Roadside Vegetation Management Research – 2016 Report

ANNUAL REPORT

June 30, 2016

By Jon M. Johnson, David A. Despot, and
James C. Sellmer

THE PENNSYLVANIA STATE UNIVERSITY

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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: Investigation of Herbicide Tank Mixes Using Increased Rates of 2,4-D for Control of Morrow's Honeysuckle (Lonicera morrowii) 2nd Year Results, Evaluating the Efficacy of 2,4-D and Triclopyr Formulations on Injury to Red Maple (Acer rubrum), Comparison of Garlon 3A and Triclopyr 3 for Quaking Aspen Control Using Foliar Treatments, Evaluation of Dormant Stem Treatments with Growth Regulator Based Herbicides for Control of Amur Honeysuckle, Evaluation of the Herbicides Streamline® and Viewpoint® for Control of Black Birch (Betula lenta) – Results Two Years After Treatment, Alternatives to Embark for Plant Growth Regulation of Roadside Turf, Demonstrating the Utility of Turf Growth Regulators Under Cable Guiderail Structures, Investigating Grass Species, Seeding Rates, and Fertilizer Plus Broadleaf Herbicide Application for Groundcover Establishment in Roadside Applications – Second Year Results, Comparing Spring Seeded Formula L Seed Mix at Two Rates and Sheep Fescue for Groundcover Establishment in a Roadside Application – First Year Results, Testing Alternative Modes of Action in Combination with Esplanade or Plateau for Season Long Bareground Weed Control, Comparison of Sulfentrazone Products for Bareground Weed Control Applications.</td></tr>
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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 2015 season: Dow AgroSciences, BASF Corporation, Bayer Environmental Science, NuFarm Specialty Products, and Wilbur-Ellis Company.

TABLE OF CONTENTS

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

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, total vegetation control, native species establishment and roadside vegetation management demonstrations. 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
Anuew	prohexadione calcium	27.5 WDG	NuFarm Americas, Inc.
Aquasweep	2,4-D + triclopyr	34.2 + 15.2 S	Nufarm Americas, Inc.
Arsenal Powerline	imazapyr	2 S	BASF Corporation
Derigo	foramsulfuron + iodosulfuron thiencarbazone	36.4 WDG	Bayer Environmental Science
DMA 4 IVM	2,4-D	3.8 S	Dow AgroSciences LLC
Embark	mefluidide	2 S	PBI/Gordon Corporation
Escort XP	metsulfuron methyl	60 WDG	E.I. DuPont de Nemours & Co.
Esplanade	indaziflam	200 SC	Bayer Environmental Science
Garlon 3A	triclopyr amine	3 S	Dow AgroSciences LLC
Hyvar X	bromacil	80 WP	E.I. DuPont de Nemours & Co.
Imazapyr	imazapyr	75 WG	E.I. DuPont de Nemours & Co.
MAT28, Method 50SG	aminocyclopyrachlor	50 WDG	E.I. DuPont de Nemours & Co.
Milestone VM	aminopyralid	2 S	Dow AgroSciences LLC
Panoramic	imazapic	2 SL	Alligare LLC
Patron 170	2,4-D + 2,4-DP-p L.V. ester	1.71 + 0.87 S	NuFarm Americas, Inc.
PennDOT Blend (or PDT Custom Blend)	aminocyclopyrachlor + metsulfuron	47.9 + 2.5 DF	E.I. DuPont de Nemours & Co.
Plateau	imazapic	2 SL	BASF Corporation
Portfolio	sulfentrazone	4 F	Wilbur-Ellis Company
Relegate	triclopyr butoxyethyl ester	4 EC	NuFarm Americas, Inc.
Roundup Pro Concentrate	glyphosate	5 S	Monsanto Company
Roundup ProMax	glyphosate	5.5 S	Monsanto Company
Segment	sethoxydim	1 S	BASF Corporation
Streamline	aminocyclopyrachlor + metsulfuron	39.5 + 12.6 DF	E.I. DuPont de Nemours & Co.
Sulfentrazone	sulfentrazone	75 DG	E.I. DuPont de Nemours & Co.
Telar XP	chlorsulfuron	75 DF	E.I. DuPont de Nemours & Co.
Triclopyr 3	triclopyr amine	3 S	Alligare, LLC.
Triclopyr Choline	triclopyr choline	4 S	Dow AgroSciences, LLC.
Viewpoint	aminocyclopyrachlor + metsulfuron + imazapyr	22.8 + 7.3 + 31.6 DF	E.I. DuPont de Nemours & Co.
Velpar DF	hexazinone	75 DF	E.I. DuPont de Nemours & Co.
Weedar 64	2,4-D	3.8 S	NuFarm Inc.

INVESTIGATION OF HERBICIDE TANK MIXES USING INCREASED RATES OF 2,4-D FOR CONTROL OF MORROW'S HONEYSUCKLE (LONICERA MORROWII) 2ND YEAR RESULTS

Herbicide trade and common names: Aquasweep (*2,4-D + triclopyr*); Escort XP (*metsulfuron*); Garlon 3A (*triclopyr* amine); Roundup Pro Concentrate (*3.7 lb ae glyphosate/gal*); MAT28, Method (*aminocyclopyrachlor*); PennDOT Blend (*aminocyclopyrachlor + metsulfuron*); 2,4-D, DMA 4 IVM, Weedar 64 (*2,4-D*).

Plant common and scientific names: amur honeysuckle (*Lonicera maackii*), Morrow's honeysuckle (*Lonicera morrowii*), tatarian honeysuckle (*Lonicera tatarica*).

ABSTRACT

The proliferation of exotic shrub honeysuckle species including tatarian, amur, and Morrow's honeysuckle has become a problem along the roads of Pennsylvania. Exotic shrub honeysuckle plants, as with other woody species invading transit corridors limit sight distance and interfere with highway maintenance activities. We have observed that herbicide tank mixes commonly used as foliar sprays to manage other tree and shrub species are often ineffective at controlling the exotic shrub honeysuckles. Glyphosate has been effective, however, it readily damages the understory. Control of Morrow's honeysuckle was achieved in a previous trial using 2,4-D. The goal of this experiment was to use progressive rates of 2,4-D and identify grass safe herbicide tank mix partners that are effective at controlling Morrow's honeysuckle while offering the potential to control a broad spectrum of other woody species. A total of eight herbicide combinations were tested. All treatments containing 96 oz/ac or greater of 2,4-D or Aquasweep resulted in significant initial injury with values from 90 to 98 percent. In contrast, at one year after treatment (YAT) the control diminished for all treatments, except those containing Roundup Pro Conc. At two years after treatment, all treatments continued to show a decline in control. Only treatments containing Roundup Pro Conc. demonstrated acceptable control from 93 to 95 percent. Marginal control, statistically similar to the best treatments, was observed with 8 oz/ac PennDOT Blend tank mixed with 96 oz/ac 2,4-D; 64 oz/ac Garlon 3A tank mixed with 128 oz/ac 2,4-D; and 184 oz/ac Aquasweep tank mixed with 0.5 oz/ac Escort XP (59 to 69 percent). Other treatments offered unacceptable control between 29 and 43 percent. Larger plant size and limited spray pattern resulted in reduced spray coverage of the canopy, which contributed to lower than expected control levels for 2,4-D. Despite these obstacles, treatments containing glyphosate performed well. Further work using these products, rates, and mixes, but applying to the entire canopy thus assuring better coverage should be the focus of future investigations.

INTRODUCTION

The very nature of construction and maintenance of roadways creates disturbed, open areas that provide an ideal setting for the establishment of exotic and invasive species. Low growing shrubs, like exotic shrub honeysuckle, are able to colonize these sites quickly thus gaining a foothold and spreading aggressively. Unfortunately, the herbicide tank mixes commonly used by PennDOT to control woody plants have had minimal success on exotic shrub honeysuckle. A trial, established in 2012, identified 2,4-D or Aquasweep (2,4-D plus triclopyr) as effective against shrub honeysuckle while offering safety to grass understory.[1] Identification of tank mix partners to help ensure control of a wider range of brush species is needed. One potential tank mix partner, PennDOT Blend, contains MAT28 (aminocyclopyrachlor, ACP) and Escort XP (metsulfuron). An 8 oz rate of the PennDOT Blend equates to 7.67 oz of MAT28 (50% ACP) and 0.33 oz Escort XP. Other possible candidates as tank mix partners with 2,4-D are Garlon 3A or Escort XP while Aquasweep could be combined with Escort XP. Further testing of 2,4-D and Aquasweep in progressive rates and within label guidelines in combination with other herbicides for foliar applied control of Morrow's honeysuckle was the focus of the following experiment.

MATERIALS AND METHODS

The experiment was established in close proximity to the interchange of I-99 and I-80 near Bellefonte, PA. Eight herbicide treatments were tested including: 8 oz/ac PennDOT Blend tank mixed with 96 oz/ac 2,4-D; 1 oz/ac Escort XP tank mixed with 128 oz/ac 2,4-D; 64 oz/ac Garlon 3A tank mixed with 64 oz/ac 2,4-D; 64 oz/ac Garlon 3A tank mixed with 128 oz/ac 2,4-D; 64 oz/ac Garlon 3A tank mixed with 104 oz/ac Roundup Pro Concentrate[2]; 104 oz/ac Roundup Pro Conc. alone; 96 oz/ac Aquasweep tank mixed with 0.75 oz/ac Escort XP; 184 oz/ac Aquasweep tank mixed with 0.5 oz/ac Escort XP; and an untreated check. All herbicide treatments included a non-ionic surfactant at 0.25 percent v/v. Plots 10 by 25 feet in size were arranged in a randomized complete block design with four replications. Herbicides were applied at 50 gal/ac on August 2, 2013, using a CO_2 powered backpack sprayer equipped with a GunJet spray gun and single Boomjet XP 20R nozzle.

Percent injury (0 = no injury, 100 = complete necrosis) to Morrow's honeysuckle was visually rated on September 12, 2013, 41 days after treatment, DAT. Percent control based on percent canopy loss of the treated branches to Morrow's honeysuckle was evaluated on July 31, 2014 and September 22, 2015, 1 and 2 years after treatment, YAT. All data were subject to analysis of variance, and when treatment effect F-tests were significant ($p \leq 0.05$), treatment means were compared using Tukey's HSD separation test.

RESULTS AND DISCUSSION

Initial injury to Morrow's honeysuckle ranged from 56 to 98 percent for the herbicide treatments at 41 days after treatment, DAT. All treatments containing 96 oz/ac or greater of 2,4-D or Aquasweep resulted in significant injury with values from 90 to 98 percent. Other treatments that included either 64 oz/ac 2,4-D or Roundup Pro Conc. resulted in injury values of 56 to 72 percent. At one YAT, treatments containing Roundup Pro Conc. resulted in the greatest control averaging 94 and 97 percent. Regrowth of the canopy was observed with the remaining treatments resulting in reduced long-term control. Treatments containing 96 oz/ac or greater of 2,4-D or Aquasweep offered moderate control at 69 to 75 percent. While 96 oz/ac Aquasweep plus 0.75 Escort XP only produced 54 percent control. The least effective treatment was 64 oz/ac Garlon 3A tank mixed with 64 oz/ac 2,4-D producing only 31 percent control. All treatments showed a decline in control at 2 YAT. Only treatments that included Roundup Pro

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[1] Johnson, J.M. et al 2014. Investigating Herbicide Tank Mixes for Control of Morrow's Honeysuckle (Lonicera Morrowii) – Second Year Results. Roadside Vegetation Management Research – 2014 Report. pp 1-4.

[2] Roundup Pro Concentrate (3.7 lb ae glyphosate/gal), Monsanto Co., St. Louis, MO. 104 oz Roundup Pro Concentrate contains the equivalent amount of glyphosate acid as found in 128 oz Roundup Pro.

Conc. provided acceptable control of the treated branches at 93 and 95 percent. Marginal control, statistically similar to the best treatments, was observed with 8 oz/ac PennDOT Blend tank mixed with 96 oz/ac 2,4-D, 64 oz/ac Garlon 3A tank mixed with 128 oz/ac 2,4-D, and 184 oz/ac Aquasweep tank mixed with 0.5 oz/ac Escort XP (59 to 69 percent). Other treatments offered unacceptable control between 29 and 43 percent.

CONCLUSIONS

Using increased rates of 2,4-D and Aquasweep did not provide effective control of the treated branches. However, in this experiment larger shrubs were targeted and only one side of most shrubs received spray to mimic a typical truck-based, sidetrimming spray pattern. Despite the reduced coverage of the Morrow's honeysuckle canopy, treatments containing glyphosate (Roundup Pro Conc.) did defoliate the treated branches and may offer an option where loss of existing understory can be tolerated.

MANAGEMENT IMPLICATIONS

Tank mixes that include 96 to 128 oz/ac 2,4-D tank mixed with either 8 oz/ac PennDOT Blend or 64 oz/ac Garlon 3A or, alternatively, 184 oz/ac Aquasweep tank mixed with 0.5 oz/ac Escort XP did not offer effective control when side-trimming exotic honeysuckle shrubs. However, even lesser rates of 2,4-D and Aquasweep in similar tank mixes have shown promising results in past work. With sufficient coverage of the targeted shrubs by the herbicide spray and a planned retreatment to eliminate newly emerging sprouts, effective control can be expected. These tank mixes should also control a spectrum of other common brush species while minimizing impact to the grass understory. The 2,4-D plus Escort XP treatment was added primarily to determine the contribution Escort XP offers on Morrow's honeysuckle control and may prove to be weak on controlling other woody species. Roundup Pro Conc. alone and in combination has offered excellent brush control, including Morrow's honeysuckle, but is damaging to grasses. A targeted application with mixes containing glyphosate or use on sites that contain little or no desirable understory is an option in some instances. Altering the spray pattern to allow for greater coverage of the shrubs should be investigated to determine if more effective control could be achieved using the elevated rates of 2,4-D and Aquasweep in the tank mix combinations tested in this experiment.

Table 1: Percent injury and control of Morrow's honeysuckle (*Lonicera morrowii*, LONMO). The trial was visually rated for percent injury on September 12, 2013 (41 days after treatment, DAT) plus control on July 31, 2014 and September 22, 2015 (1 & 2 years after treatment, YAT). Treatments were applied on August 2, 2013. All 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 $p \leq 0.05$.

product	rate	Percent Injury (41 DAT) LONMO	Percent Control (1 YAT) LONMO	Percent Control (2 YAT) LONMO
	(oz/ac)			
untreated	---	0 a	0 a	0 a
PennDOT Blend 2,4-D	8 96	94 c	72 cd	59 bcd
Escort XP 2,4-D	1 128	94 c	69 cd	43 bc
Garlon 3A 2,4-D	64 64	68 bc	31 b	29 ab
Garlon 3A 2,4-D	64 128	95 c	69 cd	66 bcd
Garlon 3A Roundup Pro Conc.	64 104	56 b	94 ef	93 d
Roundup Pro Conc.	104	72 bc	97 f	95 d
Aquasweep Escort XP	96 0.75	90 c	54 c	39 abc
Aquasweep Escort XP	184 0.5	98 c	75 de	69 cd

EVALUATING THE EFFICACY OF 2,4-D AND TRICLOPYR FORMULATIONS ON INJURY TO RED MAPLE (*ACER RUBRUM*)

Herbicide trade and common names: DMA 4 IVM (*2,4-D* amine); Escort XP (*metsulfuron*); Garlon 3A, Triclopyr 3 (*triclopyr* amine); Method (*aminocyclopyrachlor*); Milestone VM (*aminopyralid*); PennDOT Blend (*aminocyclopyrachlor* + *metsulfuron*); Triclopyr Choline (*triclopyr choline*).

Plant common and scientific names: exotic shrub honeysuckle (*Lonicera* spp.); goldenrod (*Solidago* spp.); red maple (*Acer rubrum*).

