100 d	100 d	100 c	99 c
Plateau Escort XP Method 240SL	4 0.2 10	100 b	100 d	99 d	100 c	100 c
Escort XP Method 240SL	0.33 10	100 b	90 b	50 b	62 b	80 b
Embark Escort XP Method 240SL	6 0.2 10	100 b	100 d	99 d	100 c	97 c
Segment Method 240SL	8 10	98 b	96 c	92 c	94 c	92 bc
Segment Method 240SL	16 10	100 b	100 d	100 d	97 c	92 bc
Segment Method 240SL	24 10	100 b	100 d	100 d	100 c	98 c
Sign. Level ($p \leq 0.05$)		0.000	0.000	0.000	0.000	0.000

Table 10: Phytotoxicity of the turfgrass stand at Port Matilda. The experiment was visually rated for turf phytotoxicity using a scale of 0-10 where "0" = healthy, green; "5" = moderate discoloration; "10"= completely necrotic, brown. Evaluations were made on May 20, June 3, June 17, and July 1, 2016 (2, 4, 6, and 8 weeks after treatment, WAT). Treatments were applied on May 6, 2016. All treatments included 0.25% v/v non-ionic surfactant. 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	turf phytotoxicity (0-10 scale)			
		2 WAT	4 WAT	6 WAT	8 WAT
	(oz/ac)				
Untreated	----	0 a	0 a	0 a	0 a
Plateau Method 240SL	2 10	2.8 b	1.8 bc	1.5 ab	1.8 ab
Plateau Method 240SL	3 10	2.8 b	2 bcd	2 bc	1.8 ab
Plateau Method 240SL	4 10	2.5 b	3 cd	2.5 b-e	2.2 ab
Plateau Escort XP Method 240SL	2 0.2 10	2.8 b	2.8 cd	2.2 bcd	1.8 ab
Plateau Escort XP Method 240SL	3 0.2 10	2.8 b	2.5 bcd	4 de	2.5 b
Plateau Escort XP Method 240SL	4 0.2 10	2.8 b	3.5 d	4.2 e	2.5 b
Escort XP Method 240SL	0.33 10	2.5 b	1.8 bc	1.2 ab	1.8 ab
Embark Escort XP Method 240SL	6 0.2 10	2.8 b	2.8 cd	2.8 b-e	2.2 ab
Segment Method 240SL	8 10	1.5 ab	1 ab	0 a	1.5 ab
Segment Method 240SL	16 10	2.5 b	6 e	2.2 bcd	1 ab
Segment Method 240SL	24 10	2.8 b	8 f	3.8 cde	1.5 ab
Sign. Level ($p \leq 0.05$)		0.000	0.000	0.000	0.041

SEASONAL TIMING EFFECTS ON WARM-SEASON GRASS ESTABLISHMENT RELATIVE TO CROWNVETCH AND ANNUAL RYEGRASS – YEAR SEVEN

Plant common and scientific names: annual ryegrass (*Lolium multiflorum*), big bluestem (*Andropogon gerardii*), cereal rye (*Secale cereale*), crownvetch (*Coronilla varia*), Indiangrass (*Sorghastrum nutans*), little bluestem (*Schizachyrium scoparium*), partridge pea (*Chamaecrista fasciculata),* showy tick-trefoil (*Desmodium canadense*), spring oats (*Avena sativa*), sweet clover (*Melilotus officinalis*), switchgrass (*Panicum virgatum*), Virginia wildrye (*Elymus virginicus*).

ABSTRACT

Rapid and successful establishment of vegetative cover is an important consideration for managers of roadside construction and renovation projects. Native ground covers, specifically warm season grasses (WSG), offer a potential alternative to crownvetch, which has been used extensively to provide cover for poor quality, low maintenance sites. In 2009 a long-term replicated comparison experiment was initiated to determine the seasonal effects on establishment of Formula N, a native seed mix containing WSG and several legumes, to that of Formula C, a standard mix of crownvetch and annual ryegrass. Planting dates for the trial were February 13th, April 23rd, July 7th, and August 21st. Data collected in fall of 2016, seven years (8 growing seasons) after initial seeding, showed that cover by WSG more than doubled from the 2011 rating with the February seeding having the highest WSG cover followed by April, July and August. Plant counts from 2016 indicate that WSG plants per square foot decreased by 38 to 50 percent from 2012, suggesting that as plants grew larger and covered more ground, the number of plants decreased. It appears that late winter through spring may be the best time to seed WSG mixtures. Crownvetch established poorly on this site from the start and by 2016, the August timing had the highest cover by crownvetch and February had the lowest with 8 and 0.03 percent, respectively.

INTRODUCTION

Reestablishment of groundcover on disturbed sites following road construction or during remediation is a major concern for project designers and managers. Crownvetch, the major component of Formula C, is capable of establishment on poor quality sites with infertile, compacted, or coarse textured soils and can be seeded at any time of year except September and October.[1] However, in 2000 it was listed as a "situational invasive" in the publication *Invasive Plants in Pennsylvania* by the Pennsylvania Department of Conservation and Natural Resources. Native warm-season grasses (WSG) provide a possible alternative to introduced species for revegetation of sites disturbed by road construction activities. One drawback is that WSG are slow and sometimes difficult to establish.[2] The purpose of this 2009 long-term experiment was to compare the establishment of native WSG species over four seeding dates spaced throughout the year to that of crownvetch. This report represents the seventh year of results following seeding.

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[1] PennDOT. Pub. 408 Specifications (2007), Section 804 – Seeding and Soil Supplement

[2] Johnson, J.M. et al. 2012. Native Seed Mix Establishment Implementation – Year Four. Roadside Vegetation Management Research – 2012 Report, pp. 16-20.

MATERIALS AND METHODS

This experiment was established on a gently sloping site previously disturbed by road construction along I-99 northbound, west of State College, PA. The experiment utilized two seed mixes, Formula C (Table 1) and Formula N (Table 2), seeded during four planting periods: Nov to Feb, Mar to May, June to July, and Aug to Sept. Seeding occurred on February 13, April 23, July 7, and August 21, 2009. The eight treatments were applied to 20 by 24 ft. plots in a randomized complete block design with three replications. The 0.49 ac. site, was prepared by ripping and grading the soil to reduce compaction and smooth the surface on October 16, 2008, followed by seeding cereal rye and straw mulch on October 22, 2008 to provide a winter vegetative cover. The site was amended with 46-0-0 urea and 39-0-0 sulfur coated urea at a rate of 15 and 5.9 lbs per 1000 S.Y., respectively. At each seeding time, additional soil amendments were broadcast across the plots to be seeded. These amendments included pelletized limestone at 800 lbs per 1000 S.Y. and 20-10-10 fertilizer at 140 lbs per 1000 S.Y. Plots seeded to Formula N also received 39-0-0 sulfur-coated urea at 49 lb per 1000 S.Y. at seeding. Soil amendments were based on PennDOT Pub 408 specifications for seeding cool season grasses. All plots were straw mulched following seeding and soil amendment applications.

On July 18, 2012, all plots were mowed with a string trimmer at a height of approximately 12 inches to remove competition from broadleaf weeds, specifically sweet clover. On July 11, 2013, in an effort to control broadleaf weeds, WSG plots were treated with Triplet LO at 64 oz/ac plus 0.25% v/v CWC 90 surfactant, while crownvetch plots were treated with Panoramic 2SL at 6 oz/ac plus 0.25% v/v CWC 90 surfactant. On July 2, 2015 crownvetch plots were mechanically cut with a string trimmer at a height of approximately 8 inches, while WSG plots were treated with Triplet LO at 64 oz/ac plus 0.25% v/v Induce surfactant. Plots seeded with native mixes in February, April, and July produced enough WSG plants to warrant counts of individual species. Beginning in 2012, fixed subplot sampling was used to count the WSG plants on 2% of the area within these plots. Subplots were located by establishing a single transect across the plot. A string was stretched diagonally between opposite corners of each plot. Subplots, two square feet in size, with a center point of 5’3”, 10’6”, 15’9”, 21’0”, 26’3” were set up along the transect line. Individual WSG plants within each subplot were identified and tallied. The mean number of plants per square foot was calculated from data gathered within the five subplots. Quantitative data were subjected to analysis of variance. When treatment effect F-tests were significant ($p \leq 0.05$), means were compared using the Tukey HSD test.

RESULTS AND DISCUSSION

Cover by WSG recorded two growing seasons after seeding (in fall 2011) ranged from 25 percent for the February seeding to 1 percent for July and August seedings (Table 3). February and April seedings produced the best overall cover ratings at 25 and 20 percent cover by WSG, respectively. By 2016, 7 years (8 growing seasons) after initial seeding, cover by WSG for plots with all timings more than doubled from the 2011 rating, and the order remained the same with the February seeding having the highest WSG cover followed by April, July, and August with 59, 55, 39, and 7 percent cover, respectively.

Plants per square foot decreased by 38 to 50 percent from 2012 to 2016 for the February, April, and July timings with counts in 2016 of 2.1, 2.2, and 0.5 plants per square foot, respectively (Table 4). The decrease in plants per unit area was accompanied by an increase in cover by WSG, suggesting as the plants grew larger over the years, fewer plants were found per square foot. It would be expected that larger plants would have larger root systems and there appears to be no loss of erosion protection with the shift to fewer but larger WSG plants. Big bluestem and Indiangrass are the components of the mix that have established in the largest numbers. Plots in the August timing did not have enough WSG plants present to warrant sampling prior to the 2015 ratings, and even then yielded relatively low plant counts.

