Roadside Vegetation Management Research – 2010 Report

ANNUAL REPORT

May 26, 2010

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16. Abstract

This report details a cooperative research project performed for the Pennsylvania Department of Transportation's Bureau of Maintenance and Operations by Penn State. The report includes the following: A Comparison of Dry Defoamers; Response of Black Locust to Foliar Applications of Aminocylopyrachlor; Response of Woody Species to Cut Surface Applications of Aminocylopyrachlor; Kixor^{TM}/BAS80003H for Selective Control of Kochia and Marestail in Roadside Turf; Comparison of Control Methods for Japanese Knotweed; Japanese Knotweed Controlled with Glyphosate or Triclopyr Applied Sequentially or Following Cutting; Selective Weed Control in Turf; Aminocyclopyrachlor for Bareground and Suppression of Kochia; Indaziflam/AE1170437 for Bareground and Suppression of Kochia; Suppression of Annual Grasses along Highway Guiderails; Evaluation of Turf Growth Regulator Combinations; Investigating Herbicides for Combined Weed and Brush plus Plant Growth Regulator Applications; Native Seed Mix Establishment Implementation – Year Two; Perennial Wildflower Mix Demonstration; Site and Soil Quality Effects on Native Grass Establishment; Seasonal Timing Effects on Warm-Season Grass Establishment Relative to Crownvetch and Annual Ryegrass; Germination of Annual Rye and Tall Fescue in Knotweed Infested Soil; Slopemaster White Clover Seed Mix Demonstration.

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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. Our sincere appreciation goes to Mr. Joe Demko for his support of this research project. We also thank student employees Ms. Bethany Kindiger, Ms. Andrea Schwander, and Mr. Travis Johnson for their contributions. Lastly, Dr. Roger Koide lent both his expertise and laboratory space to allow for the investigation of mycorrhizal symbioses.

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 2009 season: BASF Specialty Products, Bayer Environmental Sciences, and E.I. DuPont de Nemours & Co.

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INTRODUCTION

In October 1985, personnel at Penn State began a cooperative research project with the Pennsylvania Department of Transportation (PennDOT) to investigate several aspects of roadside vegetation management. An annual report has been submitted each year which 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

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 statistics, particularly techniques involved in the analysis of variance. The use of these techniques allows for the establishment of criteria for significance, or, when the differences between numbers are most likely due to the different treatments, rather than due to 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. At the bottom of the results tables where analysis of variance has been employed, there is a value for least significant difference (LSD). When analysis of variance indicates that the probability that the variation in the data is due to chance is equal or less than 0.05, Fisher's LSD means separation test is used. When the difference between two treatment means is equal or greater than the LSD value, these two values are significantly different. When the probability that the variation in the data is due to chance is greater than 0.05, the LSD value is reported as "n.s.," indicating non-significant.

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. E=emulsion, EC=emulsifiable concentrate, F = flowable liquid, ME=microencapsulated, S=water soluble, WDG=water-dispersible granules, WP = wettable powder.