ABSTRACT

Recent experiments have shown 2,4-D to be an effective herbicide for control of exotic shrub honeysuckle; however, its effectiveness on other woody vegetation has not been proven. This experiment was established to evaluate the performance of 2,4-D alone and in combination with other herbicides to control red maple, a tree species common to the right-of-way. In addition, this experiment provided an opportunity to compare Garlon 3A (the standard form of *triclopyr*) with generic Triclopyr 3 and an experimental formulation of Triclopyr choline for control of red maple. Preliminary data, collected at 29 days after treatment, DAT, indicated that 2,4-D caused only moderate injury to red maple (50%) when used alone. Injury to red maple increased when 2,4-D was tank mixed with other herbicides. For example an injury rating of 93 percent was achieved with a combination that included 2,4-D, Garlon 3A, and Escort XP. *Triclopyr* caused significant injury, both alone and in a tank mix with injury values from 82 to 93 percent. Plots treated with *triclopyr* alone, regardless of formulation, resulted in similar injury ratings. Further evaluation of red maple control was not possible because the research plots were compromised due to over-spray by spray crews before control efficacy ratings could be conducted one year after treatment. Future testing of these products on a variety of species and at various rates and combinations with data collected over multiple seasons will provide better insight on the overall effectiveness of these products using foliar sprays.

INTRODUCTION

Some woody plants found on the right-of-way (e.g., exotic shrub honeysuckle) are becoming more difficult to control using standard brush herbicides such as Escort XP, Garlon 3A, and PennDOT Blend (*aminocyclopyrachlor* + *metsulfuron*)[3]. Recent experiments with an older chemistry, 2,4-D, have shown effective control of exotic shrub honeysuckle; however, 2,4-D alone may not be as effective on a broad range of woody species. The ideal tank mix would control exotic shrub honeysuckle and other woody plants that arise in the right-of-way. This experiment was established to evaluate the performance of 2,4-D alone and in combination with other herbicides to control red maple on a roadside right-of-way. In addition, this experiment tested Triclopyr 3[4], a generic *triclopyr* herbicide, and Triclopyr Choline[5] an experimental formulation of *triclopyr* against the standard Garlon 3A[6].

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[3] 8 oz PennDOT Blend = 7.67 oz Method + 0.33 oz Escort XP.
[4] Triclopyr 3 (3 lbs. a.e./ gallon) Alligare LLC, 13 N. 8th Street Opelika, AL 36801
[5] Triclopyr Choline (4 lbs. a.e./ gallon) Dow AgroSciences LLC, 9330 Zionsville Road, Indianapolis, IN 46268
[6] Garlon 3A (3 lbs. a.e./ gallon) Dow AgroSciences LLC, 9330 Zionsville Road, Indianapolis, IN 46268

MATERIALS AND METHODS

The experiment was established on the shoulder of SR 220N between mile marker 109 and 111, near the Lock Haven, PA exit. Treatments included PennDOT Blend at 8 oz/ac tank mixed with DMA 4 IVM at 96 oz/ac and Escort XP at 0.25 oz/ac; PennDOT Blend at 5.33 oz/ac tank mixed with DMA 4 IVM at 96 oz/ac and Escort XP at 0.5 oz/ac; DMA 4 IVM alone at 96 oz/ac; Garlon 3A at 64 oz/ac tank mixed with DMA 4 IVM at 96 oz/ac and Escort XP at 0.5 oz/ac; Milestone VM at 7 oz/ac tank mixed with DMA 4 IVM at 96 oz/ac and Escort XP at 0.5 oz/ac; Garlon 3A alone at 64 oz/ac; Triclopyr Choline alone at 48 oz/ac; Triclopyr 3 alone at 64 oz/ac; and an untreated check. The products containing *triclopyr* were applied at rates intended to deliver an equivalent rate of *triclopyr* acid. A non-ionic surfactant (CWC Surfactant 90) was added to all treatments at 0.25% v/v. All products were applied at a carrier volume of 50 gallons per acre, GPA. The experiment was established as a randomized complete block design with four replications. Plots were 10 by 20 feet in size. The red maple trees ranged in size from 2 to 8 feet tall and were in full canopy with no fall coloration evident at application time on September 4, 2014. Treatments were applied using a CO_2 powered backpack sprayer operating at 36 psi and equipped with a Gunjet 30 spray gun and Boomjet 20L or 20R nozzle. Percent injury to red maple trees and goldenrod understory was evaluated on October 3, 2014, 29 days after treatment (DAT). All data were subjected to analysis of variance, and when treatment effect F-tests were significant ($p \leq 0.05$), treatment means were compared using Tukey's HSD separation test.

RESULTS AND DISCUSSION

Preliminary data, collected at 29 DAT, showed treatments that included the active ingredient *triclopyr* alone or in combination with other products caused at least 82% injury to red maple (Table 1). DMA 4 IVM provided only moderate injury to red maple (50%) when used alone. Injury ratings improved when DMA 4 IVM was tank mixed with other herbicides. For example, an injury rating of 93% was achieved with a mix that included DMA 4 IVM, Garlon 3A, and Escort XP. It is difficult to draw conclusions about long-term control provided by the treatments with only first year data. Some treatments with poor initial performance, for example DMA 4 IVM alone and the tank mix that contained Milestone, may be slower to act. The control ratings collected at one year after treatment could not be utilized because some of the plots were over sprayed during 2016 operational treatments, confounding the effects of treatments applied for this experiment. None of the herbicide treatments spared the goldenrod understory as might be expected with herbicides designed to control broadleaf vegetation. DMA 4 IVM alone did the least damage to goldenrod with 69% injury; however, all treatments were statistically similar at 69 to 97 percent injury.

CONCLUSIONS

All *triclopyr* products caused significant and similar short-term injury to red maple in this experiment, whether the product was applied alone or in a tank mix, produced by a name brand or generic manufacturer, or formulated as an amine or choline. Some of the other products or mixes tested such as DMA 4 IVM, PennDOT Blend, and Milestone may require more time to produce results. Data collected at one year after treatment was compromised due to plots being over-sprayed by spray crews during the 2016-growing season thus preventing a further and clean evaluation of the treatments. Further testing is recommended to compare the long-term efficacy of these products and mixes on a range of species.

Table 1. Percent injury to red maple and goldenrod understory. Treatments were applied on September 4, 2014. The experiment was visually rated for percent injury on October 3, 2014 (29 days after treatment, DAT). All 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 $p \leq 0.05$.

product	rate	injury red maple 29 DAT	injury goldenrod 29 DAT
	(oz/ac)	(%)	(%)
untreated	---	0 a	0 a
PDT Blend DMA 4 IVM Escort XP	8 96 0.25	72 bc	91 b
PDT Blend DMA 4 IVM Escort XP	5.33 96 0.5	85 c	97 b
DMA 4 IVM	96	50 b	69 b
Garlon 3A DMA 4 IVM Escort XP	64 96 0.5	93 c	92 b
Milestone VM DMA 4 IVM Escort XP	7 96 0.5	70 bc	83 b
Garlon 3A	64	90 c	89 b
Triclopyr Choline	48	85 c	79 b
Triclopyr 3	64	82 c	76 b

COMPARSION OF GARLON 3A AND TRICLOPYR 3 FOR QUAKING ASPEN CONTROL USING FOLIAR TREATMENTS

Herbicide trade and common names: Garlon 3A, Triclopyr 3 (*triclopyr* amine).
Plant common and scientific names: quaking aspen (*Populus tremuloides*).

ABSTRACT

Garlon 3A contains the active ingredient *triclopyr* and is manufactured by Dow AgroSciences, LLC. This herbicide is a common component of tank mixes used for woody and broadleaf vegetation management along roadsides. There are generic product versions that also contain this active ingredient, such as Triclopyr 3 manufactured by Alligare LLC. The purpose of this experiment was to compare the effectiveness of Garlon 3A, the name brand against Triclopyr 3, the generic for control of quaking aspen using foliar treatments. At one year after treatment, YAT, control was similar for trees sprayed using either Garlon 3A or Triclopyr 3.

INTRODUCTION

Garlon 3A (active ingredient *triclopyr* amine) manufactured by Dow Agrosciences is a broad-spectrum herbicide used for brush and broadleaf weed control. It is included in many of the tank mixes employed for woody vegetation control along roadsides in Pennsylvania. Other manufacturers also produce herbicides that contain *triclopyr* amine as the active ingredient. This experiment was established to compare the performance of Garlon 3A[7] to Triclopyr 3[8] for control of quaking aspen using foliar treatments.

MATERIALS AND METHODS

The experiment was established alongside the entrance ramp leading from SR22W to SR219N in Cambria County just west of Ebensburg, PA. Treatments included Garlon 3A at 64 oz/ac; Triclopyr 3 at 64 oz/ac; and an untreated check. A non-ionic surfactant (CWC Surfactant 90) was added to all treatments at 0.25% v/v. All products were applied at a carrier volume of 50 GPA. The experiment was established as a randomized complete block design with four replications. Plots were 10 by 20 feet in size. The quaking aspen trees ranged in height from 5 to 12 feet and were in full canopy with no sign of fall coloration on August 29, 2014 when treated. Treatments were applied using a CO_2 powered backpack sprayer equipped with a GunJet 30 spray gun and a Boomjet 20L nozzle. Percent injury was evaluated on September 29, 2014 (31 days after treatment, DAT) and percent control on August 28, 2015 (1 year after treatment, YAT). Both injury and control were assessed based on canopy reduction compared to the untreated check. 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.

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[7] Garlon 3A (3 lb a.e./gallon) Dow AgroSciences LLC, 9330 Zionsville Road, Indianapolis, IN 46268
[8] Triclopyr 3 (3 lb a.e./gallon) Alligare LLC, 13 N. 8th Street Opelika, AL 36801

RESULTS AND DISCUSSION

At 31 DAT both herbicides produced a moderate to high level of injury to quaking aspen characterized by a combination of necrosis and defoliation totaling 76 to 90 percent, with no significant difference between the products tested. At one year after treatment, control was similar for trees subjected to either Garlon 3A or Triclopyr 3 resulting in inadequate control, 69 and 66 percent defoliation, respectively (Table 1).

CONCLUSIONS

In this experiment, Garlon 3A and Triclopyr 3 performed equally well for control of quaking aspen. Other factors, including environmental or site conditions (e.g., drought or low fertility), treatment timing, and tree species or size, could influence results so more testing is suggested.

MANAGEMENT IMPLICATIONS

Generic products may offer cost savings and may be substituted as long as performance is similar to the name brand. Based on results from this experiment, Triclopyr 3 could be used as a reasonable replacement for Garlon 3A when targeting quaking aspen. Experiments on other species and under varying conditions should be conducted to determine whether both products perform equally well for roadside brush applications.

Table 1. Percent injury to quaking aspen trees located along an entrance ramp to SR219N near Ebensburg, PA. The application rates represent equal amounts of active ingredient per acre for the products. Treatments were applied on August 29, 2014. The experiment was visually rated for injury on September 29, 2014, 31 days after treatment, DAT, and control on August 28, 2015, 1 year after treatment, YAT. 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 injury 31 DAT	percent control 1 YAT
	(oz/ac)		
untreated	---	0 a	0 a
Garlon 3A	64	90 b	69 b
Triclopyr 3	64	76 b	66 b

EVALUATION OF DORMANT STEM TREATMENTS WITH GROWTH REGULATOR BASED HERBICIDES FOR CONTROL OF AMUR HONEYSUCKLE

Herbicide trade and common names: Patron 170 (*2,4-D + 2,4-DP-p L.V. ester*); Relegate (*triclopyr butoxyethyl ester*).
Plant common and scientific names: amur honeysuckle (*Lonicera maackii*), Morrow's honeysuckle (*Lonicera morrowii*), tatarian honeysuckle (*Lonicera tatarica*).

ABSTRACT

Exotic shrub honeysuckle has quickly emerged as a problem on many roadside corridors. It spreads aggressively and develops large stands of dense, woody vegetation that limit site distance and interfere with highway maintenance activities. The more common species within Pennsylvania include tatarian, amur, and Morrow's honeysuckle. Observations suggest that exotic shrub honeysuckle is not well controlled with herbicide tank mixes commonly utilized in foliar sprays to manage other encroaching tree and shrub species. Dormant stem treatments have generally been ineffective in roadside brush control efforts targeting single stem trees; however, exotic shrub honeysuckle may be more susceptible due to greater branch surface area target provided by exotic shrub honeysuckle. In addition, foliar applications of 2,4-D have been successful in their control. The goal of this experiment was to evaluate two mixes (e.g., Patron 170, and Patron 170 tanked mixed with Relegate) to determine the efficacy of the 2,4-D alone and in combination with triclopyr for injury and control of amur honeysuckle using dormant stem applications. Patron 170 alone did not provide adequate control, but tank mixed with Relegate herbicide, control was sufficient to prompt further investigation. Perhaps sequential treatments using dormant stem or foliar applications in consecutive seasons will result in complete control.

INTRODUCTION

The roadside provides the perfect environment for the establishment of unwanted exotic shrub honeysuckle species. The instability of the plant community caused by construction and ongoing maintenance activities create an open environment and excellent opportunity for these shrubs to become established and thrive. Unfortunately, the foliar herbicide tank mixes commonly used by PennDOT to control woody plants have had minimal impact on exotic shrub honeysuckle species along Pennsylvania's roads. Dormant stem treatments have shown nearly acceptable control with the proper herbicide mixture on certain species (e.g., green ash and red oak).[9] 2,4-D has demonstrated encouraging results for control of exotic shrub honeysuckle using foliar sprays[10], so treatments combining this active ingredient with a dormant stem application method may offer a control option. Both Patron 170[11] and Relegate[12] herbicides have current

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[9] Gover, A.E. et al. 2002. Controlling Brush with Dormant Stem Applications of Escort and Garlon 4. Roadside Vegetation Management Research Report – Sixteenth Year Report. pp. 1-3.
[10] Johnson, J.M. et al. 2014. Investigating Herbicide Tank Mixes for Control of Morrow's Honeysuckle (*Lonicera morrowii*) – Second Year Results. Roadside Vegetation Management Research – 2014 Report. pp. 1-4.
[11] NuFarm Americas, Inc. Patron 170 Herbicide Supplemental Labeling (expires May 28, 2017). Online. Internet. February 22, 2015.
[12] NuFarm Americas, Inc. Relegate Herbicide. Online. Internet. February 22, 2015.

labeling for this application. Dormant stem treatment using these herbicides for control of amur honeysuckle was the focus of this experiment.

MATERIALS AND METHODS

The experiment was established within a woodlot at the Landscape Management Research Center University Park, PA. Two herbicide treatments were tested including 96 oz/ac Patron 170 alone or 96 oz/ac Patron 170 tank mixed with 144 oz/ac Relegate, and an untreated check. All herbicide treatments included a crop oil concentrate at 3.0 percent v/v and non-ionic surfactant at 0.25 percent v/v. Plots 10 by 25 feet in size were arranged in a randomized complete block design with four replications. Herbicides were applied at 75 gal/ac on April 16, 2014, using a CO_2 powered backpack sprayer equipped with a GunJet 30 spray gun and single Boomjet XP 20R nozzle.

Percent injury (0 = no injury, 100 = complete necrosis or defoliation) to amur honeysuckle was visually rated on May 22, 2014, 36 days after treatment, DAT. Percent control based on percent canopy loss of the treated amur honeysuckle branches was evaluated on August 14, 2014, May 20, 2015, and September 23, 2015, 120, 386, and 512 days after treatment, DAT. All data were subject to analysis of variance, and when treatment effect F-tests were significant ($p \leq 0.05$), treatment means were compared using Tukey's HSD separation test.

RESULTS AND DISCUSSION

The 96 oz/ac Patron 170 treatment alone caused initial injury symptoms of 79 percent at 36 DAT on amur honeysuckle. By 120 DAT, a control rating of 49 percent was observed, but control ratings declined to 9 and 12 percent at 386 and 512 DAT, respectively. The addition of 144 oz/ac Relegate to 96 oz/ac Patron 170 increased both initial injury and control of amur honeysuckle. Initial injury for this treatment was observed at 98 percent; however, the effect declined over time with control ratings of 84, 62, and 50 percent at 120, 386, and 512 DAT, respectively.

CONCLUSIONS

Using 96 oz/ac Patron 170 alone did not provide adequate control of amur honeysuckle with dormant stem treatments. The addition of 144 oz/ac Relegate to 96 oz/ac Patron 170 increased effectiveness, but did not provide adequate control with a single application. Further work investigating the use of repeated treatments may prove beneficial in controlling this species and other common invasive honeysuckle species where mixed stands exist.