Percent total vegetative cover remained relatively constant over the 5 years (Table 5) from 2011 to 2016 although there has been some species shift especially in the February, April and July seeded plots as WSG plants replaced other vegetation such as goldenrod, oxeye daisy, and aster. The 2013 growing season is anomalous because this is the first year an herbicide was applied for broadleaf weed control. The 2013 total vegetative cover ratings for April, July and August timings reflect the loss of broadleaf cover by the end of the growing season as a result of this application.

Plots seeded to crownvetch established inconsistently from the start. In 2011 crownvetch cover ranged from 65 to 3 percent with no significant differences between treatments (Table 6). In July of 2013, Panoramic 2.5SL was applied at 6 oz/ac to control broadleaf weeds. The patchy crownvetch cover was severely reduced by this treatment and never recovered as evidenced by the 2016 cover rating that ranged from 8 to 0.03 percent for August and February seedings respectively. A thorough description of the site and first, second, third, fourth, and fifth full year results after seeding can be found at Johnson et al.[3,4,5,6,7]

CONCLUSIONS

From the data gathered over 8 growing seasons, late winter through early spring appears to be the most favorable time to establish WSG cover. This corresponds with germination and growth expectations outlined by the Ernst Seeds company (www.ernstseeds.com) which suggest that spring soil moisture conditions and soil temperatures of 55°F or greater provide for the greatest development. Even with the most favorable seeding dates, WSG plants require years to establish and effectively cover the soil.

July and August appear to be a poor time to seed sites with WSG mixes, although the plots seeded in July continue to show an increase in WSG stems. At this point in the experiment, seedlings are likely developing from seed produced by WSG plants present on the site being wind dispersed across the treatments.

The April and August seeding resulted in the greatest crownvetch establishment. The decrease in crownvetch cover since 2012 is in part due to the application of Panoramic made in July of 2013 to help control broadleaf weeds. Even prior to this application, the crownvetch

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[3] Johnson et al. 2010. Seasonal Timing Effects on Warm-Season Grass Establishment Relative to Crownvetch and Annual Ryegrass. Roadside Vegetation Management Research – 2010 Report. pp. 57-60.
[4] Johnson et al. 2011. Seasonal Timing Effects on Warm-Season Grass Establishment Relative to Crownvetch and Annual Ryegrass – Year Two. Roadside Vegetation Management Research – 2011 Report. pp. 59-63.
[5] Johnson et al. 2012. Seasonal Timing Effects on Warm-Season Grass Establishment Relative to Crownvetch and Annual Ryegrass – Year Three. Roadside Vegetation Management Research – 2012 Report. pp. 6-10.
[6] Johnson et al. 2013. Seasonal Timing Effects on Warm-Season Grass Establishment Relative to Crownvetch and Annual Ryegrass – Year Four. Roadside Vegetation Management Research – 2013 Report. pp. 42-47.
[7] Johnson et al. 2015. Seasonal Timing Effects on Warm-Season Grass Establishment Relative to Crownvetch and Annual Ryegrass – Year Five. Roadside Vegetation Management Research – 2015 Report. pp. 40-45.

plots did not have consistent crownvetch cover. Other than the broadleaf herbicide treatment, the factors that restricted crownvetch establishment are not clear.

MANAGEMENT IMPLICATIONS

More work needs to be done on establishment of WSG cover, but it appears that late winter through early spring is the best time to seed. An intermediate cover crop may be necessary to provide cover until the WSG develop. In addition, temporary erosion control may have to be maintained during the extended establishment period. Since the 2012 growing season, it has become obvious that maintenance such as mowing, treatment with herbicides, or both are necessary to keep the site from being overrun with broadleaf weeds and brush. This should be a planned component for any operation where Formula N will be established.

Table 1. Formula C seed mix per PennDOT Pub. 408, Section 804 – Seeding and Soil Supplements.

Scientific Name	Common Name	Seeding Rate	
		lb/ac	lb/1000 S.Y.
Coronilla varia	crownvetch	19.4	4.0
Lolium multiflorum	annual ryegrass	24.2	5.0

Table 2. Formula N seed mix. PLS = pure live seed (%) = % germination x % purity / 100.

Scientific Name	Common Name	Seeding Rate (PLS)	
		lb/ac	lb/1000 S.Y.
Avena sativa	spring oats	30	6.0
Elymus virginicus	Virginia wildrye	10	2.0
Andropogon gerardii	big bluestem	6	1.2
Schizachyrium scoparium	little bluestem	6	1.2
Sorghastrum nutans	Indiangrass	6	1.2
Panicum virgatum	switchgrass	2	0.4
Desmodium canadense	showy tick-trefoil	2	0.4
Chamaecrista fasciculate	partridge pea	2	0.4

Table 3. Cover by warm season grasses (WSG) for plots seeded to Formula N on February 13, April 23, July 7, and August 21, 2009. Percent cover was determined by visual observation. The number followed by YAS indicates the number of years after seeding the data was collected. Within each column, numbers followed by different letters are significantly different at the .05 level.

Timing	2011 (2 YAS)	2012 (3YAS)	2013 (4YAS)	2014 (5YAS)	2015 (6YAS)	2016 (7YAS)
February	25 a	40 a	67 a	49 a	49 a	59 a
April	20 a	17 b	53 a	42 a	48 ab	55 a
July	1 b	2 b	9 b	11 b	23 bc	39 a
August	1 b	0.2 b	1 b	2 b	3 c	7 b

Table 4. Plant counts for plots seeded to Formula N, warm season grasses (WSG). Numbers include big bluestem, little bluestem, Indiangrass, switchgrass, and Virginia wildrye seeded on February 13, April 23, July 7, and August 21, 2009. Data was collected in the fall of each year. The number followed by YAS indicates the number of years after seeding the data was collected. Each value is the mean of three replications. Within each column, numbers followed by different letters are significantly different at the .05 level.

	Plants per Square Foot					% Change 2012 to 2016
Timing	2012 (3YAS)	2013 (4YAS)	2014 (5YAS)	2015 (6YAS)	2016 (7YAS)	
February	4.2 a	3.6 a	2.5 a	2.7 a	2.1 a	-50
April	3.6 ab	2.6 a	2.0 a	2.3 a	2.2 a	-39
July	0.8 bc	0.5 b	0.4 b	0.6 b	0.5 b	-38
August	0 c	0 b	0 b	0.4 b	0.03 b	

Table 5. Total vegetative cover ratings for plots planted to Formula N. Seeding occurred on February 13, April 23, July 7, and August 21, 2009. Percent vegetative cover was determined by visual observation. The number followed by YAS indicates the number of years after seeding the data was collected. Each value is the mean of three replications. Within each column, numbers followed by different letters are significantly different at the .05 level. Numbers in columns without letters are not significantly different from each other (i.e., N.S. = not significant).

Timing	2011 (2YAS)	2012 (3YAS)	2013 (4YAS)	2014 (5YAS)	2015 (6YAS)	2016 (7YAS)
February	68	67	68 a	53	50	63
April	72	65	55 ab	55	50	65
July	87	68	32 ab	60	62	75
August	73	67	18 b	63	72	82
	N.S.	N.S.		N.S.	N.S.	N.S.

Table 6. Cover ratings for plots seeded to Formula C, crownvetch. Seeding occurred February 13, April 23, July 7, and August 21, 2009. Each value is the mean of three replications. Differences between means were considered statistically significant at $p \leq 0.05$. N.S. = not significant.

Timing	2011 % Total Cover	2011 % Crownvetch Cover	2016 % Total Cover	2016 % Crownvetch Cover
February	48	3	67	.03
April	88	65	72	7
July	73	4	72	1
August	63	30	70	8
	N.S.	N.S.	N.S.	N.S.

COMPARING SPRING SEEDED FORMULA L SEED MIX AT TWO RATES AND SHEEP FESCUE FOR GROUNDCOVER ESTABLISHMENT IN A ROADSIDE APPLICATION - SECOND YEAR RESULTS

Herbicide trade and common names: Accord XRT II *(4 lb per gallon glyphosate acid*); 2,4-D choline, Freelexx (*2,4-dichlorophenoxyacetic acid*); Vastlan (*triclopyr choline*).

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

ABSTRACT

Competitive turf groundcovers are designed to provide a dense stand of vegetation that helps to reduce erosion and control unwanted weeds. To be suitable for use in the roadside environment, a groundcover must establish within a reasonable amount of time despite the harsh conditions and often compacted soils. Formula L, a combination of hard fescue, creeping red fescue, and annual ryegrass at 55, 35, and 10 percent by weight, respectively is a standard PennDOT seed mix for low maintenance areas. This experiment compared establishment of Formula L at both 24 and 48 lb. per 1000 sq yard (SY) seeding rates and sheep fescue at 54 lb per 1000 SY following a spring seeding. At the end of the second growing season, establishment was extremely successful for all treatments with no significant difference in grass cover ranging from 93 to 95 percent. The high level of fine fescue establishment in all treatments left little room for weeds with the maximum reaching only 3% cover in the sheep fescue plots.

INTRODUCTION

Grasses are often chosen for use as groundcovers on the roadside right-of-way because they are competitive, provide a manageable plant community, and tolerate herbicide treatments used to control broadleaf species. Selecting grass species that will survive and remain vigorous in harsh environments is imperative. Low organic matter, compacted soils, and low fertility are some of the site conditions that challenge turfgrass establishment and growth along the roadside. PennDOT's current seed mix, Formula L, is well suited for the roadside environment, containing hard fescue, creeping red fescue, and annual ryegrass at 55, 35, and 10 percent by weight, respectively. The current recommendation for seeding Formula L is 48 lb/1000 sq. yards (SY), which represents a doubling of the previous seeding recommendation rate of 24 lb/1000 SY. PennDOT specifications allow for spring or fall seeding with fall seeding preferred; however, the timing of some projects dictates that a spring seeding be performed. Sheep fescue is another species with tolerance to harsh conditions such as dry, compacted soil. The purpose of this experiment was to compare two rates of Formula L and one rate of sheep fescue for establishment and growth in a roadside environment following spring seeding.