Trade Name	Active Ingredients	Formulation	Manufacturer
AE1170437	indaziflam	20 WP	BAYER Crop and Environmental Sciences
Aquamaster	glyphosate	4 S	Monsanto
Aquaneat	glyphosate	4 S	Nufarm Turf & Specialty
Arsenal	imazapyr	2 S	BASF Specialty Products
Assure II	quizalofop	0.88 EC	E.I. DuPont de Nemours & Co.
Authority	sulfentrazone	75 WDG	E.I. DuPont de Nemours & Co.
BAS80003H/KixorTM	saflufenacil	1 EC	BASF Specialty Products
Chateau	flumioxazin	51 WDG	Valent U.S.A. Corporation
DPX-KJM44	aminocyclopyrachlor	80 WDG	E.I. DuPont de Nemours & Co.
DPX-MAT28	aminocyclopyrachlor	50 WDG	E.I. DuPont de Nemours & Co.
Embark T&O	mefluidide	0.2 S	PBI Gordon Corporation
Escort XP	metsulfuron methyl	60 WDG	E.I. DuPont de Nemours & Co.
Garlon 3A	triclopyr amine	3 S	Dow AgroSciences LLC
Garlon 4	triclopyr ester	4 EC	Dow AgroSciences LLC
Glyphomate 41	glyphosate	2.8	PBI Gordon Corporation
Journey	glyphosate + imazapic	0.75+1.5 S	BASF Specialty Products
Karmex XP	diuron	80 WDG	E.I. DuPont de Nemours & Co.
Krenite S	fosamine	4 S	E.I. DuPont de Nemours & Co.
Krovar I	bromacil + diuron	40 + 40 WDG	E.I. DuPont de Nemours & Co.
Landmark XP	sulfometuron + chlorsulfuron	50 + 25 WDG	E.I. DuPont de Nemours & Co.
Matrix	rimsulfuron	25 WDG	E.I. DuPont de Nemours & Co.
Milestone VM	aminopyralid	2 S	Dow AgroSciences LLC
Milestone VM Plus	aminopyralid + triclopyr	0.1+1 S	Dow AgroSciences LLC
Oust XP	sulfometuron	75 DG	E.I. DuPont de Nemours & Co.
Oust Extra	sulfometuron + metsulfuron	56.25 + 15 WDG	E.I DuPont de Nemours & Co.
Overdrive	dicamba + diflufenzopyr	70 WDG	BASF Specialty Products
Panoramic	imazapic	2 S	Alligare LLC
Pendulum AQ	pendimethalin	3.8 ME	BASF Specialty Products
Plateau	imazapic	2 S	BASF Specialty Products
Proclipse	prodiamine	65 WDG	Nufarm Speciality Products
Rodeo	glyphosate	4 S	Dow AgroSciences LLC
RoundUp	glyphosate	3 S	Monsanto
RoundUp PRO Conc	glyphosate	3.7 S	Monsanto
Simazine	simazine	4F	Drexel Chemical Co.
Stalker	imazapyr	2 EC	BASF Specialty Products
Surflan AS	oryzalin	4 F	United Phosphorus, Inc.
Telar XP	chlorsulfuron	75 WDG	E.I. DuPont de Nemours & Co.
Throttle XP	chlorsulfuron, sulfometuron, + sulfentrazone	9 + 18 + 48 WDG	E.I. DuPont de Nemours & Co.
Vanquish	dicamba-glycolamine	4 S	Syngenta Professional Products
Velpar DF	hexazinone	75 WDG	E.I. DuPont de Nemours & Co.
Vista	fluroxypyr	1.5 EC	DowAgroSciences LLC

A COMPARISON OF DRY DEFOAMERS

Herbicide trade and common chemical names: Escort XP (*metsulfuron*), Garlon 3A (*triclopyr*), Overdrive (*dicamba* + *diflufenzopyr*).

ABSTRACT

Defoamers are used to reduce foam buildup in spray tanks arising from agitation, herbicide and surfactant interactions in the mixing process,and environmental conditions, which slow and disrupt the herbicide application process. This laboratory simulation compared the effectiveness of the Alenza versus Arborchem Dry Defoamer products for reducing foam amounts. Both were found to be equally effective when added at identical rates. Concerns arose during the 2008 season by one operational crew that experienced problems using Alenza Dry Defoamer. The amount of defoamer used operationally was thought to be added below label rate (0.12 oz/100 gal) and not adequate enough to reduce foam. Minimum labeled use rates of 1 oz/100 gal for each defoamer product did not provide significant reduction in foam. When added at 4 oz/100 gal both products were able to reduce foam amounts by half. The defoamer comparison was conducted under laboratory conditions rather than field conditions without the use of sprayer equipment agitation. For this reason the agitation rate may have exceeded that of equipment used in operational work and created greater foam amounts. At this time a field-level test of the defoamers at the higher rates has not been performed; however, it was discovered that both performed equally when used at equivalent rates and levels of agitation.

INTRODUCTION

Defoamers are regularly used in operational herbicide treatments to reduce the amount of foam buildup within the tank caused by mechanical agitation, the mixture of herbicide and surfactants, and even environmental conditions. Greater amounts of foam typically require additional defoamer. Excessive foam causes problems for the applicator, and several products are sold to address this concern. These defoamer products can be found in both dry and liquid formulations.

Concerns arose from operational applications during 2008 regarding the lack of effectiveness of Alenza Dry Defoamer[1/]. This product contains 20 percent polydimethylsiloxane. To determine the validity of the concern, it was decided to perform a side-by-side comparison of another commonly used and available product, Arbochem Dry Defoamer[2/]. This product label does not provide the percentage of polydimethylsiloxane but rather lists "polydimethylsiloxane, selected emulsifiers and base carrier 100 percent." The label for Arborchem Dry Defoamer requires amounts of 1 to 4 oz/100 gal (under agitation) or 1 to 6 oz/ac (if foam already exists), while the Alenza Dry Defoamer label calls for including 1 oz/100 gal and incrementally adding until foam is controlled.