MANAGEMENT IMPLICATIONS

The herbicide treatments tested do not provide adequate control of amur honeysuckle with a single application. Dual applications should be investigated to determine if cost-effective control could be achieved using Patron 170 plus Relegate with dormant stem alone or dormant stem plus foliar treatments applied in successive seasons. The sequential defoliation of the shrub honeysuckle targets may open the canopy, allow for greater spray coverage, and result in more complete control. However, these treatments are not suggested without further testing.

Table 1: Percent injury and control of amur honeysuckle (*Lonicera maackii*, LONMA). The trial was visually rated for percent injury on May 22, 2014 (36 days after treatment, DAT) plus control on August 14, 2014, May 20, 2015, and September 23, 2015 (120, 386, and 512 days after treatment, DAT). Treatments were applied on April 16, 2014. All treatments included 3.0 percent v/v crop oil concentrate and 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 $p \leq 0.05$.

product	rate	percent injury 36 DAT	percent control 120 DAT	percent control 386 DAT	percent control 512 DAT
	(oz/ac)				
untreated	---	0 a	0 a	0 a	0 a
Patron 170	96	79 b	49 b	9 b	12 b
Patron 170 Relegate	96 144	98 c	84 c	62 c	50 c

EVALUATION OF THE HERBICIDES STREAMLINE® AND VIEWPOINT® FOR CONTROL OF BLACK BIRCH (BETULA LENTA) – RESULTS TWO YEARS AFTER TREATMENT

Herbicide trade and common names: Escort XP (*metsulfuron*); Garlon 3A (*triclopyr* amine); Imazapyr 75WG (*imazapyr*); MAT28 50 SG (*aminocyclopyrachlor*); Streamline (*aminocyclopyrachlor* + *metsulfuron*); Viewpoint (*aminocyclopyrachlor* + *metsulfuron* + *imazapyr*).

Plant common and scientific names: black birch (*Betula lenta,* BETLE), flattened oatgrass (*Danthonia compressa*, DANCO), tapered rosette grass (*Dicanthelium acuminatum*).

ABSTRACT

Unwanted trees and shrubs can quickly invade the roadsides of Pennsylvania where they limit sight distance, form obstacles, and create the potential for falling limbs. Black birch is among the many species with the ability to rapidly colonize the roadway corridors. New herbicides with varying modes of action are continually investigated to find the most effective chemistry to control woody plants and preserve grasses in the understory.

Aminocyclopyrachlor has shown efficacy in control of a number of tree species on the roadside. Dupont had three herbicide premixes, later acquired by Bayer Environmental Science, that contain the active ingredient *aminocyclopyrachlor* and two (i.e., Streamline and Viewpoint) are labeled for general weed and brush control along highway rights-of-way. This experiment was established to determine the efficacy of these products at various rates and their safety to grasses compared to the standard Garlon 3A plus Escort XP combination using foliar applications for control of black birch.

Review of the site 1-year after treatment, YAT, showed control of black birch and injury symptoms to flattened oatgrass, the predominate grass species present, with all treatments. Streamline at 9.5 oz/ac or greater, Viewpoint at 13 oz/ac or greater, and 64 oz/ac Garlon 3A plus 0.5 oz/ac Escort XP offered excellent control of black birch from 88 to 96 percent. Both Streamline and Viewpoint injured the understory grass; however, Viewpoint, which contains *imazapyr* resulted in the greatest injury. At 2 YAT, only Viewpoint at the highest rate tested (20 oz/ac) produced greater than 90% control of black birch, while the standard, Garlon 3A combined with Escort XP was nearly as effective with 84% control.

INTRODUCTION

The goal of managing roadsides in Pennsylvania is to maintain a stable, low growing plant community adjacent to travel lanes, which provides a buffer from standing trees and the hazards associated with them, such as collision targets, falling limbs, and limited sight distance. Trees and shrubs, especially early successional species, quickly gain a foothold in these areas and targeted spraying or removal is used to keep the roadways safe. Herbicide programs are implemented using a variety of tank mixes to target unwanted trees and shrubs. Streamline and Viewpoint are two relatively new products in the marketplace labeled for control of a wide variety of woody species. This experiment examined several rates of each product through foliar applications to control black birch and to determine their effect on understory plants compared to the standard Garlon 3A plus Escort XP herbicide treatment.

MATERIALS AND METHODS

An experiment was established within the right-of-way of SR 322 near Port Matilda, PA. Treatments included Streamline at 7.5, 9.5, and 11.5 oz/ac; Viewpoint at 13, 16.5, and 20 oz/ac; Garlon 3A at 64 oz/ac combined with Escort XP at 0.5 oz/ac; and an untreated check. Methylated seed oil was added to all herbicide treatments at 1% v/v. The experiment was established as a randomized complete block design with three replications. Plots were 10 by 30 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-6 tip operating at 30 psi for an application volume of 25 gallons per acre. The black birch was treated on July 2, 2013. A brief rain shower with large droplets began while spraying the last plot with enough rain to wet the pavement but ended quickly and was not considered to have impacted the treatments.

Percent injury to black birch was evaluated August 26, 2013, 55 days after treatment, DAT. Percent control of black birch was later evaluated on July 14, 2014, 1 year after treatment, YAT and September 8, 2015, approximately 2 YAT. Both percent injury and control of black birch were a reflection of the percentage of defoliation. Percent injury to the understory, in particular ferns and two grass species, flattened oatgrass and tapered rosette grass, were visually evaluated August 26, 2013 and June 27, 2014 (55 DAT and 1 YAT). However, only flattened oatgrass was present in enough quantity to yield sufficient data for reporting.

RESULTS AND DISCUSSION

Initial injury to black birch was statistically similar and ranged from 43 to 70 percent for all herbicide treatments (Table 1). Streamline herbicide applied at 9.5 oz/ac, Viewpoint at 16.5 or 20 oz/ac, and Garlon 3A at 64 oz/ac plus Escort XP at 0.5 oz/ac resulted in the greatest injury with rating values from 57 to 70 percent. All other treatments including Streamline at 7.5 and 11.5 oz/ac and Viewpoint at 13 oz/ac resulted in injury values of 43 to 47 percent. One year later, excellent control of black birch was observed with Streamline at 9.5 oz/ac or greater, Viewpoint at 13 oz/ac or greater, and Garlon 3A at 64 oz/ac plus Escort XP at 0.5 oz/ac with values from 88 to 96 percent. The lowest rate of Streamline at 7.5 oz/ac resulted in 70 percent control.

By 2 YAT, all herbicide treatments produced statistically similar results and only Viewpoint at the highest rate (20 oz/ac) produced control in excess of 90% (i.e., 93%). The industry standard Garlon 3A plus Escort XP mix produced the second highest control rating of 84 percent. Streamline at rates of 7.5 to 11.5 oz/ac and lesser rates of Viewpoint (13 and 16.5 oz/ac) had control values of 53 to 80 percent.

At 55 DAT, moderate injury to flattened oatgrass occurred with Viewpoint at 13 and 20 oz/ac, the lowest and highest rates tested in this trial, with 63 and 53 percent injury, respectively (Table 2). All other herbicide treatments resulted in less injury to this grass species from 20 to 37 percent and were not significantly different from the untreated check. By 1 YAT, injury to flattened oatgrass increased for all Streamline and Viewpoint treatments. Both products displayed significant injury symptoms, with Streamline ranging from 48 to 65 percent and Viewpoint from 76 to 100 percent. The Garlon 3A and Escort treatment resulted in the least injury to flattened oatgrass at 18 percent.

CONCLUSIONS

Excellent long-term control of black birch can be expected with the Garlon 3A plus Escort XP combination or Viewpoint at 20 oz/ac, although all herbicide treatments were statistically similar in control. At 2 YAT, control diminished for all herbicide treatments. It appears that the persistence of aminocyclopyrachlor does not translate into better control of black birch than was achieved with the Garlon 3A plus Escort XP mix. Nearly permanent loss of the grass understory occurred with Viewpoint while Streamline did allow some grass understory to remain. This would be expected with the addition of *imazapyr* found in Viewpoint. In contrast, the Garlon 3A plus Escort XP treatment showed only a minor impact on the flattened oatgrass.

MANAGEMENT IMPLICATIONS

The 64 oz/ac Garlon 3A plus 0.5 oz/ac Escort XP combination is very effective at controlling black birch while causing less damage to the grass understory. Streamline or Viewpoint 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 Streamline and Viewpoint due to their soil activity and potential to injure nearby desirable trees. For these reasons we do not recommend replacing the standard herbicide combination with these aminocyclopyrachlor products under this roadside scenario.

Table 1: Percent injury and control to black birch (*Betula lenta,* BETLE). The experiment was visually rated for percent injury on August 26, 2013, 55 days after treatment, DAT, percent control on July 14, 2014, 1 year after treatment (YAT) and percent control on September 8, 2015, approximately 2 YAT. Treatments were applied on July 2, 2013. All treatments included 1 percent v/v methylated seed oil. Each value is the mean of three replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	rate	Percent Injury	Percent Control	Percent Control
		BETLE 8/26/13	BETLE 7/14/14	BETLE 9/8/15
	(oz/ac)			
Untreated	---	0 a	0 a	0 a
Streamline	7.5	45 ab	70 b	53 ab
Streamline	9.5	58 b	91 b	68 b
Streamline	11.5	43 ab	88 b	75 b
Viewpoint	13	47 ab	96 b	80 b
Viewpoint	16.5	57 b	95 b	68 b
Viewpoint	20	63 b	96 b	93 b
Garlon 3A Escort XP	64 0.5	70 b	96 b	84 b

Table 2: Percent injury to flattened oatgrass (*Danthonia compressa*, DANCO). The experiment was visually rated for percent injury on August 26, 2013, 55 days after treatment, DAT and June 27, 2014, 1 year after treatment, YAT. Treatments were applied on July 2, 2013. All treatments included 1 percent v/v methylated seed oil. Each value is the mean of three replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	rate	Percent Injury DANCO 8/26/13	Percent Injury DANCO 6/27/14
	(oz/ac)		
untreated	---	0 a	0 a
Streamline	7.5	20 ab	48 ab
Streamline	9.5	27 ab	65 ab
Streamline	11.5	27 ab	57 ab
Viewpoint	13	63 b	84 ab
Viewpoint	16.5	30 ab	100 b
Viewpoint	20	53 b	76 ab
Garlon 3A Escort XP	64 0.5	37 ab	18 ab

ALTERNATIVES TO EMBARK FOR PLANT GROWTH REGULATION OF ROADSIDE TURF

Herbicide trade and common names: Anuew (*prohexadione calcium*), Embark (*mefluidide*), Escort XP (*metsulfuron*), Method (*aminocyclopyrachlor*), Milestone (*aminopyralid*), Plateau or Panoramic (*imazapic*), Segment (*sethoxydim*).

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

ABSTRACT

One management strategy for reducing mowing activities along the roadside while delaying growth and inhibiting seed head development of cool season grasses in the spring and controlling broadleaf weed development is to tank mix and apply turf growth regulators and broadleaf herbicides. 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. Several alternative turf growth regulators were tested in combination with broadleaf herbicides for turf suppression and broadleaf weed control at three separate locations in Pennsylvania. The goal of this work was to identify an acceptable substitute for Embark 2S. A total of thirteen product combinations were tested. Six potential individual or combination turf growth regulators were evaluated for seedhead suppression and reduced blade growth on tall fescue (*Festuca arundinacea*) and Kentucky bluegrass (*Poa pratensis* L.). The treatments included: a comparison of the trade and generic formulations (i.e., Plateau and Panoramic at 2 oz/ac; Embark at 6 oz/ac plus Escort XP at 0.2 oz/ac; Segment at 24 oz/ac; Anuew at 21.8 oz/ac; and Escort XP at 0.33 oz/ac. These treatments were combined with either Method or Milestone VM at 5 oz/ac. One additional treatment was tested: Plateau at 2 oz/ac plus Escort XP at 0.2 oz/ac plus Method at 5 oz/ac. The experiment also included an untreated check. All herbicide treatments included Induce, non-ionic surfactant at 0.25 percent v/v.

For seedhead suppression, treatments that included Plateau or Panoramic were not significantly different from Embark 2S. Escort XP consistently provided less seedhead suppression than Embark 2S. The height of tall fescue and Kentucky bluegrass was statistically similar for Embark 2S, Plateau or Panoramic, and Escort XP through ten weeks after treatment (WAT) with few exceptions. Although not significantly different, Embark 2S frequently provided the greatest height reduction in tall fescue. Turf height ratings were not consistent across the three sites and two species often showing little difference when compared to the untreated plots. Turf blade growth rebounded to equal that of untreated control across nearly all treatments by 10 WAT. In some instances, turf phytotoxicity was greater for Embark 2S compared to Plateau, Panoramic, or Escort XP. Treatments containing Segment caused unacceptable damage and significant discoloration of the turf, but by 10 WAT turf cover was restored. Anuew offered safety, but did not prevent seedhead development. All mixes provided similar and effective control of birdsfoot trefoil (*Lotus corniculatus* L.) and chicory (*Cichorium intybus* L.). Plateau or Panoramic, at the rates tested in these experiments, combined with either Method or Milestone VM appear to provide acceptable turf growth suppression of cool-season roadside turf and broadleaf weed control. Further investigation is needed to ensure the safety of

these products on a range of turf species and environmental conditions before adopting these treatments.

INTRODUCTION

Turf growth regulators, TGRs, combined with broadleaf herbicides is one strategy used by the Pennsylvania Department of Transportation, PennDOT, to reduce mowing cycles by suppressing the development of turfgrass and control broadleaf weeds. This treatment is meant to reduce the number of mowing cycles conducted in the spring when the cool-season grasses are undergoing rapid growth. TGR applications are often made where mechanical mowing operations are difficult due to traffic hazards or obstacles. These applications are generally a cost saving measure that eliminates added mowing cycles and offer an alternative to complete reliance on mechanical operations.

The standard TGR 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 TGR, Plateau, Panoramic, Escort XP, Anuew, and Segment were compared against the standard. Plateau and the generic equivalent Panoramic are labeled for the growth regulation of cool-season roadside grasses (e.g., K-31 tall fescue and “wildtype” Kentucky bluegrass) at rates of 2 to 4 oz/ac.[13,14] Precautions on the label limit the use of surfactants and offer a very short list of turf species tolerant to the products. 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.[15] Anuew is a recent introduction to the marketplace, while Segment is older chemistry labeled for turf growth suppression on commercial lawns or roadsides.[16,17] This experiment compares these alternative TGR products in combination with either Method or Milestone at three separate locations within central Pennsylvania.

GENERAL SUMMARY OF MATERIALS AND METHODS

The experiment was repeated at three separate locations within central Pennsylvania. The first site was located along the I-99N on ramp from Innovation Park, just east of State College, PA (Experiment 1). The second site was located within the median of I-99 just north of the SR26 overpass, near Pleasant Gap, PA (Experiment 2). The third site was located on the shoulder of SR 322E approximately two miles north of Port Matilda, PA (Experiment 3). Plots were six by fifteen or six by twenty-five feet in size and were arranged as a randomized complete block design with four replications. Treatments included Plateau or Panoramic at 2 oz/ac; Embark at 6 oz/ac combined with Escort XP at 0.20 oz/ac; Segment at 24 oz/ac; Anuew at 21.8 oz/ac; Escort XP at 0.33 oz/ac. These treatments were combined with either Method or Milestone VM at 5 oz/ac. Additionally, Plateau at 2 oz/ac plus Escort XP at 0.2 oz/ac plus Method at 5 oz/ac was tested. The experiment also included an untreated check. Induce, a non-ionic surfactant (NIS) at 0.25% v/v, was added to all treatments. Treatments were applied

[13] Plateau, BASF Corporation, Research Triangle Park, NC.
[14] Panoramic, Alligare, LLC, Opelika, AL.
[15] Escort XP, Bayer Environmental Science, Research Triangle Park, NC.
[16] Anuew, Cleary Chemicals, LLC, Alsip, IL.
[17] Segment, BASF Corporation, Research Triangle Park, NC.

between May 6 and 11, 2015 at 35 gal/ac using a CO_2-powered backpack sprayer equipped with a six-foot boom and four 8003VS nozzles.