MATERIALS AND METHODS

The experiment was established within the right-of-way along SR 322E, near Philipsburg, PA. Formula L was seeded at rates of 24 and 48 lb/1000 SY; sheep fescue was seeded at 54 lb/1000 SY. Plots were 15 by 24 feet in size and arranged in a randomized complete block design with four replications. All plots were sprayed with Accord XRT II at 1 gallon per acre (GPA) in a carrier volume of 50 GPA on April 16, 2015 and again on May 8, 2015 to eliminate existing vegetation. The entire site was then prepared with a disc harrow on May 12, 2015. Seed and soil supplements were applied on May 16, 2015, followed by installation of East Coast ECS-2B erosion control blankets on May 22, 2015. Plots were fertilized according to soil test recommendations at a rate of 1 lb N, 5 lb P_2O_5, 0.5 lb K_2O, and 70 lb pelletized lime per 1000 sq ft. On August 1, 2016, all plots were treated with Vastlan at 1.5 qt/ac plus 2,4-D choline at 2 qt/ac to control broadleaf weeds. [1]

Percent cover by desirable grasses and percent cover by weeds (visual evaluation) were recorded on July 28 and October 5, 2015 as well as June 3 and September 14, 2016, 73, 139, 380, and 483 days after seeding (DAS) respectively. Desirable grasses were defined as species that were included in the seed mixes. 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

No significant difference in percent cover was found among seeding treatments. At 73, 139, and 483 DAS, the 48 lb rate of Formula L produced the most cover by desirable grasses (49, 54, and 95%, respectively) followed by Formula L at 24 lb (30, 38, and 94%, respectively) and sheep fescue at 54 lb (18, 31, and 93%, respectively) (Table 1). At the end of two growing seasons, the high level of fine fescue establishment in all treatments left little room for weed cover, which reached its highest level of 3 percent in plots seeded to sheep fescue (Table 2).

CONCLUSIONS

Observations at the end of the second growing season indicate that both rates of Formula L as well as sheep fescue were comparable in establishment with cover ratings that exceeded 90 percent from a spring seeding. Fine fescues have the ability to suppress weeds.[2] All seed mixes did an excellent job of covering the soil to compete with weeds aided by a broadleaf herbicide treatment in August 2016. In addition to having the lowest cover by weeds at the end of the first season, our field notes suggest that sheep fescue plots contained smaller weeds even though there was adequate space to develop at that time. Further investigation of the potential allelopathic effects of sheep fescue would be a good topic for future research.

MANAGEMENT IMPLICATIONS

Even though seeding Formula L at 24 lb/1000 SY was successful on this site, the 48 lb/1000 SY rate of Formula L provides a greater assurance of cover where soil and site conditions are unfavorable to seed germination and establishment. The 48 lb rate of Formua L also puts more annual rye seed on the ground, which provides fast growing, short term cover. Sheep fescue appears to have the ability to establish on difficult sites and possibly suppress weeds; however, further experiments would be necessary before recommendations could be made.

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[1] Dow AgroSciences LLC, Freelexx (*2,4-D choline*), Internet. February 22, 2017.
[2] Bertin et al. 2009. Evaluation of Selected Fine-leaf Fescue Cultivars for Their Turfgrass Quality and Weed Suppressive Ability in Field Settings. HortTechnology vol. 19 no. 3 pp. 660-668.

Site preparation is essential prior to seeding. Sites that are designated for seeding should receive proper soil preparation and soil supplements based on soil test results at the time of seeding.

Table 1: Percent cover by desirable grasses. The experiment was visually rated for percent cover by desirable (seeded) grasses on July 28, 2015, October 5, 2015 and September 14, 2016 (73, 139, and 483 days after seeding, DAS, respectively). The experiment was seeded and fertilized on May 16, 2015. Erosion control blankets were installed on May 22, 2015. Each value is the mean of four replications. N.S. indicates that means in that column are not significantly different from each other.

		Percent Cover by Desirable Grasses		
seed mix	rate	July 28, 2015 73 DAS	October 5, 2015 139 DAS	September 14, 2016 483 DAS
Formula L	24 lb/1000 SY	30	38	94
Formula L	48 lb/1000 SY	49	54	95
Sheep Fescue	54 lb/1000 SY	18	31	93
Significance Level ($p \leq 0.05$)		N.S.	N.S.	N.S.

Table 2: Percent cover by weeds. The experiment was visually rated for percent cover by weeds on July 28, 2015, October 5, 2015, and September 14, 2016 (73, 139, and 483 days after seeding, DAS, respectively). The experiment was seeded and fertilized on May 16, 2015. Erosion control blankets were installed on May 22, 2015. Each value is the mean of four replications. N.S. indicates that means in that column are not significantly different from each other.

		Percent Cover by Weeds		
seed mix	rate	July 28, 2015 73 DAS	October 5, 2015 139 DAS	September 14, 2016 483 DAS
Formula L	24 lb/1000 SY	13	19	2.5
Formula L	48 lb/1000 SY	17	23	2.0
Sheep Fescue	54 lb/1000 SY	13	14	3.25
Significance Level ($p \leq 0.05$)		N.S	N.S.	N.S.

INVESTIGATING GRASS SPECIES, SEEDING RATES, AND FERTILIZER PLUS BROADLEAF HERBICIDE APPLICATION FOR GROUNDCOVER ESTABLISHMENT IN ROADSIDE APPLICATIONS - THIRD YEAR RESULTS

Herbicide trade and common names: Escort XP (*metsulfuron*), Roundup Pro Max (*3.7 lb ae glyphosate/gal*); Method (*aminocyclopyrachlor*), PennDOT Custom Blend (*aminocyclopyrachlor* + *metsulfuron*).

Plant common and scientific names: annual ryegrass (*Lolium multiflorum*), creeping red fescue (*Festuca rubra* L.), foxtail fescue (*Vulpia myuros*), hard fescue (*Festuca brevipila*), orchardgrass (*Dactylis glomerata* L., var. 'Maintain'), sheep fescue (*Festuca ovina* L., var. 'Whisper').

ABSTRACT

The success of a vegetation management program in the roadside environment relies heavily on the use of competitive groundcovers. An effective groundcover should develop quickly, provide a dense stand, prevent unwanted weeds, require minimal maintenance, survive under harsh environmental conditions, and thrive in compacted soils. Formula L, a combination of hard fescue, creeping red fescue, and annual ryegrass at 55, 35, and 10 percent by weight, respectively, is a standard PennDOT seed mix. This experiment compared the doubling of the previous standard Formula L seeding rate of 24 lb/1000 sq. yards (SY) to the newly established standard rate of 48 lb/1000 SY in their ability to form a complete cover during establishment. In addition, three new species (i.e. two perennial species, 'Whisper' sheep fescue and 'Maintain' orchardgrass, and one annual species, foxtail fescue) were seeded to evaluate their effectiveness in establishing under roadside conditions as a possible addition to future roadside seed mixes. The seeding treatments included a split block overlay in which supplemental fertilizer and a broadleaf herbicide were applied to half of each of the seeded plots during the growing season following seeding to determine their effect on establishment. A broadleaf herbicide application made to all plots during the 2016 growing season helped to reduce the expanding broadleaf weed population that began to compete with the desirable grasses.

Both rates of Formula L and the sheep fescue established equally well. The 'Maintain' variety of orchardgrass required two years of establishment at the seeding rate recommended along with the addition of supplemental fertilizer and a broadleaf herbicide to provide the same level of cover observed with the fine fescues (Formula L or sheep fescue). Foxtail fescue did not demonstrate utility as a stand-alone species for seeding on the roadside. In all cases, supplemental fertilizer and broadleaf herbicide applications were effective in encouraging good grass stand development and reduced broadleaf weed establishment.

INTRODUCTION

The establishment of a competitive groundcover in the roadside environment is crucial to slowing natural succession and providing a manageable plant community. Grasses are often the best-suited groundcover in these situations. Grass allows for greater flexibility in maintenance through periodic mowing and/or selective broadleaf weed control. Selecting grass species that will survive and remain vigorous in harsh environments is imperative. Roadside soils present challenges for grass establishment in part because they often lack organic matter and have been subjected to compaction resulting in a reduced ability to handle moisture. One combination of turf species that is well suited for the roadside and is currently used by PennDOT in both construction and revitalization projects is referred to as 'Formula L'. This mix consists of hard fescue, creeping red fescue, and annual ryegrass. Seeding rate recommendations can vary, although the PennDOT Maintenance Manual, Pub 408, Section 804 currently suggests 48 lb/1000 sq. yards (SY). Previous recommendations were 24 lb/1000 SY. Foxtail fescue, an annual grass species, and two perennial species, 'Maintain' orchardgrass and sheep fescue have been promoted as short in height, drought tolerant, and hardy.[1] This experiment compared the seeding rates of Formula L and examined the ability of the new species to establish under roadside conditions. In addition, the effect and potential benefit of a supplemental fertilizer and a broadleaf herbicide application during the first year of establishment was examined.