Trials were evaluated at two-week intervals for percent seedhead reduction of tall fescue and Kentucky bluegrass, average height of tall fescue and Kentucky bluegrass, percent total turf cover, phytotoxicity of the turf, and percent injury and control of birdsfoot trefoil or chicory. Past research and use of turf 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 affects on turf are presented here. Tables representing results relative to tall fescue blade height reduction, Kentucky bluegrass, total cover of turf stands after treatment, and weed control of 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.

EVALUATIONS PLUS RESULTS AND DISCUSSION OF EACH EXPERIMENTAL SITE

INNOVATION PARK, EXPERIMENT 1

EVALUATIONS

Treatments were applied May 6, 2015. The trial was visually rated for percent seedhead reduction of tall fescue on June 4, June 16, and July 6, 2015 (29, 41, and 61 days after treatment, DAT). The percent seedhead reduction of Kentucky bluegrass was visually assessed and recorded on May 20, June 4, June 16, and July 6, 2015 (14, 29, 41, and 61 DAT). Percent seedhead reduction reflects the decrease of tall fescue and Kentucky bluegrass seedheads compared to the untreated check with consideration for the amount of each species present within the plot. The average height of tall fescue and Kentucky bluegrass was measured on May 20, June 4, June 16, July 6, and July 16, 2015 (14, 29, 41, 61, and 71 DAT). Percent total turf cover was visually estimated at the onset and conclusion of the experiment on May 6 and July 16, 2015 (0 and 71 DAT). The percent change in turf cover was mathematically derived using the formula [(% ending turf cover-% initial turf cover)/% initial turf cover x 100]. Phytotoxicity of the turfgrass was visually rated on May 20, June 4, June 16, July 6, and July 16, 2015 (14, 29, 41, 61, and 71 DAT). Turf phytotoxicity was rated on a scale of 0 to 10 where "0" = healthy, green; "5" = moderate discoloration; and "10" = completely necrotic, dead. Percent injury or control of birdsfoot trefoil was evaluated on May 20, June 4, June 16, and July 6, 2015 (14, 29, 41, and 61 DAT).

RESULTS AND DISCUSSION

All treatments, except Anuew and Escort XP, provided acceptable seedhead reduction of tall fescue and ranged from 88 to 100 percent (Table 1). Tall fescue seedhead reduction in plots treated with Anuew ranged from 31 to 48 percent. Although the performance of Escort XP was statistically similar to the best treatments it was consistently less effective at seedhead reduction of tall fescue, ranging from 70 to 81 percent. None of the treatments provided acceptable reduction of Kentucky bluegrass seedheads during the experiment (Table 2, appendix). Final values of Kentucky bluegrass seedhead reduction at 61 days after treatment, DAT, ranged from 19 to 75 percent, which was deemed unacceptable control.

Panoramic and Embark plus Escort XP were the only treatments to maintain tall fescue turf significantly shorter than the untreated plots at 29 DAT (Table 3, appendix). Height variability was observed among plots; however, the untreated plots continued to grow. At 41 DAT, all treatments except Plateau plus Method were significantly shorter and ranged from 6.0 to 8.0 inches. By 61 DAT most of the chemistry had lost its effectiveness on the turf and blade length across the treatments was not significantly different than untreated plots. All treatments were similar in height to the untreated check at 71 DAT and ranged from 10.6 to 15.0 inches.

Similar variability in height was found among Kentucky bluegrass plots (Table 4, appendix). All turf growth regulators provided suppression of Kentucky bluegrass height, but not consistently at 61 DAT. However, at 71 DAT only Anuew plus Method remained statistically shorter (10.2 inches) compared to the untreated check at 14.8 inches.

One concern with the use of TGRs 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. At the onset of the experiment, turf cover was similar and ranged from 42 to 58 percent for all treatments, including the untreated check (Table 5, appendix). By the final evaluation, 71 DAT, turf cover was similar and increased in percentage for all treatments ranging from 60 to 85 percent. Turf phytotoxicity was significant and unacceptable for treatments that included Segment with values up to 5.5 on a scale of 0 to 10 (Table 6). In one instance the standard Embark plus Escort XP treatment reached a value of 4.5. Otherwise, treatments were similar to untreated plots and did not cause unacceptable discoloration to the turf with values of 0 to 2.75.

All herbicide treatments provided equivalent and excellent control of birdsfoot trefoil from 71 to 96 percent (Table 7, appendix).

PLEASANT GAP, EXPERIMENT 2

EVALUATIONS

Treatments were applied on May 11, 2015. The trial was visually rated for percent seedhead reduction of tall fescue on May 26, June 9, June 24, and July 7, 2015 (15, 29, 44, and 57 days after treatment, DAT). The percent seedhead reduction of Kentucky bluegrass was visually assessed and recorded on June 9, June 24, and July 7, 2015 (29, 44, and 57 days after treatment, DAT). Percent seedhead reduction reflects the decrease of tall fescue and Kentucky bluegrass seedheads compared to the untreated check with consideration for the amount of each species present within the plot. The average height of tall fescue and Kentucky bluegrass was measured on May 26, June 9, June 24, July 7, and July 20, 2015 (15, 29, 44, 57, and 70 days after treatment, DAT). Percent total turf cover was visually estimated at the onset and conclusion of the experiment on May 11 and July 20, 2015 (0 and 70 days after treatment, DAT). The percent change in turf cover was mathematically derived using the formula [(% ending turf cover-% initial turf cover)/% initial turf cover x 100]. Phytotoxicity of the turfgrass was visually rated on May 26, June 9, June 24, July 7, and July 20, 2015 (15, 29, 44, 57, and 70 days after treatment, DAT). Turf phytotoxicity was rated on a scale of 0 to 10 where “0” = healthy, green; “5” = moderate discoloration; and “10” = completely necrotic, dead.

RESULTS AND DISCUSSION

All treatments, except Anuew and Escort XP, provided acceptable seedhead reduction of tall fescue and ranged from 83 to 100 percent (Table 8). Anuew resulted in less tall fescue seedhead reduction ranging from 12 to 44 percent. Although Escort XP combined with Method or Milestone VM was statistically similar to the best performing treatments through 44 DAT it consistently resulted in less tall fescue seedhead reduction from 55 to 100 percent. None of the treatments provided acceptable reduction of Kentucky bluegrass seedheads during the experiment (Table 9, appendix). Final values of Kentucky bluegrass seedhead reduction at 57 days after treatment, DAT, ranged from 0 to 22 percent.

There was no significant difference among treatments relative to tall fescue height through the duration of the experiment. The only exception occurred at 29 DAT when three treatments were significantly different than the untreated plots (Table 10, appendix). No treatments significantly reduced Kentucky bluegrass height compared to the untreated plots at any rating date (Table 11, appendix).

An overall evaluation of the turf cover suggested that none of the treatments were detrimental to the turf density. At the start of the experiment turf cover was similar and ranged from 40 to 48 percent for all treatments, including the untreated check (Table 12, appendix). By the final evaluation, 70 DAT, turf cover was similar for all treatments ranging from 79 to 93 percent. Turf phytotoxicity was significant and unacceptable for treatments that included Segment with values up to 5.2 on a scale of 0 to 10 (Table 13). The standard Embark plus Escort XP and Plateau plus Escort XP treatments also displayed greater injury symptoms on turf compared to untreated plots during the experiment and reached a value of 3.0, otherwise treatments were similar to untreated plots and did not cause unacceptable discoloration to the turf with values of 0 to 2.8.

PORT MATILDA, EXPERIMENT 3

EVALUATIONS

Treatments were applied on May 7, 2015. The trial was visually rated for percent seedhead reduction of tall fescue and Kentucky bluegrass on May 22, June 5, June 22, and July 6, 2015 (15, 29, 46, and 60 days after treatment, DAT). Percent seedhead reduction reflects the decrease of tall fescue and Kentucky bluegrass seedheads compared to the untreated check with consideration for the amount of each species present within the plot. The average height of tall fescue was measured on May 22, June 5, June 22, July 6, and July 17, 2015 (15, 29, 46, 60, and 71 DAT). Phytotoxicity of the turfgrass was visually rated on May 22, June 5, June 22, July 6, and July 17, 2015 (15, 29, 46, 60, and 71 DAT). Turf phytotoxicity was rated on a scale of 0 to 10 where “0” = healthy, green; “5” = moderate discoloration; and “10” = completely necrotic, dead. Percent injury or control of birdsfoot trefoil was evaluated on May 22, June 5, June 22, and July 6, 2015 (15, 29, 46, and 60 DAT). Percent total turf cover, cover by birdsfoot trefoil, and cover by chicory were visually estimated at the onset and conclusion of the experiment on May 7 and July 17, 2015 (0 and 71 DAT). The percent change in each was mathematically derived using the formula [(% ending turf cover-% initial turf cover)/% initial turf cover x 100].

RESULTS AND DISCUSSION

All treatments, except Anuew and Escort XP, provided acceptable seedhead reduction of tall fescue and ranged from 98 to 100 percent (Table 14). Anuew resulted in less tall fescue seedhead reduction beginning at 29 DAT and ranged from 0 to 38 percent. Escort XP consistently offered less tall fescue seedhead reduction when mixed with Milestone VM from 56 to 86 percent. Several treatments provided acceptable ranges of reduction of Kentucky bluegrass seedheads for the duration of the experiment from 72 to 100 percent (Table 15, appendix). These treatments included Embark plus Escort XP, Segment, Panoramic plus Milestone, and Plateau plus Escort XP plus Method. Other treatments that included Plateau or Panoramic provided sporadic seedhead reduction of Kentucky bluegrass from 52 to 91 percent. Anuew and Escort treatments did not significantly reduce seedhead numbers of Kentucky bluegrass compared to the untreated plots beyond 15 DAT from 19 to 58 percent, except Escort XP plus Milestone VM at 60 DAT (85 percent).

All treatments were similar and reduced heights of tall fescue compared to the untreated plots through 46 DAT from 8.9 to 10.7 inches (Table 16, appendix). Though this trend continued through 60 DAT, Segment resulted in the shortest blade length among the treatments (11.8 to 12.8 inches). Turf height rebounded in nearly all treatments and was comparable in height to the untreated plots by 71 DAT. Only Embark plus Escort XP and Segment plus Milestone VM were significantly shorter than untreated plots (17.8 to 18.8 versus 23.4 inches).

An overall evaluation of the turf cover suggested that none of the treatments were detrimental to the turf density. At the beginning of the experiment turf cover was similar and ranged from 39 to 46 percent for all treatments, including the untreated check (Table 17, appendix). By the final evaluation, 71 DAT, turf cover was similar ranging from 69 to 84 percent for all treatments, except Segment plus Method (52 percent). Overall turf cover increased for all treatments during the experiment (34 to 100 percent). Turf phytotoxicity was significant and unacceptable for treatments that included Segment with values up to 8.2 on a scale of 0 to 10 (Table 18). Embark plus Escort XP treatments were also harsh on the turf reaching values of 5.8. While Plateau, Panoramic, Escort, or Anuew treatments did not cause objectionable discoloration of the turf (0 to 3.2), Plateau plus Escort XP plus Method resulted in higher values through 60 DAT (1.5 to 4.0).

All herbicide treatments provided equivalent and excellent control of birdsfoot trefoil from 92 to 100 percent (Table 19, appendix) and complete control of chicory (data not shown).

GENERAL CONCLUSIONS

Plateau or Panoramic combined with either Method or Milestone VM 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 plus Method was also effective, but the addition of Escort XP could increase the potential for turf injury with no added benefit. Anuew and Segment did not provide the results needed to serve as a replacement in roadside turf applications. Anuew did not suppress tall fescue seedheads while Segment was injurious and caused unacceptable discoloration of the turf.

OVERALL MANAGEMENT IMPLICATIONS

Plateau or Panoramic combined with either Method or Milestone VM offer alternative tank mixes to PennDOT's plant growth regulation (7711-03) program and the standard Embark plus Escort XP plus broadleaf herbicide treatment. Plateau and Panoramic are 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 either Method or Milestone VM as these products are soil active and have the potential to injure some desirable tree species.

Table 1: Percent seedhead suppression of the tall fescue stand at Innovation Park. The experiment was visually rated for seedhead reduction of tall fescue on June 4, June 16, and July 6, 2015 (29, 41, and 61 days after treatment, DAT). 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 ≤ 0.05.

product	Rate	tall fescue percent seedhead reduction 6/4/15	6/16/15	7/6/15
	(oz/ac)			
Untreated	----	25 a	0 a	0 a
Plateau Method	2 5	100 b	100 b	100 d
Panoramic Method	2 5	100 b	100 b	98 d
Embark Escort XP Method	6 0.2 5	94 ab	97 b	88 cd
Segment Method	24 5	100 b	100 b	100 d
Anuew Method	21.8 5	48 ab	41 ab	38 abc
Escort XP Method	0.33 5	70 ab	72 b	81 bcd
Plateau Milestone VM	2 5	100 b	97 b	100 d
Panoramic Milestone VM	2 5	88 ab	85 b	98 d
Embark Escort XP Milestone VM	6 0.2 5	100 b	100 b	100 d
Segment Milestone VM	24 5	100 b	100 b	100 d
Anuew Milestone VM	21.8 5	38 ab	37 ab	31 ab
Escort XP Milestone VM	0.33 5	72 ab	74 b	81 bcd
Plateau Escort XP Method	2 0.2 5	100 b	100 b	100 d
Sign. Level ($p \leq 0.05$)		0.002	0.000	0.000

Table 6: Phytotoxicity of the turfgrass stand at Innovation Park. The experiment was visually rated for turf phytotoxicity using a scale of 0-10 where “0” = healthy, green; “5” = moderate discoloration; “10”= completely necrotic, dead. Evaluations were made on May 20, June 4, June 16, July 6, and July 16, 2015 (14, 29, 41, 61, and 71 days after treatment, DAT). 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	turfgrass phytotoxicity (0-10 scale)				
		5/20/15	6/4/15	6/16/15	7/6/15	7/16/15
	(oz/ac)					
Untreated	----	0 a	0 a	0 a	0 a	0 a
Plateau Method	2 5	1.0 bc	2.5 abc	1.8 abc	2.0 a	1.5 a
Panoramic Method	2 5	1.0 bc	1.0 a	1.2 ab	1.8 a	0.8 a
Embark Escort XP Method	6 0.2 5	1.0 bc	2.2 abc	2.0 abc	1.8 a	0.8 a
Segment Method	24 5	1.0 bc	5.5 d	4.5 c	5.0 b	3.8 b
Anuew Method	21.8 5	1.0 bc	2.0 abc	1.2 ab	2.8 ab	2.0 ab
Escort XP Method	0.33 5	1.0 bc	1.0 a	1.0 ab	1.5 a	0.8 a
Plateau Milestone VM	2 5	0.5 ab	1.2 ab	1.0 ab	0.5 a	0.2 a
Panoramic Milestone VM	2 5	1.0 bc	2.2 abc	0.8 ab	0.2 a	0 a
Embark Escort XP Milestone VM	6 0.2 5	1.5 c	4.5 cd	2.0 abc	1.0 a	0.5 a
Segment Milestone VM	24 5	1.0 bc	4.0 bcd	3.5 bc	0.8 a	0 a
Anuew Milestone VM	21.8 5	1.0 bc	0 a	0.5 a	0.8 a	0.2 a
Escort XP Milestone VM	0.33 5	1.0 bc	0.5 a	0.5 a	0.5 a	0.2 a
Plateau Escort XP Method	2 0.2 5	1.0 bc	2.0 abc	2.2 abc	2.2 ab	1.2 a
Sign. Level ($p \leq 0.05$)		0.000	0.000	0.000	0.000	0.000

Table 8: Percent seedhead reduction of the tall fescue stand at Pleasant Gap. The experiment was visually rated for seedhead reduction of tall fescue on May 26, June 9, June 24, and July 7, 2015 (15, 29, 44, and 57 days after treatment, DAT). Treatments were applied on May 11, 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	tall fescue percent seedhead reduction			
		5/26/15	6/9/15	6/24/15	7/7/15
	(oz/ac)				
Untreated	----	0 a	0 a	0 a	0 a
Plateau Method	2 5	100 b	92 d	98 c	98 de
Panoramic Method	2 5	100 b	100 d	100 c	99 de
Embark Escort XP Method	6 0.2 5	100 b	98 d	96 c	96 de
Segment Method	24 5	100 b	99 d	99 c	99 de
Anuew Method	21.8 5	0 a	44 bc	44 b	12 a
Escort XP Method	0.33 5	75 b	62 bcd	61 bc	55 bc
Plateau Milestone VM	2 5	100 b	100 d	100 c	100 e
Panoramic Milestone VM	2 5	100 b	99 d	99 c	100 e
Embark Escort XP Milestone VM	6 0.2 5	100 b	99 d	96 c	83 cde
Segment Milestone VM	24 5	100 b	100 d	100 c	100 e
Anuew Milestone VM	21.8 5	25 a	25 ab	25 ab	19 ab
Escort XP Milestone VM	0.33 5	100 b	79 cd	61 bc	60 cd
Plateau Escort XP Method	2 0.2 5	100 b	100 d	100 c	94 cde
Sign. Level ($p \leq 0.05$)		0.000	0.000	0.000	0.000

Table 13: Phytotoxicity of the turfgrass stand at Pleasant Gap. The experiment was visually rated for turf phytotoxicity using a scale of 0-10 where "0" = healthy, green; "5" = moderate discoloration; "10"= completely necrotic, dead. Evaluations were made on May 26, June 9, June 24, July 7, and July 20, 2015 (15, 29, 44, 57, and 70 days after treatment, DAT). Treatments were applied on May 11, 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 $p \leq 0.05$. A '---' for significance level indicates that a mean separation could not be calculated.

product	rate	turfgrass phytotoxicity (0-10 scale)				
		5/26/15	6/9/15	6/24/15	7/7/15	7/20/15
	(oz/ac)					
Untreated	----	0	0 a	0 a	0 a	0 a
Plateau Method	2 5	0.8	2.0 ab	1.5 ab	1.2 a-d	2.0 ab
Panoramic Method	2 5	1.2	2.5 ab	1.8 ab	1.8 a-d	1.8 ab
Embark Escort XP Method	6 0.2 5	2.5	2.8 ab	1.8 ab	2.2 bcd	1.8 ab
Segment Method	24 5	1.0	4.8 b	4.0 b	3.2 d	3.0 b
Anuew Method	21.8 5	0.8	1.8 ab	0.8 a	1.2 a-d	1.5 ab
Escort XP Method	0.33 5	2.8	2.5 ab	0.8 a	0.8 abc	0.8 ab
Plateau Milestone VM	2 5	0.8	1.8 ab	0.8 a	0.5 abc	1.0 ab
Panoramic Milestone VM	2 5	1.0	2.2 ab	1.5 ab	1.0 abc	1.2 ab
Embark Escort XP Milestone VM	6 0.2 5	0.8	3.0 ab	1.8 ab	0.8 abc	1.2 ab
Segment Milestone VM	24 5	2.5	5.2 b	2.8 ab	0.5 abc	0.5 a
Anuew Milestone VM	21.8 5	2.0	2.0 ab	0.5 a	0.2 ab	0.2 a
Escort XP Milestone VM	0.33 5	2.5	2.0 ab	0.5 a	0.2 ab	0.8 ab
Plateau Escort XP Method	2 0.2 5	1.0	3.0 ab	2.8 ab	2.5 cd	3.0 b
Sign. Level ($p \leq 0.05$)		---	0.004	0.002	0.000	0.001

Table 14: Percent seedhead suppression of the tall fescue stand at Port Matilda. The experiment was visually rated for seedhead reduction of tall fescue on May 22, June 5, June 22, and July 6, 2015 (15, 29, 46, and 60 days after treatment, DAT). Treatments were applied on May 7, 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 ≤ 0.05.

product	rate	tall fescue percent seedhead reduction			
		5/22/15	6/5/15	6/22/15	7/6/15
	(oz/ac)				
Untreated	----	0 a	0 a	0 a	0 a
Plateau Method	2 5	100 b	100 c	100 d	100 c
Panoramic Method	2 5	100 b	100 c	100 d	100 c
Embark Escort XP Method	6 0.2 5	100 b	100 c	99 d	100 c
Segment Method	24 5	100 b	100 c	100 d	100 c
Anuew Method	21.8 5	100 b	38 b	38 b	12 a
Escort XP Method	0.33 5	100 b	96 c	95 d	91 c
Plateau Milestone VM	2 5	100 b	100 c	100 d	100 c
Panoramic Milestone VM	2 5	100 b	100 c	100 d	99 c
Embark Escort XP Milestone VM	6 0.2 5	100 b	98 c	100 d	100 c
Segment Milestone VM	24 5	100 b	100 c	100 d	98 c
Anuew Milestone VM	21.8 5	100 b	25 b	25 b	0 a
Escort XP Milestone VM	0.33 5	100 b	86 c	78 c	56 b
Plateau Escort XP Method	2 0.2 5	100 b	100 c	100 d	100 c
Sign. Level (p≤0.05)		0.000	0.000	0.000	0.000

Table 18: 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, dead. Evaluations were made on May 22, June 5, June 22, July 6, and July 17, 2015 (15, 29, 46, 60, and 71 days after treatment, DAT). Treatments were applied on May 7, 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	turfgrass phytotoxicity (0-10 scale)				
		5/22/15	6/5/15	6/22/15	7/6/15	7/17/15
	(oz/ac)					
Untreated	----	0 a	0 a	0 a	0 a	0 a
Plateau Method	2 5	1.0 abc	3.2 cd	1.8 b	0.8 abc	0 a
Panoramic Method	2 5	1.0 abc	2.2 bcd	2.0 b	0.8 abc	0.5 a
Embark Escort XP Method	6 0.2 5	4.5 e	5.5 e	5.8 d	4.0 d	3.0 b
Segment Method	24 5	3.5 de	8.2 f	7.8 e	2.2 bcd	2.5 b
Anuew Method	21.8 5	1.0 abc	1.0 ab	0.8 ab	1.2 abc	0.5 a
Escort XP Method	0.33 5	2.0 a-d	2.8 bcd	1.8 b	0.5 ab	0.5 a
Plateau Milestone VM	2 5	1.0 abc	2.8 bcd	1.2 ab	0 a	0.2 a
Panoramic Milestone VM	2 5	1.5 a-d	3.0 bcd	2.0 b	0.2 a	0.5 a
Embark Escort XP Milestone VM	6 0.2 5	3.0 cde	5.8 e	4.5 cd	2.5 cd	1.5 ab
Segment Milestone VM	24 5	3.0 cde	8.0 f	5.0 cd	1.8 abc	1.5 ab
Anuew Milestone VM	21.8 5	0.5 ab	1.2 abc	0.8 ab	1.2 abc	0 a
Escort XP Milestone VM	0.33 5	1.0 abc	1.8 abc	1.0 ab	0 a	0 a
Plateau Escort XP Method	2 0.2 5	2.5 b-e	4.0 de	3.8 c	1.5 abc	0.2 a
Sign. Level ($p \leq 0.05$)		0.000	0.000	0.000	0.000	0.000

DEMONSTRATING THE UTILITY OF TURF GROWTH REGULATORS UNDER CABLE GUIDERAIL STRUCTURES

Herbicide trade and common names: Embark (*mefluidide*); Escort XP (*metsulfuron*); Method 50SG (*aminocyclopyrachlor*); Plateau (*imazapic*).
Plant common and scientific names: fine fescue (*Festuca* spp.); Kentucky bluegrass (*Poa pratensis*); orchardgrass (*Dactylis glomerata*); tall fescue (*Festuca arundinacea*).

ABSTRACT

The installation of cable guiderails throughout the Commonwealth of Pennsylvania has created some interesting maintenance challenges. These barriers are being placed within existing turf areas of the median. This turf is needed to prevent erosion, provide competition to unwanted vegetation, and offer an aesthetically appealing landscape. There are no ideal tools on the market for cutting turf beneath these obstacles. Mowing with string trimmers is both time-consuming and potentially dangerous. Turf growth regulators are an option to impede the growth of the existing turf and reduce the number of seedheads. Embark has historically been the standard turf growth regulator used by PennDOT; however, it was recently announced that this product will no longer be manufactured. Plateau, a product that is currently used by PennDOT for other applications is also labeled as a turf growth regulator and has provided promising results in other experiments. This demonstration looked at the potential for using Plateau as an alternative to Embark. Results suggest that both products offer similar growth and seedhead suppression of tall fescue.

INTRODUCTION

Cable guiderails are being installed to prevent vehicles from crossing medians and colliding with oncoming traffic. The installation of these barriers generally occurs in areas designed for and previously established to turf. This creates a difficult maintenance scenario. Standard mowing equipment is not designed to cut around and under these obstacles. A second option, elimination of the existing groundcover, results in erosion. Placing stone or asphalt beneath these structures causes safety concerns, added expense, and a new array of maintenance problems. While string trimming is an option, it too comes at an expense and poses safety risks for workers. Maintaining low growing grasses beneath these structures is one possible solution. Since most cable guiderails are built in existing medians, the grass stand is already established. Turf growth regulators provide an opportunity to maintain a shorter turf stand by offering short-term growth inhibition of the grass blades and eliminating seedheads for the entire season. Typically, a broadleaf herbicide is added to the tank mix to control unwanted weeds. This demonstration investigates the utility of using a tank mixture of a turf growth regulator and broadleaf herbicide to provide height reduction of the grass stand under these structures with a single spring application. Currently Embark 2S at 6 oz/ac combined with Escort XP at 0.2 oz/ac and Method 50SG at 5 oz/ac is a standard for many of these applications within PennDOT. However, the production of Embark has ceased and the product is no longer available. Plateau at 2 oz/ac combined with Method 50SG at 5 oz/ac was tested as an alternative in this demonstration.

MATERIALS AND METHODS

Two demonstration sites were established within the I-99 median and beneath cable guiderails near the Shiloh Road and Port Matilda exits. Treatments included Plateau at 2 oz/ac tank mixed with Method 50SG at 5 oz/ac; Embark 2S at 6 oz/ac tank mixed with Escort XP at 0.2 oz/ac and Method 50SG at 5 oz/ac; and an untreated check. A non-ionic surfactant (Induce) was added to all treatments at 0.25% v/v. All products were applied at a carrier volume of 35 gallons per acre, GPA. The demonstrations were established with two replications per site. Treated plots were 550 to 575 feet long by 4 feet wide. Turf height averaged 6 inches at Shiloh Road and 8 inches at Port Matilda when treatments were applied on May 1 and 13, 2015, respectively. Treatments were applied from both sides of the cable guiderail using a CO_2 powered backpack sprayer operating at 38 psi and equipped with a single OC-04 nozzle.

The Shiloh Road site was evaluated every 2 weeks, over a 10-week period. Average height and percent seedhead suppression of tall fescue, Kentucky bluegrass, and fine fescue, along with percent broadleaf weed control were evaluated May 18, May 29, June 16, June 25, and July 8, 2015, representing 2, 4, 6, 8, and 10 weeks after treatment, WAT.

The Port Matilda site was evaluated over an 11-week period. Average height and percent seedhead suppression of tall fescue, Kentucky bluegrass, and fine fescue, along with percent broadleaf weed control were evaluated May 27, June 10, July 8, and July 27, 2015, representing 2, 4, 8, and 11 weeks after treatment, WAT. 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

Both turf growth regulator mixes performed similarly at Shiloh Road. Tall fescue was the primary consideration for height reduction and seedhead suppression since it had the greatest potential for height among the species present. The standard Embark:Escort XP treatment maintained consistent blade height on tall fescue through 8 WAT at 8.67 inches, but by 10 WAT tall fescue resumed growth reaching an average height of 15.5 inches. The effects of the Plateau treatment seemed shorter-lived. At 6 WAT tall fescue height averaged 8.50 inches, but by 8 WAT tall fescue height averaged 11.17 inches and was similar to untreated areas at 12.67 inches. For both treatments, seedhead suppression of tall fescue was between 95 and 100 percent. No broadleaf weeds were found within treated areas.

The Port Matilda site resulted in similar heights of tall fescue for both treatments at every evaluation. Though not statistically different than the untreated areas for height they were clearly shorter until 8 WAT. At 11 WAT heights were consistent at 12.33, 12.67, and 12.67 for the Plateau, Embark:Escort XP, and untreated areas, respectively. For both treatments, seedhead suppression of tall fescue was between 95 and 100 percent. Broadleaf weed control was complete (i.e., 100 percent) for the herbicide treatments.

CONCLUSIONS

Both treatments performed equally well. Each provided over 6 weeks of growth suppression of the tall fescue before normal growth resumed. The treatments nearly eliminated seedhead development of this species. Additionally, the treatments were effective at removing unwanted broadleaf weeds that could potentially grow tall and become problematic.

MANAGEMENT IMPLICATIONS

Plateau will provide equivalent growth and seedhead suppression of the cool-season turf compared to Embark plus Escort XP. This product is a viable and cost-effective substitute for Embark plus Escort XP in the turf growth regulator program. A broadleaf herbicide is needed in the mix to eliminate unwanted growth of dicots. One concern that will require additional research is whether the prolonged use of turf growth regulators will cause thinning of the turf stand.

INVESTIGATING GRASS SPECIES, SEEDING RATES, AND FERTILIZER PLUS BROADLEAF HERBICIDE APPLICATION FOR GROUNDCOVER ESTABLISHMENT IN ROADSIDE APPLICATIONS - SECOND 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. A successful 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.

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 but could be further investigated as an annual component in seed mixes for roadside application. 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.[18] 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 6 lb/1000 sq ft., ‘Maintain’ orchardgrass at 12 lb/ac, 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 and soil supplements as well as 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.

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, and September 23, 2015, 11, 20, and 23 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 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.

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

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, and October 5, 2015 (11, 20, and 24 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

Formula L applied at either the 24 or 48 lb rate provided similar cover (Table 1). At 8 MAS cover was 60 and 69 percent for the 24 and 48 lb rates, respectively. The addition of herbicide and supplemental fertilizer during the 2014 growing season significantly increased cover at 11 MAS (96 versus 62 or 69 percent). Cover by these desirable grasses steadily increased over time with values from 70 to 87 percent by 23 MAS. The effects of the broadleaf herbicide plus supplement fertilizer continued to provide some benefit. By 23 MAS, cover by grasses was 70 to 73 percent where no supplemental fertilizer or broadleaf herbicide was applied, while adding this treatment resulted in 85 to 87 percent cover.

Plots seeded to sheep fescue provided cover similar to Formula L and also reacted favorably to fertilizer and broadleaf treatments. Plots treated with fertilizer and broadleaf herbicide maintained a significantly higher cover rating through 23 months (97 compared to 62 percent). Orchardgrass reacted favorably to the treatments as well. At 23 months, orchardgrass plots that had been treated had 86 percent cover by desirable grasses compared to only 14 percent in untreated plots. Foxtail fescue never developed more than a 25 percent cover by desirable grasses, but did benefit from the supplemental treatments.

Percent cover by weeds was sharply lower in all plots that had been treated with broadleaf herbicide during the summer of 2014 (Table 2). By September 2015 plots of Formula L or sheep fescue treated with broadleaf herbicide had only 1 or 2 percent weed cover, whereas untreated plots ranged from 26 to 38 percent. Weed cover in orchardgrass was 82 and 3 percent for untreated and treated plots, respectively. Weed cover in foxtail fescue was rated at 93 percent in untreated plots and 58 percent in treated plots.

Site 2

Both seeding rates of Formula L resulted in similar cover. Percent cover by desirable grasses was higher and statistically different in treated plots compared to untreated plots for both rates of Formula L at the September 2014 rating (Table 3). Cover by grasses was either 72 or 84 percent for untreated plots compared to 96 or 97 percent for treated plots at the 24 and 48 lbs. seeding rates, respectively. By October 2015, regardless of treatment or seeding rate, plots had nearly complete cover of desirable turf from 97 to 99 percent.