MATERIALS AND METHODS

The experiment was established at two separate locations. The first (Site 1) was located on the shoulder of SR 322E, near Philipsburg, PA. Formula L was seeded at rates of 24 and 48 lb/1000 SY, while the others species were applied at rates recommended for the specific seed type. The 'Whisper' sheep fescue was seeded at 54 lb/1000 SY, 'Maintain' orchardgrass at 12 lb/ac (i.e. 2.5 lb/1000 SY) and foxtail fescue at 12 lb/ac. Plots 15 by 24 feet in size and arranged in a randomized complete block design with four replications were initially sprayed with a 1.5% v/v solution of Roundup Pro Max to eliminate all existing vegetation on September 20, 2013. The entire site was prepared with a disc harrow on September 30, 2013. Seed, soil supplements, and an erosion control blanket were applied on October 4, 2013. Plots were fertilized according to soil test recommendations at a rate of 1 lb N, 5 lb P_2O_5, 0.5 lb K_2O, and 70 lb pelletized lime per 1000 sq ft. The following season, on July 7, 2014, one half of each plot was fertilized using an 18-5-9 fertilizer to achieve 1 lb N/1000 sq ft. On August 8, 2014 an application of 4 oz/ac PennDOT Custom Blend herbicide (equivalent to 3.84 oz/ac Method + 0.16 oz/ac Escort XP) plus 0.25 percent v/v non-ionic surfactant was applied in 35 gallons per acre carrier to the same half of each plot. On August 1, 2016, all plots were entirely treated with PennDOT Custom Blend at 4 oz/ac plus 0.25 percent v/v non-ionic surfactant in 35 gallons per acre carrier.

Percent cover by desirable grasses was evaluated on June 20, 2014, 8 months after seeding (MAS). Percent cover by desirable grasses and percent cover by weeds were rated on September 15, 2014, June 8, 2015, September 23, 2015, June 23, 2016, and September 14, 2016 11, 20, 23, 32, and 35 MAS, respectively. Desirable grasses were defined as species that were included in the seed mixes. 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.

The second experiment (Site 2) was located at Penn State University's Landscape Management Research Center, University Park, PA. Only the two seeding rates of Formula L were investigated at this site. Plots 9 by 8 feet in size were arranged in a randomized complete block design with four replications. Plots were initially sprayed with glyphosate to eliminate all existing vegetation. Several weeks later, on October 9, 2013, the entire site was prepared with a disc harrow. Seed and soil supplements as well as straw mulch were applied on October 10, 2013. Plots were fertilized according to soil test recommendations at a rate of 1 lb N, 0.5 lb P_2O_5, 2 lb K_2O, and 70 lb pelletized lime per 1000 sq ft. Straw mulch was applied at a rate of

[1] AshlyAnn Lemhouse, personal communication, July 25, 2013.

1200 lb/1000 SY. The following growing season, on July 7, 2014, one half of each plot was fertilized using an 18-5-9 fertilizer to achieve 1 lb N/1000 sq ft. On August 8, 2014 an application of 4 oz/ac PennDOT Custom Blend herbicide plus 0.25 percent v/v non-ionic surfactant was applied in 35 gallons per acre carrier to the same half of each plot. On August 1, 2016, all plots were entirely treated with PennDOT Custom Blend at 4 oz/ac plus 0.25 percent v/v non-ionic surfactant in 35 gallons per acre carrier.

Percent cover by desirable grasses was evaluated on June 19, 2014 (8 MAS). Percent cover by desirable grasses and percent cover by weeds were rated on September 16, 2014, June 9, 2015, October 5, 2015, June 23, 2016, and September 14, 2016 (11, 20, 24, 32, and 35 MAS, respectively). All data were subjected to analysis of variance, and when treatment effect F-tests were significant ($p \leq 0.05$), treatment means were compared using Tukey's HSD separation test.

RESULTS AND DISCUSSION

Site 1

By fall 2015 at 23 MAS, the effects of the 2014 broadleaf herbicide plus supplemental fertilizer continued to provide some cover benefit by desirable grasses for both rates of Formula L, although differences were not statistically significant. Cover by grasses was 70 to 73 percent where no supplemental fertilizer or broadleaf herbicide had been applied, while adding this treatment resulted in 85 to 87 percent cover (Table 1). The spring 2016 rating demonstrated the need for some additional broadleaf weed control as many plots had fine fescue in the understory, overtopped and shaded by broadleaf weeds. By September 2016 (35 MAS), following a summer broadleaf treatment, plots seeded with either rate of Formula L had recovered and further developed with 89 to 93 percent cover.

Plots seeded to sheep fescue provided cover similar to Formula L and also reacted favorably to 2014 fertilizer and broadleaf treatments, resulting in significantly higher cover ratings for treated plots compared to untreated plots at 23 MAT (97 to 62 percent). By fall 2016 (35 MAS), advantages from the 2014 treatments no longer persisted and ratings were identical at 96 percent.

Orchardgrass reacted favorably to the treatments as well. At 23 months, orchardgrass plots that had been treated in 2014 had 86 percent cover by desirable grasses compared to only 14 percent in untreated plots. Fall 2016 ratings show that plots treated in 2014 were still statistically ahead of plots not treated in 2014, 76 compared to 45 percent.

Foxtail fescue initially benefited from the 2014 treatments and developed a 25 percent cover by desirable grasses at 23 MAT; however, cover ratings decreased steadily over time until by fall 2016, there was no cover by foxtail fescue.

By September 2015, percent cover by weeds was sharply lower in all plots that had been treated with fertilizer and broadleaf herbicide during the summer of 2014, compared to untreated plots (Table 2). Plots of Formula L or sheep fescue treated with broadleaf herbicide in 2014 had only 1 or 2 percent weed cover, whereas untreated plots ranged from 26 to 38 percent. June 2016 saw a sharp increase in weed cover for the previously untreated Formula L and sheep fescue plots which was reversed by the broadleaf weed treatment applied during the summer of 2016. Orchardgrass plots also responded to the summer 2016 broadleaf treatment with weed cover ratings dropping from 79 to 25 percent for previously untreated plots and from 9 to 3 percent for previously treated plots. A significant quantity of broadleaf weeds developed in the foxtail fescue plots where little grass existed. Fewer broadleaf weeds were present in plots treated with fertilizer and broadleaf herbicide compared to untreated plots in both fall 2015 (58 versus 93 percent) and spring 2016 (73 versus 96 percent). Following the broadleaf weed treatment in August 2016 weed cover was similar for all foxtail fescue plots and ranged from 49 to 51 percent.

Site 2

By October 2015, both rates of Formula L produced nearly complete cover by desirable grasses (97 to 99 percent), whether or not plots had been treated with fertilizer and broadleaf herbicide in 2014 (Table 3). In September 2016, following the broadleaf herbicide treatment applied in August, desirable species remained statistically similar with cover that ranged from 93 to 96 percent for all rating dates and treatments. Weed cover was minimal and never exceeded 1.75 percent (Table 4).

CONCLUSIONS

Both rates of Formula L and sheep fescue established well. Treatment with supplemental fertilizer and broadleaf herbicide during the summer of 2014 increased the cover by desirable grasses and decreased cover by weeds. In several instances, these effects were still evident by fall of 2015. A treatment with broadleaf herbicide in August of 2016 boosted desirable cover in plots seeded to orchardgrass, sheep fescue, and both rates of Formula L from the June to September 2016 rating. The variety of orchardgrass and seeding rate tested in this experiment did not provide the cover observed with the fine fescues (i.e., Formula L or sheep fescue), except after using a supplemental fertilizer and broadleaf application and waiting two years for establishment (Sept 2015). Orchardgrass is a bunch-type grass that would require another component within a seed mix to establish in the voids created by this growth habit. Foxtail fescue is an annual grass that has not demonstrated utility as a stand-alone species for seeding on the roadside. Supplemental fertilizer and broadleaf herbicide applications are effective in encouraging a developing grass stand and ongoing broadleaf herbicide applications are an important way to keep turf competitive.

MANAGEMENT IMPLICATIONS

Even though seeding Formula L at 24 lb/1000 SY was successful on these sites, the 48 lb/1000 SY rate of Formula L may provide earlier cover and afford a greater assurance of site protection where soil and site conditions are unfavorable to seed germination and establishment. Sheep fescue appears to have the ability to establish on difficult sites and in this experiment performed similar to Formula L; however, further experiments would be necessary before recommendations could be made.

Sites that are designated for seeding should receive site preparation and the proper soil supplements at the time of seeding. The use of fertilizer and weed control during the establishment phase is suggested. Occasional broadleaf weed control may be necessary depending on the weed pressure and the density of turf cover. Sites should be monitored annually and treated when necessary to offer the turf a competitive advantage over competing broadleaf weeds.

Table 1: Percent cover by desirable grasses (Site 1). The trial was visually rated for percent cover by desirable (seeded) grasses on September 23, 2015, June 23, 2016 and September 14, 2016 (23, 32, and 35 months after seeding, MAS). The experiment was seeded, fertilized, and straw mulched on October 4, 2013. Fertilizer and broadleaf herbicide (bl) were applied to half of each plot on July 7 and August 8, 2014, respectively. All plots were entirely treated with broadleaf herbicide on August 1, 2016. Each value is the mean of four replications. Means within similarly shaded areas followed by the same letter are not significantly different at $p \leq 0.05$.

		Percent Cover by Desirable Species					
seed mix	rate	Sept 2015 23 MAS		June 2016 32 MAS		Sept 2016 35 MAS	
	lbs. per 1000 SY	No Fert/bl	Fert/bl	No fert/bl	Fert/bl	No fert/bl	Fert/bl
Formula L	24	70 bc	87 bc	34 abc	76 cd	89 c	90 c
Formula L	48	73 bc	85 bc	28 ab	77 cd	93 c	91 c
Sheep Fescue	54	62 b	97 c	34 abc	90 d	96 c	96 c
Orchardgrass	2.5	14 a	86 bc	15 ab	58 bcd	45 b	76 c
Foxtail Fescue	2.5	0.5 a	25 a	0.5 a	6 a	0 a	0 a

Table 2: Percent cover by weeds (Site 1). The trial was visually rated for percent cover by weeds on September 23, 2015, June 23, 2016, and September 14, 2016 (23, 32, and 35 months after seeding, MAS). The experiment was seeded, fertilized, and straw mulched on October 4, 2013. Fertilizer and broadleaf herbicide (bl) were applied to half of each plot on July 7 and August 8, 2014, respectively. All plots were entirely treated with broadleaf herbicide on August 1, 2016. Each value is the mean of four replications. Means within similarly shaded areas followed by the same letter are not significantly different at $p \leq 0.05$.

		Percent Cover by Weeds					
seed mix	rate	Sept 2015 23 MAS		June 2016 32 MAS		Sept 2016 35 MAS	
	lbs. per 1000 SY	No fert/bl	Fert/bl	No fert/bl	Fert/bl	No fert/bl	Fert/bl
Formula L	24	29 ab	2 a	61 b	7 a	1 a	1 a
Formula L	48	26 ab	1 a	67 b	4 a	0.5 a	0.1 a
Sheep Fescue	54	38 b	1 a	64 b	3 a	2 a	0.1 a
Orchardgrass	2.5	82 cd	3 a	79 b	9 a	25 ab	3 a
Foxtail Fescue	2.5	93 d	58 bc	96 b	73 b	51 b	49 b

Table 3: Percent cover by desirable grasses (Site 2). The trial was visually rated for percent cover by desirable (seeded) grasses on October 5, 2015, June 23, 2016, and September 14, 2016 (24, 32, and 35 months after seeding, MAS). The experiment was seeded, fertilized, and straw mulched on October 10, 2013. Fertilizer and broadleaf herbicide (bl) were applied to half of each plot on July 7 and August 8, 2014, respectively. All plots were entirely treated with broadleaf herbicide on August 1, 2016. Each value is the mean of four replications. Means within similarly shaded areas followed by the same letter are not significantly different at p ≤ 0.05. "n.s." indicates means are not significantly different for that shaded area.

		Percent Cover by Desirable Species					
seed mix	rate	Oct 2015 24 MAS		June 2016 32 MAS		Sept 2016 35 MAS	
	lbs per 1000 SY	no fert/bl	fert/bl	no fert/bl	fert/bl	no fert/bl	fert/bl
Formula L	24	97	99	86 ab	79 a	96	94
Formula L	48	98	99	87 b	79 a	95	93
Sign. level (p≤0.05)		n.s.	n.s.			n.s.	n.s.

Table 4: Percent cover by weeds (Site 2). The trial was visually rated for percent cover by weeds on October 5, 2015, June 23, 2016, and September 14, 2016 (24, 32, and 35 months after seeding, MAS). The experiment was seeded, fertilized, and straw mulched on October 10, 2013. Fertilizer and broadleaf herbicide (bl) were applied to half of each plot on July 7 and August 8, 2014, respectively. All plots were entirely treated with broadleaf herbicide on August 1, 2016. Each value is the mean of four replications. Means within similarly shaded areas followed by the same letter are not significantly different at p ≤ 0.05. "n.s." indicates means are not significantly different for that shaded area.

		Percent Cover by Weeds					
seed mix	rate	Oct 2015 24 MAS		June 2016 32 MAS		Sept 2016 35 MAS	
	lbs per 1000 SY	no fert/bl	fert/bl	no fert/bl	fert/bl	no fert/bl	fert/bl
Formula L	24	1.75 b	0 a	1	0	1	0.25
Formula L	48	1.3 ab	0 a	0.25	0	0.75	0
Sign. level (p≤0.05)				n.s.	n.s.	n.s.	n.s.

TESTING PREEMERGENCE HERBICIDES ALONE AND IN COMBINATION WITH ESPLANADE FOR SEASON LONG BAREGROUND WEED CONTROL

Herbicide trade and common names: Accord XRT II (*glyphosate*); Pindar GT, Cleantraxx (*oxyfluorfen + penoxsulam*); Esplanade 200SC (*indaziflam*); Milestone VM (*aminopyralid*); Pendulum AquaCap (*pendimethalin*); Plateau (*imazapic*); Portfolio 4F (*sulfentrazone*); 25% SG *rimsulfuron*.

Plant common and scientific names: common evening primrose (*Oenothera biennis*); common lambsquarters (*Chenopodium album*); horsenettle (*Solanum carolinense*); prostrate spurge (*Euphorbia maculata*); spotted knapweed (*Centaurea stoebe*); poverty dropseed (*Sporobolus vaginiflorus*); wild carrot (*Daucus carota*).

ABSTRACT

Bareground weed control is an essential component of the roadside vegetation management program. The emphasis in bareground weed control is to eliminate all vegetation around obstacles and under guiderails to provide for cost-effective maintenance and ensure the proper movement of surface water from the roadway. A bareground program relies on herbicides to keep these areas weed-free for the entire growing season. To achieve the desired results, a tank mix including a broad-spectrum residual, preemergence, and postemergence herbicide is generally applied in the spring of the year. Recent label restrictions have led to the removal of herbicides historically used in this program. A variety of herbicides are necessary to allow for the rotation of modes-of-action to reduce herbicide resistance among targeted weed species. This experiment, repeated at two locations, was established to identify the efficacy of individual herbicides used alone and in combination with Esplanade. This information will help when recommending bareground products in rotational programs. None of the individual herbicides tested provided complete weed control. However, the addition of Esplanade to each herbicide did improve performance. Data collected on individual species showed that Milestone VM provided excellent control of spotted knapweed, Accord XRTII controlled the existing common lambsquarter population, and no treatment was consistently effective on control of horsenettle.

INTRODUCTION

Many areas of the roadside, such as under guiderails and around signposts are treated with herbicides each spring to completely eliminate weeds in order to accommodate the proper flow of water from the roadway and allow for maintenance activities. It is recognized that reliance on the same chemistries year after year may lead to the development of resistant weed species, especially among annual weeds. Many herbicides relied on in the past are no longer useful due to constraints placed on the labeling (e.g., Oust, Karmex). Additionally, the category of broad-spectrum residual herbicides offers a very limited number of products available for this application. Generally, a broad-spectrum residual herbicide controls a greater number of species compared to preemergence herbicides, has both pre and post emergence activity, offers extended herbicidal effect, and has greater potential for off-site movement. The broad-spectrum herbicide is commonly tank mixed with a preemergence and postemergence herbicide for weed control in these non-crop settings. In order to ensure a rotation of chemistry with differing modes-of-action, alternate herbicides and tank mixes need to be identified. This experiment tested a variety of preemergence herbicides or Milestone VM (a broad spectrum residual herbicide) alone and in combination with Esplanade (preemergence herbicide) using Accord XRTII as the postemergence component for season-long weed control.

MATERIALS AND METHODS

The experiment was established at two locations. The first site was located beneath a guiderail on the shoulder of I-99 South near Tyrone, PA. The second site was a fallow crop field planted the previous season to gourds located at Penn State's Russell E. Larson Agricultural Research Center near Pine Grove Mills, PA (i.e., Hort Farm). Treatments included Accord XRT II at 64 oz/ac alone; Esplanade at 5 oz/ac, Cleantraxx at 48 oz/ac, or Pendulum AquaCap at 134 oz/ac combined with Accord XRT II at 64 oz/ac; 25% SG rimsulfuron at 4 oz/ac, Cleantraxx at 64 oz/ac, Portfolio 4F at 12 oz/ac, Plateau at 12 oz/ac, or Milestone VM at 7 oz/ac combined with Accord XRT II at 64 oz/ac or Accord XRT II at 64 oz/ac plus Esplanade at 5 oz/ac; Cleantraxx at 64 oz/ac, Milestone VM at 7 oz/ac, plus Accord XRT II at 64 oz/ac; and an untreated check. Pindar GT was substituted for Cleantraxx throughout both experiments but is the equivalent product labeled for a separate marketplace.[1] Induce, a non-ionic surfactant was added to all herbicide treatments at 0.25% v/v. The experiment was established as a randomized complete block design with four replications (Tyrone) and two replications (Hort Farm). Plots were 20 by 6 ft. at both locations. Treatments were applied on May 19 (Tyrone) and May 24, 2016 (Hort Farm) using a CO_2-powered sprayer equipped with a wand and single TeeJet BoomJet XP20R nozzle (Tyrone) or six ft. boom and (4) 8004VS tips (Hort Farm) at an application rate of 50 gallons per acre.

The Tyrone site was visually rated for percent total vegetative cover and cover by individual species as they developed including spotted knapweed, wild carrot, prostrate spurge, common evening primrose, and poverty dropseed at monthly intervals from 0 to 5 months after treatment, MAT. Only percent total vegetative cover and cover by spotted knapweed data collected May 20, August 19, September 23, and October 20, 2016, representing 0, 3, 4, and 5 MAT are reported (Tables 1 and 2). The Hort Farm was evaluated for percent total vegetative cover and cover by common lambsquarters at monthly intervals from 0 to 5 MAT. Horsenettle was evaluated at 1 to 5 MAT. Percent total vegetative cover and cover by common lambsquarters data collected May 24, August 30, September 22, and October 25, 2016, representing 0, 3, 4, and 5 MAT are reported (Tables 3 and 4). Cover by horsenettle collected at 1, 3, 4, and 5 MAT is also reported (Table 5).