Cover by weeds in plots treated with fertilizer and broadleaf herbicide was lower and significantly different from untreated plots for both seeding rates of Formula L in September 2014, 11 MAS. Plots seeded at the 24 lbs. rate with no supplemental treatment in 2014 had 22 percent cover by weeds, while treated plots had only 1 percent weed cover (Table 4). Plots seeded at the 48 lbs. rate with no supplemental treatment in 2014 had 8 percent cover by weeds, while treated plots had only 1 percent weed cover. By October 2015 (24 MAS), treated plots had no weed cover while untreated plots had only 2 and 1 percent cover for the 24 and 48 lbs. rates, respectively.

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 and in several instances effects were still evident by fall of 2015. The variety of orchardgrass and seeding rate tested in this experiment did not provide the cover observed with the fine fescues (Formula L or sheep fescue), except after using a supplemental fertilizer and broadleaf application and waiting two years for establishment. Orchardgrass has a few drawbacks for use in roadside applications: 1) it is a bunch-type grass that would require another component within a seed mix to establish in the voids created by this growth habit; 2) it grows taller in comparison to the fine fescues, requiring additional mowing; 3) as a forage grass it may attract wildlife to the roadside; and 4) plant growth regulators have been observed to be less effective on this species. Foxtail fescue is an annual grass that has not demonstrated utility as a stand-alone species for seeding on the roadside. It did show some encouraging signs of development where supplemental fertilizer and a broadleaf herbicide application were applied during the establishment phase. Perhaps, foxtail fescue would have utility as an annual component in a seed mix for roadside application, but advantages over annual ryegrass would first have to be demonstrated in future experiments. Supplemental fertilizer and broadleaf herbicide applications are effective in encouraging a developing grass stand.

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 provides a greater assurance of cover where soil and site conditions are unfavorable to seed germination and establishment. Sheep fescue appears to have the ability to establish on difficult sites; 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. This will encourage the developing grasses and offer them a competitive advantage in most situations.

Table 1: Percent cover by desirable grasses (Site 1). The trial was visually rated for percent cover by desirable (seeded) grasses on June 20 and September 15, 2014 and September 23, 2015 (8, 11, and 23 months after seeding, MAS, respectively). The experiment was seeded, fertilized, and straw mulched on October 4, 2013. Fertilizer and broadleaf herbicide were applied to half of each plot on July 7 and August 8, 2014, respectively. 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.

		Percent Cover by Desirable Species				
seed mix	rate	June 2014	Sept 2014		Sept 2015	
			no fert/bl	fert/bl	no fert/bl	fert/bl
Formula L	24 lb/1000 SY	60 b	62 c	96 d	70 bc	87 bc
Formula L	48 lb/1000 SY	69 b	69 c	96 d	73 bc	85 bc
Sheep Fescue	16 lb/1000 SF	60 b	60 bc	90 d	62 b	97 c
Orchardgrass	12 lb/ac	15 a	44 b	72 c	14 a	86 bc
Foxtail Fescue	12 lb/ac	24 a	2 a	45 b	0.5 a	25 a

Table 2: Percent cover by weeds (Site 1). The trial was visually rated for percent cover by weeds on September 15, 2014 and September 23, 2015 (11 and 23 months after seeding, MAS). The experiment was seeded, fertilized, and straw mulched on October 4, 2013. Fertilizer and broadleaf herbicide were applied to half of each plot on July 7 and August 8, 2014, respectively. 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.

		Percent Cover by Weeds			
seed mix	rate	Sept 2014		Sept 2015	
		no fert/bl	fert/bl	no fert/bl	fert/bl
Formula L	24 lb/1000 SY	21 ab	1 a	29 ab	2 a
Formula L	48 lb/1000 SY	20 ab	1 a	26 ab	1 a
Sheep Fescue	16 lb/1000 SF	22 ab	2 a	38 b	1 a
Orchardgrass	12 lb/ac	37 bc	1 a	82 cd	3 a
Foxtail Fescue	12 lb/ac	66 c	14 ab	93 d	58 bc

Table 3: Percent cover by desirable grasses (Site 2). The trial was visually rated for percent cover by desirable (seeded) grasses on June 19 and September 16, 2014 and October 5, 2015 (8, 11, and 24 months after seeding, MAS, respectively). The experiment was seeded, fertilized, and straw mulched on October 10, 2013. Fertilizer and broadleaf herbicide were applied to half of each plot on July 7 and August 8, 2014, respectively. Each value is the mean of four replications. Means within similarly shaded areas followed by the same letter are not significantly different at $p \leq 0.05$.

seed mix	rate	Percent Cover by Desirable Species				
		June 2014	Sept 2014		October 2015	
			no fert/bl	fert/bl	no fert/bl	fert/bl
Formula L	24 lb/1000 SY	49 a	72 a	96 c	97	99
Formula L	48 lb/1000 SY	57 a	84 b	97 c	98	99
					n.s.	n.s.

Table 4: Percent cover by weeds (Site 2). The trial was visually rated for percent cover by weeds on September 16, 2014 and October 5, 2015 (11 and 24 months after seeding, MAS). The experiment was seeded, fertilized, and straw mulched on October 10, 2013. Fertilizer and broadleaf herbicide was applied to half of each plot on July 7 and August 8, 2014, respectively. Each value is the mean of four replications. Means within similarly shaded areas followed by the same letter are not significantly different at $p \leq 0.05$.

seed mix	rate	Percent Cover by Weeds			
		Sept 2014		October 2015	
		no fert/bl	fert/bl	no fert/bl	fert/bl
Formula L	24 lb/1000 SY	22 c	1 a	2 b	0 a
Formula L	48 lb/1000 SY	8 b	1 a	1 ab	0 a

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

<u>Herbicide trade and common names</u>: Accord XRT II *(4 lb per gallon glyphosate acid*).

<u>Plant common and scientific names</u>: 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 first growing season no significant difference in grass cover was found among the treatments; however, Formula L at the 48 lb rate produced the highest cover of desirable grasses, followed by Formula L at the 24 lb rate and sheep fescue. Although sheep fescue produced the lowest cover rating, these plots also resulted in the lowest weed cover.

INTRODUCTION

Grasses are often chosen for use as groundcovers on the roadside right-of-way because they can be competitive and provide a manageable plant community. Once established, grass groundcovers are typically maintained with mowing and occasionally a broadleaf herbicide treatment. Selecting grass species that will survive and remain vigorous in harsh environments is imperative. Low organic matter and compacted soils are two 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. 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 and 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.

Percent cover by desirable grasses and percent cover by weeds (visual evaluation) were recorded on July 28 and October 5, 2015, 73 and 139 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 both 73 and 139 DAS, the 48 lb rate of Formula L produced the most cover by desirable grasses (49 and 54%, respectively) followed by Formula L at 24 lb (30 and 38%, respectively) and sheep fescue at 54 lb (18 and 31%, respectively) (Table 1). While sheep fescue plots produced the lowest percent cover by desirable grasses at 139 DAS, these plots also showed the lowest cover by weeds (14%) (Table 2).

CONCLUSIONS

Observations at the end of the first growing season indicate that both rates of Formula L and the sheep fescue were comparable in establishment from a spring seeding. Fine fescues have the ability to suppress weeds and this was apparent in sheep fescue plots.[19] In addition to having the lowest cover by weeds at the end of the growing season, our field notes suggest that sheep fescue plots contained smaller weeds even though there was adequate space to develop. 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 these sites, 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. 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.

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.

[19] 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.

Table 1: Percent cover by desirable grasses. The experiment was visually rated for percent cover by desirable (seeded) grasses on July 28 and October 5, 2015 (73 and 139 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. Within columns, means followed by the same letter are not significantly different at $p \leq 0.05$.

seed mix	rate	Percent Cover by Desirable Grasses	
		July 28, 2015 73 DAS	October 5, 2015 139 DAS
Formula L	24 lb/1000 SY	30 a	38 a
Formula L	48 lb/1000 SY	49 a	54 a
Sheep Fescue	54 lb/1000 SY	18 a	31 a

Table 2: Percent cover by weeds. The experiment was visually rated for percent cover by weeds on July 28 and October 5, 2015 (73 and 139 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. Within columns, means followed by the same letter are not significantly different at $p \leq 0.05$.

seed mix	rate	Percent Cover by Weeds	
		July 28, 2015 73 DAS	October 5, 2015 139 DAS
Formula L	24 lb/1000 SY	13 a	19 a
Formula L	48 lb/1000 SY	17 a	23 a
Sheep Fescue	54 lb/1000 SY	13 a	14 a

TESTING ALTERNATIVE MODES OF ACTION IN COMBINATION WITH ESPLANADE OR PLATEAU FOR SEASON LONG BAREGROUND WEED CONTROL

Herbicide trade and common names: Accord XRT II (*glyphosate*), Arsenal Powerline (*imazapyr*), Derigo (*foramsulfuron + iodosulfuron + thiencarbazone*); Esplanade (*indaziflam*); Hyvar X (*bromacil*); Method 50SG (*aminocyclopyrachlor*); Milestone (*aminopyralid*); Plateau (*imazapic*); Sulfentrazone (*sulfentrazone, 75% dry*); Telar XP (*chlorsulfuron*); Velpar DF (*hexazinone*).

Plant common and scientific names: barnyardgrass (*Echinochloa crus-galli*); common purslane (*Portulaca oleracea*); fall panicum (*Panicum dichotomiflorum*); foxtail (*Setaria* spp.); kochia (*Kochia scoparia*); marestail (*Conyza canadensis*); speedwell (*Veronica* spp.); bearded sprangletop (*Leptochloa fusca* subsp. *fascicularis*).

ABSTRACT

Bareground weed control efforts are routinely undertaken by PennDOT to eliminate vegetation under guiderails, surrounding signposts, and around other mowing obstacles. The development of resistant weed populations is a continual threat where herbicides are used as the primary weed control method to maintain these bareground areas. The repeated elimination of vegetation on these sites makes them predisposed to the development of weeds with an annual life cycle and greater tendency toward herbicide resistance. Bareground tank mixes are used by PennDOT to manage these areas but rely on just a few modes of action. Products such as glyphosate, Method, and Esplanade are currently among the standard herbicides used and represent only three modes of action i.e., EPSP synthase inhibitor, plant growth regulator, and cellulose biosynthesis inhibitor, respectively. The rotation of products with different modes of action is an important strategy to discourage the development of resistant weeds. This experiment, repeated at two locations, was designed to test alternative chemistries and modes of action for inclusion into the product rotation of the bareground program. Many of the product combinations tested pose concerns when used near the root systems of trees and are best suited to interstate or limited access roadways where the likelihood for off target damage is lower. Among the treatments tested 48 oz/ac Velpar DF combined with 5 oz/ac Esplanade; 80 oz/ac Hyvar X combined with 5 oz/ac Esplanade; or 8 oz/ac Method combined with 16 oz/ac Arsenal Powerline and 5 oz/ac Esplanade demonstrated the greatest potential for season-long weed control on a variety of annual weed species.

INTRODUCTION

The PennDOT bareground weed control program relies on herbicides to control unwanted vegetation beneath guiderails, around signposts, and within areas that require the total elimination of vegetation for the growing season. It is recommended that the herbicides used are rotated to prevent the development of resistant weed populations. Unfortunately, labeling changes have reduced the list of products available for this program. Specifically, the Oust XP label now contains language that requires a buffer near water and agricultural crops while the Karmex DF label requires the use of additional personal protective equipment when mixing and loading.[20,21] The bareground herbicide mixes typically rely on a broad-spectrum residual,

[20] Bayer Environmental Science, Oust XP. Online. Internet. March 28, 2016.

preemergence, and postemergence component. Several broad-spectrum herbicides with diverse modes of action may be candidates for use in this treatment program. This experiment tested a variety of broad-spectrum residual herbicides in combination either Esplanade or Plateau (i.e., preemergent), and Accord XRT II (i.e., postemergent) for season-long weed control.

MATERIALS AND METHODS

The experiment was established at two locations. The first site was an unused compacted gravel manure storage pad found on a Penn State owned farm i.e., Farm 40 just east of the University Park Airport. The second site was located beneath a guiderail within the I-99 median near Pleasant Gap, PA. Treatments included 64 oz/ac Accord XRT II alone; 48 oz/ac Arsenal Powerline combined with 5 oz/ac Esplanade; 5 oz/ac Esplanade or alternatively, 12 oz/ac Plateau combined with the following herbicides: 7 oz/ac Milestone and 16 oz/ac Arsenal Powerline; 48 oz/ac Velpar DF; 8 oz/ac Sulfentrazone and 2 oz/ac Telar XP; 80 oz/ac Hyvar X; 8 oz/ac Method and 16 oz/ac Arsenal Powerline; 6 oz/ac Derigo (Farm 40 only); and an untreated check. Accord XRT II was added at 64 oz/ac to all herbicide treatments, except when used alone. 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. Plots were 15 by 6 ft. or 25 by 7 ft. in size at Farm 40 and Pleasant Gap, respectively. Treatments were applied on May 28 (Farm 40) and April 30, 2015 (Pleasant Gap) using a CO_2-powered sprayer equipped with a six ft. boom and (4) 8006VS tips at an application rate of 50 gallons per acre.

The Farm 40 site was visually rated for percent total vegetative cover, cover by annual grasses, and cover by marestail on May 29, June 29, July 28, August 28, September 29, and October 27, 2015, representing day 1, 32, 61, 92, 124, and 152 after treatment, DAT; cover by speedwell on May 29 and June 29, 2015, i.e., 1 and 32 DAT; and cover by specific annual species including foxtail, barnyardgrass, fall panicum, and common purslane on August 28, September 29, and October 27, 2015, representing 92, 124, and 152 DAT (Table 1). Pleasant Gap was evaluated for percent total vegetative cover and cover by kochia on April 30, May 29, June 30, July 29, August 31, September 30 and November 2, 2015, 0, 29, 61, 90, 123, 153, and 186 DAT. Percent cover by foxtail and sprangletop were evaluated on the last three rating intervals, August 31, September 30, and November 2, 2015.

RESULTS AND DISCUSSION

Farm 40 offered the greatest number and diversity of weed species. Evaluations of total vegetative cover ranged from 7 to 22.25 percent at the onset of the experiment with no significant difference among the plots. Total cover diminished and ranged from 0 to 2.32 percent for the herbicide treatments and 28 percent for the untreated plots at 32 DAT (June 29). By the end of the growing season (October 27) total vegetative cover reached 71.25 percent for the untreated plots, 41.32 percent for Accord XRT II only, and 0.02 to 12.40 percent for all remaining herbicide treatments. Annual grasses including foxtail, barnyardgrass, and fall panicum comprised the majority of the weed pressure across this site. All herbicide treatments, except Accord XRT II alone, provided comparable control of annual grasses with cover from 0 to 12.10 percent at 152 DAT (October 27).

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[21] Makhteshim Agan of North America, Inc. Karmex DF. Online. Internet. March 28, 2016.

Vegetation found at the Pleasant Gap site was almost exclusively kochia. At the time of treatment, total vegetation cover ranged from 0.3 to 8.0 percent with no significant difference among the treatments. The highest levels of kochia were recorded at 153 DAT (September 30) for the untreated plots and many of the worst performing treatments. Kochia accounted for 37 percent cover in untreated plots and ranged from 0 to 19.8 percent cover among the treatments. Treatments that included Velpar DF, Hyvar X, or Method plus Arsenal Powerline combined with either preemergent herbicide, Esplanade or Plateau, offered the greatest reduction in kochia from 0 to 3.5 percent cover. Milestone plus Arsenal Powerline combined with either preemergent herbicide, Esplanade or Plateau; Arsenal plus Esplanade; Sulfentrazone plus Telar XP plus Esplanade; and Accord XRT II alone were not significantly different than the best performing treatments and ranged from 6.8 to 17 percent cover by kochia. Sulfentrazone plus Telar plus Plateau resulted in the greatest cover by kochia (19.8 percent), not significantly different than the untreated check (37 percent).

CONCLUSIONS

Treatments that included Esplanade demonstrated improved control of both annual grasses and kochia compared to Plateau. Among the treatments containing Esplanade all performed equally well in preventing the emergence of annual grasses through the entire growing season. The treatments that included Velpar DF, Hyvar X, or Method plus Arsenal Powerline offered the greatest control of kochia.