RESULTS AND DISCUSSION

The Tyrone site had a diversity of weed species. Evaluations of total vegetative cover (Table 1) ranged from 17 to 32 percent at the onset of the experiment with no significant differences among the plots. Total vegetative cover was reduced and ranged from 1 to 19 percent for the herbicide treatments and 14 percent for the untreated plots at 3 MAT (August 19). By the end of the growing season (5 MAT, October 20) total vegetation cover reached 26 percent for the untreated plots, 25 percent for Accord XRTII only, and 2 to 24 percent for all remaining herbicide treatments. All herbicides, when combined with Esplanade, showed improved control compared to the same herbicide and rate used alone. Spotted knapweed (Table 2) was the most common species found across the experimental area. At the beginning of the experiment it

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[1] Dow AgroSciences LLC, Pindar GT. Online. Internet. February 3, 2017.

comprised from 11 to 23 percent cover with no significant differences among the plots. By 5 MAT (October 20) only treatments containing Milestone VM had significant reductions for this species compared to the untreated check, ranging from 0 to 0.1 percent cover. All other treatments showed a reduction in cover by spotted knapweed (1.6 to 8.1 percent), but not significant from the untreated check (9.2 percent).

Total vegetative cover for the Hort Farm plots (Table 3) initially ranged from 10 to 30 percent with no significant differences. By 5 MAT, all herbicides combined with only Accord XRTII were statistically similar to the untreated check (65 percent) and ranged from 12 to 55 percent for total vegetative cover, except Cleantraxx at 64 oz/ac and Plateau at 12 oz/ac where greater control was achieved (8 and 4 percent). All treatments controlled weeds more effectively when combined with Esplanade, ranging from 5 to 10 percent total vegetative cover, except for Plateau (11 percent). Two abundant species were common lambsquarters (Table 4) and horsenettle (Table 5). All treatments showed a significant reduction in common lambsquarters with 0 to 3 percent cover at 5 MAT compared to 42 percent cover in the untreated check. No significant reduction in horsenettle was apparent among the treatments including the untreated check (3 percent) with all ranging from 0 to 11 percent cover by this species at 5 MAT.

CONCLUSIONS

The individual herbicides tested in this experiment did not provide effective and comprehensive weed control. However, the addition of Esplanade improved the performance of the herbicide treatments. Data collected on individual species suggested that Milestone VM provided excellent control of spotted knapweed, Accord XRTII controlled the existing common lambsquarter population, and no treatment was consistently effective on control of horsenettle.

MANAGEMENT IMPLICATIONS

Although none of the herbicides or combinations tested offered complete control for the growing season, it was noted that adding 5 oz/ac Esplanade enhanced control. This suggests it remains a good choice as a tank mix partner in the bareground program. Further testing should occur on the list of individual products in this experiment and others to determine their efficacy on a range of species. Information gathered will help to identify products that are useful in future tank mixes to contend with species-specific problems that may develop. There are some labeling cautions and language regarding Cleantraxx and Portfolio 4F that may preclude the use of these products on PennDOT right-of-ways. The Cleantraxx label requires maintaining a 25-foot buffer between treated areas and bodies of water during ground applications.[2] The Portfolio 4F label contains groundwater and surface water advisory statements warning about potential contamination.[3] Milestone VM contains statements warning of potential injury to trees with root systems extending into the treated area.[4] Prudent judgment by Roadside Specialists and applicators is needed when selecting and using combinations containing Milestone VM, especially along secondary routes in order to avoid potential off-site damage.

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[2] Dow AgroSciences LLC. Cleantraxx. Online. Internet. February 3, 2017.
[3] Wilbur-Ellis Company LLC. Portfolio 4F. Online. Internet. February 3, 2017.
[4] Dow AgroSciences LLC. Milestone VM. Online. Internet. February 3, 2017.

Table 1: Effectiveness of herbicide treatments based on percent total vegetative cover at 0, 3, 4, and 5 months after treatment, MAT. The Tyrone site was visually rated for percent total vegetative cover on May 20, August 19, September 23, and October 20, 2016, 0, 3, 4, and 5 MAT. Treatments were applied on May 19, 2016. A non-ionic surfactant (i.e., Induce) was added to all herbicide 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	total vegetative cover 0 MAT	3 MAT	4 MAT	5 MAT
	(oz/ac)	(-----------------------------%-----------------------------)			
Untreated	---	24 a	14 bc	22 bcd	26 c
Accord XRT II	64	22 a	19 c	26 d	25 bc
Esplanade Accord XRT II	5 64	28 a	6 ab	7 abc	16 abc
25% SG rimsulfuron Accord XRT II	4 64	21 a	12 abc	17 a-d	22 bc
Cleantraxx Accord XRT II	48 64	32 a	9 abc	13 a-d	20 abc
Cleantraxx Accord XRT II	64 64	21 a	6 ab	9 a-d	17 abc
Portfolio 4F Accord XRT II	12 64	30 a	19 c	24 cd	24 bc
Plateau Accord XRT II	12 64	29 a	13 bc	14 a-d	22 bc
Pendulum AquaCap Accord XRT II	134 64	24 a	10 abc	13 a-d	19 abc
Milestone VM Accord XRT II	7 64	17 a	9 abc	20 a-d	20 abc
25% SG rimsulfuron Esplanade Accord XRT II	4 5 64	26 a	4 ab	6 ab	10 abc
Cleantraxx Esplanade Accord XRT II	64 5 64	26 a	2 ab	3 a	6 ab
Portfolio Esplanade Accord XRT II	12 5 64	30 a	6 ab	9 a-d	15 abc
Plateau Esplanade Accord XRT II	12 5 64	28 a	4 ab	6 abc	9 abc
Milestone VM Esplanade Accord XRT II	7 5 64	22 a	1 a	2 a	2 a
Cleantraxx Milestone VM Accord XRT II	64 7 64	28 a	5 ab	10 a-d	14 abc

Table 2: Effectiveness of herbicide treatments based on percent spotted knapweed cover at 0, 3, 4, and 5 months after treatment, MAT. The Tyrone site was visually rated for percent spotted knapweed cover on May 20, August 19, September 23, and October 20, 2016, 0, 3, 4, and 5 MAT. Treatments were applied on May 19, 2016. A non-ionic surfactant (i.e., Induce) was added to all herbicide 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	spotted knapweed cover			
		0 MAT	3 MAT	4 MAT	5 MAT
	(oz/ac)	(------------------------------	-------------%-------------	------------------------------)	
Untreated	---	17 a	3.5 ab	5.2 a	9.2 b
Accord XRT II	64	15 a	1.0 ab	1.1 a	1.8 ab
Esplanade Accord XRT II	5 64	12 a	2.0 ab	2.1 a	5.5 ab
25% SG rimsulfuron Accord XRT II	4 64	14 a	1.3 ab	2.1 a	1.6 ab
Cleantraxx Accord XRT II	48 64	23 a	3.0 ab	3.9 a	3.5 ab
Cleantraxx Accord XRT II	64 64	12 a	1.6 ab	1.2 a	2.8 ab
Portfolio 4F Accord XRT II	12 64	13 a	2.0 ab	3.0 a	2.6 ab
Plateau Accord XRT II	12 64	22 a	2.6 ab	2.2 a	6.8 ab
Pendulum AquaCap Accord XRT II	134 64	16 a	4.5 b	4.8 a	6.0 ab
Milestone VM Accord XRT II	7 64	11 a	0.1 a	0.1 a	0.1 a
25% SG rimsulfuron Esplanade Accord XRT II	4 5 64	16 a	2.1 ab	2.9 a	5.8 ab
Cleantraxx Esplanade Accord XRT II	64 5 64	12 a	0.8 ab	1.4 a	3.1 ab
Portfolio Esplanade Accord XRT II	12 5 64	14 a	3.3 ab	4.5 a	8.1 b
Plateau Esplanade Accord XRT II	12 5 64	14 a	2.8 ab	3.8 a	6.9 ab
Milestone VM Esplanade Accord XRT II	7 5 64	17 a	0.0 a	0.1 a	0.1 a
Cleantraxx Milestone VM Accord XRT II	64 7 64	16 a	0.1 a	0.0 a	0.0 a

Table 3: Effectiveness of herbicide treatments based on percent total vegetative cover at 0, 3, 4, and 5 months after treatment, MAT. The Hort Farm site was visually rated for percent total vegetative cover on May 24, August 30, September 22, and October 25, 2016, 0, 3, 4, and 5 MAT. Treatments were applied on May 24, 2016. A non-ionic surfactant (i.e., Induce) was added to all herbicide treatments at 0.25% v/v. Each value is the mean of two replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

product	rate	total vegetative cover 0 MAT	3 MAT	4 MAT	5 MAT
	(oz/ac)	(------------------------------%------------------------------)			
Untreated	---	30 a	90 c	78 b	65 b
Accord XRT II	64	25 a	75 bc	75 b	55 ab
Esplanade Accord XRT II	5 64	18 a	14 a	14 a	14 ab
25% SG rimsulfuron Accord XRT II	4 64	25 a	80 bc	72 b	32 ab
Cleantraxx Accord XRT II	48 64	15 a	14 a	18 a	12 ab
Cleantraxx Accord XRT II	64 64	22 a	12 a	12 a	8 a
Portfolio 4F Accord XRT II	12 64	10 a	40 abc	42 ab	32 ab
Plateau Accord XRT II	12 64	10 a	4 a	4 a	4 a
Pendulum AquaCap Accord XRT II	134 64	12 a	15 a	14 a	14 ab
Milestone VM Accord XRT II	7 64	15 a	35 ab	34 a	33 ab
25% SG rimsulfuron Esplanade Accord XRT II	4 5 64	12 a	12 a	14 a	10 a
Cleantraxx Esplanade Accord XRT II	64 5 64	10 a	6 a	8 a	7 a
Portfolio Esplanade Accord XRT II	12 5 64	10 a	6 a	8 a	5 a
Plateau Esplanade Accord XRT II	12 5 64	10 a	11 a	12 a	11 a
Milestone VM Esplanade Accord XRT II	7 5 64	22 a	8 a	10 a	5 a
Cleantraxx Milestone VM Accord XRT II	64 7 64	16 a	7 a	6 a	5 a

Table 4: Effectiveness of herbicide treatments based on percent common lambsquarter cover at 0, 3, 4, and 5 months after treatment, MAT. The Hort Farm site was visually rated for percent common lambsquarter cover on May 24, August 30, September 22, and October 25, 2016, 0, 3, 4, and 5 MAT. Treatments were applied on May 24, 2016. A non-ionic surfactant (i.e., Induce) was added to all herbicide treatments at 0.25% v/v. Each value is the mean of two replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

		common lambsquarter cover			
product	rate	0 MAT	3 MAT	4 MAT	5 MAT
	(oz/ac)	(------------------------------%------------------------------)			
Untreated	---	30 a	52 b	45 b	42 b
Accord XRT II	64	24 a	2.5 a	1.5 a	1.5 a
Esplanade Accord XRT II	5 64	17 a	3.0 a	4.0 a	3.0 a
25% SG rimsulfuron Accord XRT II	4 64	24 a	5.0 a	4.0 a	3.0 a
Cleantraxx Accord XRT II	48 64	14 a	0.5 a	1.0 a	1.0 a
Cleantraxx Accord XRT II	64 64	22 a	0.8 a	0.5 a	0.2 a
Portfolio 4F Accord XRT II	12 64	10 a	2.5 a	0 a	0.2 a
Plateau Accord XRT II	12 64	10 a	0 a	0 a	0.2 a
Pendulum AquaCap Accord XRT II	134 64	12 a	0 a	0.5 a	0.2 a
Milestone VM Accord XRT II	7 64	14 a	0 a	0 a	0 a
25% SG rimsulfuron Esplanade Accord XRT II	4 5 64	12 a	1.8 a	2.0 a	2.2 a
Cleantraxx Esplanade Accord XRT II	64 5 64	9 a	0 a	0.1 a	0.1 a
Portfolio Esplanade Accord XRT II	12 5 64	10 a	0 a	0 a	0 a
Plateau Esplanade Accord XRT II	12 5 64	8 a	0 a	0 a	0.1 a
Milestone VM Esplanade Accord XRT II	7 5 64	21 a	0.5 a	0 a	0 a
Cleantraxx Milestone VM Accord XRT II	64 7 64	16 a	0 a	0 a	0 a

Table 5: Effectiveness of herbicide treatments based on percent horsenettle cover at 1, 3, 4, and 5 months after treatment, MAT. The Hort Farm site was visually rated for percent horsenettle cover on June 24, August 30, September 22, and October 25, 2016, 1, 3, 4, and 5 MAT. Treatments were applied on May 24, 2016. A non-ionic surfactant (i.e., Induce) was added to all herbicide treatments at 0.25% v/v. Each value is the mean of two replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

		horsenettle cover			
product	rate	1 MAT	3 MAT	4 MAT	5 MAT
	(oz/ac)	(------------------------------%------------------------------)			
Untreated	---	1.0 ab	5.5 a	5.0 a	3.0 a
Accord XRT II	64	1.9 ab	12.5 ab	7.0 a	2.5 a
Esplanade Accord XRT II	5 64	0.1 a	3.0 a	1.5 a	1.5 a
25% SG rimsulfuron Accord XRT II	4 64	2.5 b	25 b	33 a	11 a
Cleantraxx Accord XRT II	48 64	0.2 ab	7.5 ab	7.0 a	6.0 a
Cleantraxx Accord XRT II	64 64	0.1 a	7.0 ab	5.0 a	3.0 a
Portfolio 4F Accord XRT II	12 64	0.1 a	1.0 a	2.5 a	2.0 a
Plateau Accord XRT II	12 64	0 a	0 a	0 a	0 a
Pendulum AquaCap Accord XRT II	134 64	0.4 ab	8.5 ab	8.0 a	5.5 a
Milestone VM Accord XRT II	7 64	0.2 a	2.0 a	0.5 a	1.5 a
25% SG rimsulfuron Esplanade Accord XRT II	4 5 64	0.1 a	2.5 a	2.0 a	2.5 a
Cleantraxx Esplanade Accord XRT II	64 5 64	0.1 a	4.5 a	5.0 a	3.5 a
Portfolio Esplanade Accord XRT II	12 5 64	0.2 ab	3.5 a	6.0 a	3.1 a
Plateau Esplanade Accord XRT II	12 5 64	0.4 ab	8.5 ab	8.0 a	6.0 a
Milestone VM Esplanade Accord XRT II	7 5 64	0.4 ab	6.5 a	7.0 a	4.0 a
Cleantraxx Milestone VM Accord XRT II	64 7 64	0.2 a	5.5 a	4.5 a	3.0 a

APPENDIX

Table 1: Average height of the tall fescue stand at Old Fort. The experiment was visually rated for height of tall fescue on May 11, May 25, June 9, June 22, and July 6, 2016 (2, 4, 6, 8, and 10 weeks after treatment, WAT). Treatments were applied on April 27, 2016. All treatments included 0.25% v/v non-ionic surfactant. 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	tall fescue average height (in)				
		2 WAT	4 WAT	6 WAT	8 WAT	10 WAT
	(oz/ac)					
Untreated	----	16.4 b	14.9 b	16 c	15.7 c	14.1 bc
Plateau Method 240SL	2 10	11.4 a	10.5 a	10.1 ab	12.5 abc	13.4 abc
Plateau Method 240SL	3 10	12.6 a	12.2 ab	10 a	12.7 abc	13.1 abc
Plateau Method 240SL	4 10	10.8 a	11.6 a	9.8 a	10.1 a	9.9 ab
Plateau Escort XP Method 240SL	2 0.2 10	12.8 a	11.2 a	11.8 ab	13.7 abc	12.3 abc
Plateau Escort XP Method 240SL	3 0.2 10	11.8 a	10.9 a	10.7 ab	12.6 abc	12.9 abc
Plateau Escort XP Method 240SL	4 0.2 10	10.8 a	10.4 a	10 a	11.4 ab	9.7 a
Escort XP Method 240SL	0.33 10	11.5 a	10.9 a	11.9 ab	14.2 bc	15.2 c
Embark Escort XP Method 240SL	6 0.2 10	11 a	9.7 a	11.8 ab	11.9 abc	13.5 abc
Plateau Overdrive 2,4-D choline	2 8 64	10.8 a	10.8 a	11.4 ab	14.7 bc	13.8 abc
Plateau Escort XP Overdrive 2,4-D choline	2 0.2 8 64	11.3 a	10.2 a	10.8 ab	13.2 abc	13.1 abc
Escort XP Overdrive 2,4-D choline	0.33 8 64	11.9 a	12.2 ab	13.2 bc	15.2 bc	15.2 c
Sign. Level ($p\leq0.05$)		0.000	0.000	0.000	0.000	0.000

Table 2: Average height of the Kentucky bluegrass stand at Old Fort. The experiment was visually rated for height of Kentucky bluegrass on May 11, May 25, June 9, June 22, and July 6, 2016 (2, 4, 6, 8, and 10 weeks after treatment, WAT). Treatments were applied on April 27, 2016. All treatments included 0.25% v/v non-ionic surfactant. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at p ≤ 0.05.

product	Rate	Kentucky bluegrass average height (in)				
		2 WAT	4 WAT	6 WAT	8 WAT	10 WAT
	(oz/ac)					
Untreated	----	10.6 b	11 a	15.2 b	11.8 a	11.9 ab
Plateau Method 240SL	2 10	8.4 ab	10.1 a	14.4 ab	12.8 a	11.7 ab
Plateau Method 240SL	3 10	7.7 a	8.6 a	11.8 ab	13.7 a	11.6 ab
Plateau Method 240SL	4 10	7.5 a	7.7 a	10.8 a	10.7 a	11.4 ab
Plateau Escort XP Method 240SL	2 0.2 10	9.5 ab	10.2 a	12.8 ab	13.1 a	14.8 b
Plateau Escort XP Method 240SL	3 0.2 10	7.5 a	8.6 a	13.3 ab	14.4 a	12.2 ab
Plateau Escort XP Method 240SL	4 0.2 10	8.6 ab	7.5 a	11.4 ab	12.4 a	9.7 a
Escort XP Method 240SL	0.33 10	8.4 ab	9.4 a	12.1 ab	12.2 a	13.2 ab
Embark Escort XP Method 240SL	6 0.2 10	8.2 ab	9.4 a	12 ab	11.6 a	11.8 ab
Plateau Overdrive 2,4-D choline	2 8 64	9.8 ab	10.8 a	12.3 ab	11.8 a	13.8 ab
Plateau Escort XP Overdrive 2,4-D choline	2 0.2 8 64	8.3 ab	9.3 a	12.2 ab	11.8 a	10.8 ab
Escort XP Overdrive 2,4-D choline	0.33 8 64	8.9 ab	10.9 a	13.1 ab	14.3 a	12.2 ab
Sign. Level (p≤0.05)		0.006	0.006	0.024	0.103	0.031