MANAGEMENT IMPLICATIONS

Tank mixes of 48 oz/ac Velpar DF plus 5 oz/ac Esplanade; 80 oz/ac Hyvar X plus 5 oz/ac Esplanade; or 8 oz/ac Method plus 16 oz/ac Arsenal Powerline and 5 oz/ac Esplanade are all possible rotation options in the bareground program. These treatments would include glyphosate at 64 oz/ac. Each appears capable of providing season-long control of the predominant annual weed species that commonly develop in these areas. Caution with all three mixes must be observed. Velpar DF[22], Hyvar X[23], Method[24], and Arsenal Powerline[25] all contain statements warning of potential injury to trees and desirable plants with root systems extending into the treated area. The use of these combinations should be limited to interstate and limited access routes to minimize potential off-site damage.

[22] E.I. DuPont de Nemours and Company. Velpar DF. Online. Internet. March 25, 2016.
[23] Bayer Environmental Science, Hyvar X. Online. Internet. March 25, 2016.
[24] Bayer Environmental Science, Method 50SG. Online. Internet. March 25, 2016.
[25] BASF Corporation. Arsenal Powerline. Online. Internet. March 25, 2016.

Table 1: Effectiveness of herbicide combination treatments based on percent total vegetative cover; cover by annual grasses; and cover by kochia (*Kochia scoparia,* KCHSC) at two sites at 152 and 153 days after treatment. The Farm 40 site was visually rated for percent total vegetative cover and cover by annual grasses on October 27, 2015, 152 days after treatment, DAT. The Pleasant Gap experiment was visually rated for percent cover by kochia on September 30, 2015, 153 DAT. Treatments were applied on May 28 (Farm 40) and April 30, 2015 (Pleasant Gap). Accord XRT II was added at 64 oz/ac to all treatments, except when used alone. 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	Farm 40 total cover 152 DAT	Farm 40 annual grass cover 152 DAT	Pleasant Gap kochia cover 153 DAT
	(oz/ac)	(------------------------------	%------------------------------	)
Untreated	---	71.25 c	70.12 c	37.00 c
Accord XRT II	64	41.32 b	40.72 b	12.06 ab
Milestone Arsenal Powerline Esplanade	7 16 5	1.50 a	1.48 a	6.75 ab
Velpar DF Esplanade	48 5	0.02 a	0 a	3.52 ab
Arsenal Powerline Esplanade	48 5	0.02 a	0 a	15.25 ab
Sulfentrazone Telar XP Esplanade	8 2 5	0.02 a	0 a	10.00 ab
Hyvar X Esplanade	80 5	0.15 a	0.12 a	0 a
Method Arsenal Powerline Esplanade	8 16 5	0.48 a	0.45 a	1.19 ab
Derigo Esplanade	6 5	1.22 a	1.12 a	---
Milestone Arsenal Powerline Plateau	7 16 12	12.40 a	12.10 a	17.00 ab
Velpar DF Plateau	48 12	8.60 a	8.35 a	3.00 ab
Sulfentrazone Telar Plateau	8 2 12	0.70 a	0.42 a	19.75 bc
Hyvar X Plateau	80 12	2.45 a	1.40 a	1.16 ab
Method Arsenal Powerline Plateau	8 16 12	3.45 a	3.38 a	3.06 ab
Derigo Plateau	6 12	3.78 a	3.20 a	---

COMPARISON OF SULFENTRAZONE PRODUCTS FOR BAREGROUND WEED CONTROL APPLICATIONS

Herbicide trade and common names: Accord XRT II (*glyphosate*); Portfolio 4F (*sulfentrazone*); Sulfentrazone (*sulfentrazone, 75% dry*).
Plant common and scientific names: barnyardgrass (*Echinochloa crusgalli*); fall panicum (*Panicum dichotomiflorum*); foxtail (*Setaria* spp.); goldenrod (*Solidago* spp.); goosegrass (*Eleusine indica*); smooth crabgrass (*Digitaria ischaemum*); stalked bur grass (*Tragus racemosus* L.); aster (*Aster* spp.); witchgrass (*Panicum capillare*).

ABSTRACT

There are areas directly adjacent to roadways, (e.g., beneath guiderails) which are maintained free of vegetation to enhance driving safety and make maintenance operations more efficient. A bareground program, consisting of a tank mix of herbicides intended to eliminate vegetation for the entire growing season is often implemented to achieve this goal. The tank mix often consists of a non-selective postemergence, preemergence, and broad-spectrum residual herbicide. Identifying alternative herbicides for use as tank mix partners is important for two reasons: 1) previously employed broad-spectrum herbicides have new label restrictions or precautionary statements that limit their use and 2) finding alternative chemistry to reduce the potential for herbicide resistant weeds is an important component of sustainability in weed control. One active ingredient used in past experiments that has shown promise in kochia control is sulfentrazone. Portfolio 4F is a liquid formulation containing sulfentrazone sold by Wilbur-Ellis and labeled for roadside sites. This product was tested against a sulfentrazone 75% dry formulation to determine if any differences in control were observed. In this experiment, annual grasses were abundant at the site and were the primary species to develop within the treated areas. There were no significant differences noted among the treatments, although little control of grasses was observed with any treatment.

INTRODUCTION

The bareground program relies on tank mixes of herbicides to control plants under guiderails, around signposts, and within areas that require the complete elimination of vegetation. Alternative chemistry is continually reviewed to ensure that rotational tank mixes are available to overcome the potential development of resistant weed species. Sulfentrazone has been tested for bareground application in past experiments and has shown effectiveness in tank mixes for control of select species, especially early developing kochia.[26,27,28] Sulfentrazone is a PPO-inhibitor used to control germinating weeds. This active ingredient is limited in it's availability, but is currently sold under the trade name Portfolio 4F. This product was evaluated in

[26] Johnson, J.M. et al. 2012. MAT28 in combination with preemergence herbicides for season-long bareground weed control. Roadside Vegetation Management Research – 2012 Report. p. 28-32.
[27] Johnson, J.M. et al. 2011. MAT28 in combination with preemergence herbicides for season-long bareground weed control. Roadside Vegetation Management Research Annual Report. p. 49-53.
[28] Johnson, J.M. et al. 2009. Further evaluation of alternatives to diuron for kochia control. Roadside Vegetation Management Research Annual Report. p. 45-49.

comparison to a 75% dry formulation tested in the past to determine whether differences in control were observed.

MATERIALS AND METHODS

The experiment was established at the Gray's Woods interchange of I-99 and Scotia Rd. near State College, PA. Treatments included 64 oz/ac Accord XRT II alone; 8 oz/ac Sulfentrazone plus 64 oz/ac Accord XRT II; and 12 oz/ac Portfolio 4F plus 64 oz/ac Accord XRT II. An 8 oz rate of the 75% dry sulfentrazone or 12 oz Portfolio 4F is equivalent to 6 oz of the active ingredient, sulfentrazone. A non-ionic surfactant (i.e., Induce) was added to all herbicide treatments at 0.25% v/v. Treatments were applied at an application volume of 50 gallons per acre to plots measuring 15 by 6 ft. The experiment was established as a randomized complete block design with four replications. Treatments were applied on July 1, 2015 using a CO_2-powered sprayer equipped with a six ft. boom and four 8006VS tips.

The site was visually rated for percent total vegetative cover, cover by annual grasses, and cover by goldenrod and/or aster on July 1, August 3, September 4, October 5, and November 7, 2015 equivalent to 0, 33, 65, 96, and 129 days after treatment, DAT. Percent cover by foxtail and goosegrass was evaluated on September 4, October 5, and November 7, 2015 equivalent to 65, 96, and 129 DAT. Percent cover by stalked bur grass and fall panicum was evaluated on November 7, 2015, 129 DAT (Table 1). The evaluation of cover by annual grasses encompassed the following species: goosegrass, foxtail, fall panicum, witchgrass, smooth crabgrass, barnyardgrass, and stalked bur grass.

RESULTS AND DISCUSSION

No differences in control were noted for any species at any rating date among the treatments. The greatest weed pressure was observed on October 5, 2016, 96 days after treatment, DAT. Total vegetative cover ranged from 16.2 to 20.0 percent for the treatments (Table 1). Annual grasses comprised the greatest portion of species encountered at the site with cover from 15.0 to 19.4 percent. Noteworthy species included goosegrass (6.5 to 8.8 percent cover) and fall panicum (3.9 to 7.1 percent cover). Goldenrod and aster were the only broadleaf species present in enough quantity to evaluate. The presence of both broadleaf species averaged far less than one percent cover after treatment and was not significantly different between treatments (not reported).

CONCLUSIONS

Annual grasses were initially impacted by the treatments but germination was not impeded. The Portfolio 4F label mentions control of select broadleaf weeds, grasses, and sedges; however, crabgrass is the only grass specifically mentioned on the label.[29] Past work has demonstrated encouraging results using the active ingredient, sulfentrazone, for bareground weed control with preemergence applications. However, this site had an abundance of annual grass species that germinated and escaped the treatments. Both formulations of sulfentrazone (i.e., sulfentrazone 75% dry and Portfolio 4F) were equally ineffective on the species encountered. Further testing of the products on a wider range of species, specifically annual broadleaf species is needed.

[29] Wilbur-Ellis Company. Portfolio 4F. Internet. April 18, 2016.

MANAGEMENT IMPLICATIONS

This experiment did not show any difference in effectiveness between the two products sulfentrazone 75% dry and Portfolio 4F at equivalent active ingredient rates. It did demonstrate the weakness of this active ingredient, sulfentrazone, on a host of annual grass species. The experiment also showed the need for reliable tank mix partners in bareground treatments to assure control of a wide range of plant species for the growing season. Further testing is needed before recommending the use of Portfolio 4F in tank mix combinations.

Table 1: Percent total vegetative cover, cover by annual grasses, cover by goosegrass (*Eleusine indica*, ELEIN), and cover by fall panicum (*Panicum dichotomiflorum*, PANDI). The site was visually rated for percent total vegetative cover, cover by annual grasses, cover by goosegrass, and cover by fall panicum on October 5, 2015, 96 days after treatment, DAT. Treatments were applied on July 1, 2015. 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 cover 96 DAT	annual grass cover 96 DAT	goosegrass cover 96 DAT	fall panicum cover 96 DAT
	(oz/ac)	(-----------------------------------	%	-----------------------------------	)
Accord XRT II	64	20.0 a	19.4 a	7.5 a	7.1 a
Accord XRT II Sulfentrazone	64 8	17.5 a	16.3 a	8.8 a	3.9 a
Accord XRT II Portfolio 4F	64 12	16.2 a	15.0 a	6.5 a	4.4 a
Significance Level ($p \leq 0.05$)		0.751	0.649	0.913	0.224

APPENDIX

Table 2: Percent seedhead suppression of the Kentucky bluegrass stand at Innovation Park. The experiment was visually rated for seedhead reduction of Kentucky bluegrass on May 20, June 4, June 16, and July 6, 2015 (14, 29, 41, and 61 days after treatment, DAT). 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	Kentucky bluegrass percent seedhead reduction			
		5/20/15	6/4/15	6/16/15	7/6/15
	(oz/ac)				
Untreated	----	0 a	0 a	0 a	0 a
Plateau Method	2 5	86 b	82 c	70 bc	31 ab
Panoramic Method	2 5	79 b	72 c	66 abc	38 ab
Embark Escort XP Method	6 0.2 5	64 b	66 bc	66 abc	50 ab
Segment Method	24 5	84 b	90 c	89 c	62 b
Anuew Method	21.8 5	68 b	50 abc	45 abc	25 ab
Escort XP Method	0.33 5	56 b	46 abc	34 abc	31 ab
Plateau Milestone VM	2 5	58 b	60 bc	70 bc	69 b
Panoramic Milestone VM	2 5	84 b	90 c	54 abc	72 b
Embark Escort XP Milestone VM	6 0.2 5	89 b	91 c	62 abc	50 ab
Segment Milestone VM	24 5	80 b	56 abc	61 abc	75 b
Anuew Milestone VM	21.8 5	70 b	15 ab	14 ab	19 ab
Escort XP Milestone VM	0.33 5	48 ab	38 abc	44 abc	19 ab
Plateau Escort XP Method	2 0.2 5	48 ab	62 bc	60 abc	25 ab
Sign. Level ($p \leq 0.05$)		0.000	0.000	0.003	0.001

Table 3: Average height of the tall fescue stand at Innovation Park. The experiment was measured for tall fescue height on May 20, June 4, June 16, July 6, and July 16, 2015 (14, 29, 41, 61, and 71 days after treatment, DAT). 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	tall fescue average height (in.)				
		5/20/15	6/4/15	6/16/15	7/6/15	7/16/15
	(oz/ac)					
Untreated	----	10.2 a	10.3 b	11.2 c	14.6 c	13.7 abc
Plateau Method	2 5	8.8 a	8.7 ab	9.5 bc	10.1 ab	11.7 ab
Panoramic Method	2 5	8.0 a	7.7 a	7.5 ab	12.8 abc	13.2 abc
Embark Escort XP Method	6 0.2 5	7.5 a	7.2 a	6.0 a	11.0 abc	10.6 a
Segment Method	24 5	9.0 a	8.1 ab	7.0 a	10.2 ab	11.4 ab
Anuew Method	21.8 5	8.5 a	9.1 ab	7.4 ab	10.3 ab	16.1 c
Escort XP Method	0.33 5	9.0 a	8.1 ab	6.8 a	10.9 abc	12.1 abc
Plateau Milestone VM	2 5	8.2 a	8.2 ab	8.0 ab	11.7 abc	13.5 abc
Panoramic Milestone VM	2 5	8.0 a	7.5 a	7.3 ab	13.8 bc	13.8 abc
Embark Escort XP Milestone VM	6 0.2 5	7.8 a	7.5 a	7.0 a	10.7 abc	11.2 ab
Segment Milestone VM	24 5	7.8 a	7.9 ab	7.2 ab	10.4 ab	12.6 abc
Anuew Milestone VM	21.8 5	9.8 a	8.2 ab	7.4 ab	11.2 abc	15.0 bc
Escort XP Milestone VM	0.33 5	9.5 a	8.5 ab	7.2 ab	13.0 abc	14.2 abc
Plateau Escort XP Method	2 0.2 5	7.2 a	7.8 ab	6.9 a	9.4 a	11.2 ab
Sign. Level ($p \leq 0.05$)		0.616	0.013	0.000	0.000	0.000

Table 4: Average height of the Kentucky bluegrass stand at Innovation Park. The experiment was measured for Kentucky bluegrass height on May 20, June 4, June 16, July 6, and July 16, 2015 (14, 29, 41, 61, and 71 days after treatment, DAT). 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	Kentucky bluegrass Average height (in.)				
		5/20/15	6/4/15	6/16/15	7/6/15	7/16/15
	(oz/ac)					
Untreated	----	9.2 a	8.6 b	8.5 b	15.8 b	14.8 b
Plateau Method	2 5	7.0 a	6.0 a	7.1 ab	11.8 a	12.2 ab
Panoramic Method	2 5	8.0 a	6.6 a	7.2 ab	10.9 a	13.6 ab
Embark Escort XP Method	6 0.2 5	7.2 a	7.4 ab	6.8 ab	13.0 ab	14.9 b
Segment Method	24 5	7.8 a	6.0 a	5.9 a	9.8 a	11.7 ab
Anuew Method	21.8 5	7.0 a	6.7 a	6.9 ab	9.6 a	10.2 a
Escort XP Method	0.33 5	7.8 a	7.5 ab	8.0 ab	11.2 a	11.9 ab
Plateau Milestone VM	2 5	7.5 a	6.7 a	6.8 ab	12.0 a	13.8 ab
Panoramic Milestone VM	2 5	8.0 a	6.8 a	6.4 ab	12.3 ab	12.8 ab
Embark Escort XP Milestone VM	6 0.2 5	7.2 a	6.4 a	7.2 ab	12.1 ab	14.1 ab
Segment Milestone VM	24 5	7.5 a	7.1 ab	7.5 ab	11.6 a	11.6 ab
Anuew Milestone VM	21.8 5	7.8 a	6.9 ab	7.1 ab	12.1 ab	14.3 b
Escort XP Milestone VM	0.33 5	7.8 a	7.2 ab	6.8 ab	12.6 ab	15.6 b
Plateau Escort XP Method	2 0.2 5	7.2 a	6.8 ab	6.2 a	12.0 a	13.4 ab
Sign. Level ($p \leq 0.05$)		0.737	0.000	0.009	0.000	0.000