Table 5: Percent cover of the turfgrass stand at Old Fort. The experiment was visually rated for turf cover on April 26 and July 6, 2016 (0 and 10 weeks after treatment, WAT). The percent change in turf cover was calculated using the formula [(% ending turf cover-% initial turf cover)/% initial turf cover x 100]. Treatments were applied on April 27, 2016. All treatments included 0.25% v/v non-ionic surfactant. 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	percent turf cover		percent change in turf cover
		0 WAT	10 WAT	10 WAT
	(oz/ac)			
Untreated	----	74 a	80 a	8 a
Plateau Method 240SL	2 10	70 a	76 a	8 a
Plateau Method 240SL	3 10	74 a	75 a	2 a
Plateau Method 240SL	4 10	72 a	78 a	7 a
Plateau Escort XP Method 240SL	2 0.2 10	76 a	80 a	5 a
Plateau Escort XP Method 240SL	3 0.2 10	71 a	74 a	3 a
Plateau Escort XP Method 240SL	4 0.2 10	74 a	76 a	3 a
Escort XP Method 240SL	0.33 10	74 a	78 a	5 a
Embark Escort XP Method 240SL	6 0.2 10	75 a	78 a	3 a
Plateau Overdrive 2,4-D choline	2 8 64	74 a	80 a	9 a
Plateau Escort XP Overdrive 2,4-D choline	2 0.2 8 64	76 a	78 a	1 a
Escort XP Overdrive 2,4-D choline	0.33 8 64	71 a	70 a	-2 a
Sign. Level ($p \leq 0.05$)		0.998	0.996	0.935

Table 6: Percent injury of chicory (*Cichorium intybus*, CHIIN) at Old Fort. The experiment was visually rated for chicory injury on May 11, May 25, June 9, June 22, and July 6, 2016 (2, 4, 6, 8, and 10 weeks after treatment, WAT). Treatments were applied on April 27, 2016. All treatments included 0.25% v/v non-ionic surfactant. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

		chicory percent injury				
product	Rate	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT
	(oz/ac)					
Untreated	----	0 a	0 a	0 a	0 a	0 a
Plateau Method 240SL	2 10	50 b	95 c	98 bc	100 b	100 b
Plateau Method 240SL	3 10	50 b	93 c	100 c	100 b	100 b
Plateau Method 240SL	4 10	50 b	95 c	100 c	100 b	100 b
Plateau Escort XP Method 240SL	2 0.2 10	50 b	90 c	100 c	100 b	100 b
Plateau Escort XP Method 240SL	3 0.2 10	50 b	95 c	100 c	100 b	100 b
Plateau Escort XP Method 240SL	4 0.2 10	50 b	95 c	100 c	100 b	100 b
Escort XP Method 240SL	0.33 10	50 b	95 c	100 c	100 b	100 b
Embark Escort XP Method 240SL	6 0.2 10	50 b	95 c	97 bc	100 b	100 b
Plateau Overdrive 2,4-D choline	2 8 64	45 b	62 b	70 b	100 b	98 b
Plateau Escort XP Overdrive 2,4-D choline	2 0.2 8 64	50 b	50 b	80 bc	100 b	100 b
Escort XP Overdrive 2,4-D choline	0.33 8 64	47 b	50 b	93 bc	100 b	100 b
Sign. Level ($p \leq 0.05$)		0.000	0.000	0.000	0.000	0.000

Table 7: Percent injury of dandelion (*Taraxacum officinale*, TAROF) at Old Fort. The experiment was visually rated for dandelion injury on May 11, May 25, June 9, and June 22, 2016 (2, 4, 6, and 8 weeks after treatment, WAT). Treatments were applied on April 27, 2016. All treatments included 0.25% v/v non-ionic surfactant. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

		dandelion percent injury			
product	Rate	2 WAT	4 WAT	6 WAT	8 WAT
	(oz/ac)				
Untreated	----	0 a	0 a	0 a	0 a
Plateau Method 240SL	2 10	50 b	90 c	92 bc	100 b
Plateau Method 240SL	3 10	50 b	94 c	95 c	100 b
Plateau Method 240SL	4 10	50 b	92 c	100 c	100 b
Plateau Escort XP Method 240SL	2 0.2 10	50 b	90 c	98 c	100 b
Plateau Escort XP Method 240SL	3 0.2 10	50 b	95 c	100 c	100 b
Plateau Escort XP Method 240SL	4 0.2 10	50 b	90 c	100 c	100 b
Escort XP Method 240SL	0.33 10	50 b	90 c	98 c	100 b
Embark Escort XP Method 240SL	6 0.2 10	50 b	90 c	88 bc	100 b
Plateau Overdrive 2,4-D choline	2 8 64	45 b	56 b	60 b	100 b
Plateau Escort XP Overdrive 2,4-D choline	2 0.2 8 64	50 b	50 b	60 b	100 b
Escort XP Overdrive 2,4-D choline	0.33 8 64	48 b	50 b	81 bc	100 b
Sign. Level ($p \leq 0.05$)		0.000	0.000	0.000	0.000

Table 8: Average height of the tall fescue stand at Port Matilda. The experiment was visually rated for height of tall fescue on May 20, June 3, June 17, July 1, and July 15, 2016 (2, 4, 6, 8, and 10 weeks after treatment, WAT). Treatments were applied on May 6, 2016. All treatments included 0.25% v/v non-ionic surfactant. 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	tall fescue average height (in)				
		2 WAT	4 WAT	6 WAT	8 WAT	10 WAT
	(oz/ac)					
Untreated	----	10.8 a	14.2 b	15.2 c	13.9 b	13.1 ab
Plateau Method 240SL	2 10	10.2 a	10.1 a	9.2 ab	11.5 a	11.2 a
Plateau Method 240SL	3 10	10.3 a	10.2 a	8.8 ab	10.7 a	13.2 ab
Plateau Method 240SL	4 10	10.8 a	9.3 a	8.8 ab	10.9 a	12.7 ab
Plateau Escort XP Method 240SL	2 0.2 10	11.7 a	9.8 a	8.8 ab	10.5 a	12.4 ab
Plateau Escort XP Method 240SL	3 0.2 10	10 a	9.9 a	8 a	11.7 ab	11.8 ab
Plateau Escort XP Method 240SL	4 0.2 10	10.4 a	10.1 a	10 ab	11.2 a	11.7 ab
Escort XP Method 240SL	0.33 10	10.8 a	10.5 a	9.8 ab	11.9 ab	12.8 ab
Embark Escort XP Method 240SL	6 0.2 10	10 a	9.5 a	10.5 ab	11.4 a	12.4 ab
Segment Method 240SL	8 10	11.9 a	11.1 a	11.5 b	13.9 b	14.2 b
Segment Method 240SL	16 10	9.7 a	9.8 a	11.2 ab	12.8 ab	12.5 ab
Segment Method 240SL	24 10	9.9 a	9.8 a	9.8 ab	12.2 ab	12.8 ab
Sign. Level ($p \leq 0.05$)		0.043	0.000	0.000	0.000	0.029

Table 11: Percent cover of the turfgrass stand at Port Matilda. The experiment was visually rated for turf cover on May 5 and July 15, 2016 (0 and 10 weeks after treatment, WAT). The percent change in turf cover was calculated using the formula [(% ending turf cover-% initial turf cover)/% initial turf cover x 100]. Treatments were applied on May 6, 2015. All treatments included 0.25% v/v non-ionic surfactant. 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	percent turf cover		percent change in turf cover
		0 WAT	10 WAT	10 WAT
	(oz/ac)			
Untreated	----	40 a	72 a	83 a
Plateau Method 240SL	2 10	44 a	69 a	64 a
Plateau Method 240SL	3 10	39 a	66 a	71 a
Plateau Method 240SL	4 10	40 a	68 a	69 a
Plateau Escort XP Method 240SL	2 0.2 10	40 a	70 a	76 a
Plateau Escort XP Method 240SL	3 0.2 10	44 a	66 a	57 a
Plateau Escort XP Method 240SL	4 0.2 10	41 a	66 a	66 a
Escort XP Method 240SL	0.33 10	41 a	71 a	75 a
Embark Escort XP Method 240SL	6 0.2 10	42 a	70 a	67 a
Segment Method 240SL	8 10	38 a	72 a	94 a
Segment Method 240SL	16 10	40 a	68 a	69 a
Segment Method 240SL	24 10	45 a	66 a	53 a
Sign. Level ($p \leq 0.05$)		0.948	0.934	0.822

Table 12: Percent injury of birdsfoot trefoil at Port Matilda. The experiment was visually rated for birdsfoot trefoil injury on May 20, June 3, June 17, and July 1, 2015 (2, 4, 6, and 8 weeks after treatment, WAT). Treatments were applied on May 6, 2015. All treatments included 0.25% v/v non-ionic surfactant. 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	birdsfoot trefoil percent injury			
		2 WAT	4 WAT	6 WAT	8 WAT
	(oz/ac)				
Untreated	----	0 a	0 a	0 a	0 a
Plateau Method 240SL	2 10	50 b	94 bc	96 b	86 b
Plateau Method 240SL	3 10	50 b	92 bc	95 b	89 b
Plateau Method 240SL	4 10	50 b	91 b	95 b	88 b
Plateau Escort XP Method 240SL	2 0.2 10	50 b	94 bc	95 b	88 b
Plateau Escort XP Method 240SL	3 0.2 10	50 b	95 bc	97 b	88 b
Plateau Escort XP Method 240SL	4 0.2 10	50 b	94 bc	96 b	88 b
Escort XP Method 240SL	0.33 10	50 b	95 bc	96 b	89 b
Embark Escort XP Method 240SL	6 0.2 10	46 b	91 b	96 b	92 b
Segment Method 240SL	8 10	50 b	96 bc	96 b	92 b
Segment Method 240SL	16 10	50 b	96 bc	97 b	94 b
Segment Method 240SL	24 10	50 b	98 c	98 b	93 b
Sign. Level ($p \leq 0.05$)		0.000	0.000	0.000	0.000