Table 5: Percent cover of the turfgrass stand at Innovation Park. The experiment was visually rated for turf cover on May 6 and July 16, 2015 (0 and 71 days after treatment, DAT). 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 $p \leq 0.05$.

		percent turf cover		percent change in turf cover
product	rate	5/6/15	7/16/15	7/16/15
	(oz/ac)			
Untreated	----	42 a	68 a	65 a
Plateau Method	2 5	54 a	70 a	35 a
Panoramic Method	2 5	52 a	70 a	35 a
Embark Escort XP Method	6 0.2 5	42 a	67 a	59 a
Segment Method	24 5	58 a	60 a	3 a
Anuew Method	21.8 5	46 a	71 a	58 a
Escort XP Method	0.33 5	44 a	72 a	64 a
Plateau Milestone VM	2 5	50 a	78 a	59 a
Panoramic Milestone VM	2 5	46 a	78 a	82 a
Embark Escort XP Milestone VM	6 0.2 5	46 a	74 a	62 a
Segment Milestone VM	24 5	54 a	84 a	69 a
Anuew Milestone VM	21.8 5	54 a	85 a	69 a
Escort XP Milestone VM	0.33 5	51 a	84 a	68 a
Plateau Escort XP Method	2 0.2 5	44 a	69 a	61 a
Sign. Level ($p \leq 0.05$)		0.742	0.077	0.327

Table 7: Percent injury and control of birdsfoot trefoil at Innovation Park. The experiment was visually rated for birdsfoot trefoil injury or control on May 20, June 4, June 16, and July 6, 2015 (14, 29, 41, and 61 days after treatment, DAT). 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 ≤ 0.05.

product	rate	Birdsfoot trefoil percent injury	Birdsfoot trefoil percent control		
		5/20/15	6/4/15	6/16/15	7/6/15
	(oz/ac)				
Untreated	----	0 a	0 a	0 a	0 a
Plateau Method	2 5	74 b	74 ab	88 b	96 b
Panoramic Method	2 5	50 b	61 ab	76 b	88 b
Embark Escort XP Method	6 0.2 5	58 b	66 ab	56 ab	71 b
Segment Method	24 5	72 b	81 ab	85 b	81 b
Anuew Method	21.8 5	64 b	60 ab	88 b	95 b
Escort XP Method	0.33 5	66 b	62 ab	81 b	96 b
Plateau Milestone VM	2 5	52 b	64 ab	78 b	81 b
Panoramic Milestone VM	2 5	52 b	49 ab	62 b	81 b
Embark Escort XP Milestone VM	6 0.2 5	58 b	85 b	84 b	91 b
Segment Milestone VM	24 5	50 b	66 ab	72 b	81 b
Anuew Milestone VM	21.8 5	50 b	58 ab	72 b	75 b
Escort XP Milestone VM	0.33 5	71 b	74 ab	88 b	88 b
Plateau Escort XP Method	2 0.2 5	60 b	72 ab	81 b	88 b
Sign. Level (p≤0.05)		0.000	0.174 (n.s.)	0.000	0.000

Table 9: Percent seedhead reduction of the Kentucky bluegrass stand at Pleasant Gap. The experiment was visually rated for seedhead reduction of Kentucky bluegrass on June 9, June 24, and July 7, 2015 (29, 44, and 57 days after treatment, DAT). Treatments were applied on May 11, 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 ≤ 0.05.

product	rate	Kentucky bluegrass percent seedhead reduction 6/9/15	6/24/15	7/7/15
	(oz/ac)			
Untreated	----	0 a	0 a	0 a
Plateau Method	2 5	0 a	0 a	0 a
Panoramic Method	2 5	0 a	0 a	0 a
Embark Escort XP Method	6 0.2 5	0 a	0 a	0 a
Segment Method	24 5	22 a	22 a	19 a
Anuew Method	21.8 5	0 a	0 a	0 a
Escort XP Method	0.33 5	0 a	0 a	0 a
Plateau Milestone VM	2 5	0 a	0 a	0 a
Panoramic Milestone VM	2 5	0 a	0 a	0 a
Embark Escort XP Milestone VM	6 0.2 5	0 a	0 a	0 a
Segment Milestone VM	24 5	0 a	0 a	0 a
Anuew Milestone VM	21.8 5	0 a	0 a	0 a
Escort XP Milestone VM	0.33 5	0 a	0 a	0 a
Plateau Escort XP Method	2 0.2 5	0 a	0 a	0 a
Sign. Level (p≤0.05)		0.468	0.468	0.468

Table 10: Average height of the tall fescue stand at Pleasant Gap. The experiment was measured for height of tall fescue May 26, June 9, June 24, July 7, and July 20, 2015 (15, 29, 44, 57, and 70 days after treatment, DAT). Treatments were applied on May 11, 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 $p \leq 0.05$. A '---' for significance level indicates that a mean separation could not be calculated.

product	rate	tall fescue average height (in.)				
		5/26/15	6/9/15	6/24/15	7/7/15	7/20/15
	(oz/ac)					
Untreated	----	11.6	13.9 b	12.0	14.8	16.3
Plateau Method	2 5	12.1	11.8 ab	12.2	17.7	18.1
Panoramic Method	2 5	11.7	12.8 ab	11.1	17.1	17.2
Embark Escort XP Method	6 0.2 5	11.6	11.7 ab	11.2	16.5	15.8
Segment Method	24 5	12.3	12.6 ab	11.5	15.5	17.3
Anuew Method	21.8 5	12.2	12.5 ab	12.8	17.4	17.5
Escort XP Method	0.33 5	11.8	12.1 ab	11.5	17.9	16.3
Plateau Milestone VM	2 5	12.1	12.1 ab	11.6	16.2	18.1
Panoramic Milestone VM	2 5	11.6	12.8 ab	10.6	17.8	18.3
Embark Escort XP Milestone VM	6 0.2 5	10.4	10.8 a	11.6	15.6	14.8
Segment Milestone VM	24 5	11.8	11.6 a	11.3	16.8	17.2
Anuew Milestone VM	21.8 5	12.2	12.9 ab	12.0	18.1	18.3
Escort XP Milestone VM	0.33 5	11.9	12.3 ab	11.7	15.8	15.8
Plateau Escort XP Method	2 0.2 5	12.2	11.6 a	11.4	15.0	15.9
Sign. Level ($p \leq 0.05$)		0.540	0.008	0.323	---	---

Table 11: Average height of the Kentucky bluegrass stand at Pleasant Gap. The experiment was measured for height of Kentucky bluegrass on May 26, June 9, June 24, July 7, and July 20, 2015 (15, 29, 44, 57, and 70 days after treatment, DAT). Treatments were applied on May 11, 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 ≤ 0.05.

		Kentucky bluegrass average height (in.)				
product	rate	5/26/15	6/9/15	6/24/15	7/7/15	7/20/15
	(oz/ac)					
Untreated	----	9.5	10.4	11.2	15.8 ab	14.6 ab
Plateau Method	2 5	9.3	10.0	10.7	16.3 b	14.3 ab
Panoramic Method	2 5	9.2	10.1	11.0	15.2 ab	14.8 ab
Embark Escort XP Method	6 0.2 5	8.8	9.5	10.5	14.2 ab	13.7 ab
Segment Method	24 5	9.6	10.8	10.2	14.6 ab	15.8 ab
Anuew Method	21.8 5	9.0	10.3	10.8	15.7 ab	12.8 ab
Escort XP Method	0.33 5	9.2	10.3	10.4	14.0 ab	14.1 ab
Plateau Milestone VM	2 5	9.4	10.6	11.1	14.8 ab	15.3 ab
Panoramic Milestone VM	2 5	8.8	10.0	9.3	12.6 a	12.7 a
Embark Escort XP Milestone VM	6 0.2 5	8.6	9.6	10.8	16.2 b	16.0 b
Segment Milestone VM	24 5	9.2	9.9	11.6	16.5 b	15.3 ab
Anuew Milestone VM	21.8 5	9.7	10.4	11.0	16.8 b	15.7 ab
Escort XP Milestone VM	0.33 5	9.5	10.3	10.8	16.2 b	14.7 ab
Plateau Escort XP Method	2 0.2 5	9.2	9.4	9.8	14.2 ab	14.4 ab
Sign. Level (p≤0.05)		0.541	0.521	0.377	0.000	0.009

Table 12: Percent cover of the turfgrass stand at Pleasant Gap. The experiment was visually rated for turf cover on May 11 and July 20, 2015 (0 and 70 days after treatment, DAT). 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 11, 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 $p \leq 0.05$.

		percent turf cover		percent change in turf cover
product	rate	5/11/15	7/20/15	7/20/15
	(oz/ac)			
Untreated	----	46	89	95
Plateau Method	2 5	42	88	110
Panoramic Method	2 5	41	88	114
Embark Escort XP Method	6 0.2 5	45	85	91
Segment Method	24 5	40	79	97
Anuew Method	21.8 5	40	85	118
Escort XP Method	0.33 5	48	92	99
Plateau Milestone VM	2 5	44	91	118
Panoramic Milestone VM	2 5	40	87	122
Embark Escort XP Milestone VM	6 0.2 5	45	86	95
Segment Milestone VM	24 5	41	90	121
Anuew Milestone VM	21.8 5	42	93	121
Escort XP Milestone VM	0.33 5	42	92	122
Plateau Escort XP Method	2 0.2 5	45	81	84
Sign. Level ($p \leq 0.05$)		0.957	0.080	0.703

Table 15: Percent seedhead suppression of the Kentucky bluegrass stand at Port Matilda. The experiment was visually rated for seedhead reduction of Kentucky bluegrass on May 22, June 5, June 22, and July 6, 2015 (15, 29, 46, and 60 days after treatment, DAT). Treatments were applied on May 7, 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	Kentucky bluegrass percent seedhead reduction			
		5/22/15	6/5/15	6/22/15	7/6/15
	(oz/ac)				
Untreated	----	0 a	0 a	0 a	0 a
Plateau Method	2 5	86 b	62 abc	62 bcd	66 abc
Panoramic Method	2 5	88 b	62 abc	62 bcd	75 bc
Embark Escort XP Method	6 0.2 5	98 b	74 bc	78 bcd	92 c
Segment Method	24 5	97 b	95 c	91 d	94 c
Anuew Method	21.8 5	71 b	31 abc	31 abc	42 abc
Escort XP Method	0.33 5	78 b	58 abc	54 a-d	50 abc
Plateau Milestone VM	2 5	91 b	52 abc	52 a-d	79 bc
Panoramic Milestone VM	2 5	85 b	77 bc	75 bcd	74 bc
Embark Escort XP Milestone VM	6 0.2 5	97 b	88 bc	89 cd	95 c
Segment Milestone VM	24 5	100 b	99 c	97 d	97 c
Anuew Milestone VM	21.8 5	88 b	25 ab	25 ab	19 ab
Escort XP Milestone VM	0.33 5	86 b	50 abc	56 a-d	85 bc
Plateau Escort XP Method	2 0.2 5	93 b	72 bc	72 bcd	72 bc
Sign. Level ($p \leq 0.05$)		0.000	0.000	0.000	0.000

Table 16: Average height of the tall fescue stand at Port Matilda. The experiment was measured for tall fescue height on May 22, June 5, June 22, July 6, and July 17, 2015 (15, 29, 46, 60, and 71 days after treatment, DAT). Treatments were applied on May 7, 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	tall fescue average height (in.)				
		5/22/15	6/5/15	6/22/15	7/6/15	7/17/15
	(oz/ac)					
Untreated	----	12.7 b	12.6 b	14.2 b	19.2 d	23.4 c
Plateau Method	2 5	9.2 a	9.5 a	10.3 a	14.5 abc	22.2 abc
Panoramic Method	2 5	9.1 a	8.8 a	10.1 a	13.4 abc	21.2 abc
Embark Escort XP Method	6 0.2 5	9.8 a	9.8 a	8.9 a	13.3 abc	18.8 a
Segment Method	24 5	8.9 a	8.8 a	9.0 a	12.8 ab	19.0 abc
Anuew Method	21.8 5	9.0 a	9.8 a	10.1 a	12.9 abc	19.9 abc
Escort XP Method	0.33 5	9.1 a	9.6 a	10.2 a	13.1 abc	23.2 bc
Plateau Milestone VM	2 5	9.3 a	8.8 a	10.2 a	14.8 bc	22.2 bc
Panoramic Milestone VM	2 5	9.6 a	9.2 a	10.0 a	15.1 bc	20.5 abc
Embark Escort XP Milestone VM	6 0.2 5	9.4 a	9.4 a	9.1 a	13.8 abc	18.8 ab
Segment Milestone VM	24 5	9.2 a	8.9 a	9.9 a	11.8 a	17.8 a
Anuew Milestone VM	21.8 5	9.6 a	10.3 ab	10.5 a	13.5 abc	20.9 abc
Escort XP Milestone VM	0.33 5	8.6 a	9.0 a	10.4 a	14.8 bc	23.2 bc
Plateau Escort XP Method	2 0.2 5	9.9 a	9.8 a	10.7 a	15.7 c	21.8 abc
Sign. Level ($p \leq 0.05$)		0.001	0.000	0.000	0.000	0.000

Table 17: Percent cover of the turfgrass stand at Port Matilda. The experiment was visually rated for turf cover on May 7 and July 17, 2015 (0 and 71 days after treatment, DAT). 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 7, 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 $p \leq 0.05$.

		percent turf cover		percent change in turf cover
product	rate	5/7/15	7/17/15	7/17/15
	(oz/ac)			
Untreated	----	42 a	78 b	85 abc
Plateau Method	2 5	45 a	76 b	71 abc
Panoramic Method	2 5	42 a	78 b	83 abc
Embark Escort XP Method	6 0.2 5	46 a	69 ab	50 ab
Segment Method	24 5	39 a	52 a	34 a
Anuew Method	21.8 5	40 a	82 b	109 c
Escort XP Method	0.33 5	42 a	79 b	88 abc
Plateau Milestone VM	2 5	45 a	84 b	91 abc
Panoramic Milestone VM	2 5	41 a	77 b	90 abc
Embark Escort XP Milestone VM	6 0.2 5	45 a	75 b	66 abc
Segment Milestone VM	24 5	41 a	71 ab	71 abc
Anuew Milestone VM	21.8 5	44 a	82 b	89 abc
Escort XP Milestone VM	0.33 5	40 a	79 b	101 bc
Plateau Escort XP Method	2 0.2 5	42 a	80 b	90 abc
Sign. Level ($p \leq 0.05$)		0.900 n.s.	0.000	0.004

Table 19: Percent injury and control of birdsfoot trefoil at Port Matilda. The experiment was visually rated for birdsfoot trefoil injury or control on May 22, June 5, June 22, and July 6, 2015 (15, 29, 46, and 60 days after treatment, DAT). Treatments were applied on May 7, 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 ≤ 0.05.

product	rate	Birdsfoot trefoil percent injury	Birdsfoot trefoil percent control		
		5/22/15	6/5/15	6/22/15	7/6/15
	(oz/ac)				
Untreated	----	0 a	0 a	0 a	0 a
Plateau Method	2 5	50 b	92 b	96 bc	96 b
Panoramic Method	2 5	50 b	90 b	97 bc	96 b
Embark Escort XP Method	6 0.2 5	56 b	94 b	98 bc	98 b
Segment Method	24 5	50 b	94 b	100 c	100 b
Anuew Method	21.8 5	50 b	92 b	98 bc	99 b
Escort XP Method	0.33 5	58 b	95 b	98 bc	99 b
Plateau Milestone VM	2 5	50 b	86 b	92 b	92 b
Panoramic Milestone VM	2 5	50 b	89 b	95 bc	96 b
Embark Escort XP Milestone VM	6 0.2 5	50 b	89 b	96 bc	96 b
Segment Milestone VM	24 5	50 b	92 b	96 bc	95 b
Anuew Milestone VM	21.8 5	50 b	91 b	96 bc	99 b
Escort XP Milestone VM	0.33 5	50 b	95 b	100 c	100 b
Plateau Escort XP Method	2 0.2 5	56 b	94 b	99 c	97 b
Sign. Level ($p \leq 0.05$)		0.000	0.000	0.000	0.000