A demonstration was performed in the lab to evaluate these two products for the reduction in foam at several rates in combination with 0.25 percent v/v CWC Surfactant 90 alone plus a treatment mimicking the tank mix used operationally.

[1/] Alenza Dry Defoamer, Alenza, Hazleton, PA
[2/] Arborchem Dry Defoamer, Arborchem Products Co., Fort Washington, PA

MATERIALS AND METHODS

To measure the effectiveness of each defoamer, a smaller but similarly proportional mixture of 48 oz/ac Garlon 3A, 4 oz/ac Overdrive, 0.5 oz/ac Escort XP, and 0.25 percent v/v CWC Surfactant 90[3/] was created to mimic the tank mix used in the field operation. These products were diluted in the equivalent of 35 gal water/ac. Included with the tank mix of herbicides plus surfactant was either 0.12 oz/100 gal of Alenza Dry Defoamer or Arborchem Dry Defoamer. Additionally, a 0.25 percent v/v CWC Surfactant 90 diluted in water was used to create foam and assess the ability of each product to reduce foam amounts. Varying rates of each defoamer were assessed including 0, 0.12, 1, 2, and 4 oz/100 gal. One quart of each treatment was created, including the defoamer, and then placed in a household blender at a 'whip' setting. The Hamilton Beach blender used in this investigation was set at a speed of 1 with a range of 1 through 7 settings. Treatments were blended for 30 seconds and left standing for 4 minutes. Then the height of the foam column within the blender was measured.

RESULTS AND DISCUSSION

CWC Surfactant 90 alone, without defoamer, created a foam column of 65 mm in height. All treatments varied from 32 to 75 mm in height. Defoamer rates of 0.12 oz/100 gal combined with the tank of herbicides and surfactant used operationally resulted in an increase in foam compared to the surfactant alone. Defoamers added to surfactant at 0.12 oz/100 gal showed a small reduction in foam compared to surfactant alone, with foam column heights of 62 and 60 mm for Alenza Dry Defoamer and Arborchem Dry Defoamer, respectively. Even the suggested lowest use rate for the defoamer products of 1 oz/100 gal did not provide acceptable foam reduction. Here values for the Alenza Dry Defoamer were 52 mm while the Arborchem Dry Defoamer was 54 mm in foam column height. At higher use rates (4 oz/100 gal) the foam was reduced nearly in half compared to surfactant alone, with values of 34 and 32 mm for the Alenza and Arborchem products, respectively.

CONCLUSIONS

Although this was not a replicated trial, it is apparent that there was little difference between defoamer brands tested when used at equivalent rates, and adding increasing amounts of either defoamer resulted in less foam. Acceptable levels of foam reduction did not occur until reaching near maximum recommended label rates. However, even the lowest setting used on the blender likely exceeded the agitation experienced within an herbicide spray tank. This would have increased the amount of defoamer needed in the laboratory simulation relative to an operational setting.

MANAGEMENT IMPLICATIONS

The products tested performed equally well. Either defoamer, when used at equivalent rates, should have the same effect at reducing foam amounts during the herbicide mixing and application process. At this date, Alenza Dry Defoamer is on the PA State Herbicide Contract and costs $0.19/oz. In comparison, the Arborchem Dry Defoamer is approximately $0.25/oz.

[3/] CWC Surfactant 90, CWC Chemical, Cloverdale, VA

Table 1: Measurements of foam column height (mm) for each treatment. Each value represents a single observation.

Treatment	Rate	Alenza	Arborchem
		Foam Column Height	
	oz/ac	mm	mm
CWC 90	0.25% v/v	65	65
Garlon 3A	48	75	75
Overdrive	4		
Escort XP	0.5		
CWC 90	0.25% v/v		
Defoamer	0.12 oz/100 gal		
CWC 90	0.25% v/v	62	60
Defoamer	0.12 oz/100 gal		
CWC 90	0.25% v/v	52	54
Defoamer	1 oz/100 gal		
CWC 90	0.25% v/v	46	50
Defoamer	2 oz/100 gal		
CWC 90	0.25% v/v	34	32
Defoamer	4 oz/100 gal		

RESPONSE OF BLACK LOCUST TO FOLIAR APPLICATIONS OF AMINOCYCLOPYRACHLOR

Herbicide trade and common chemical names: Arsenal (*imazapyr*), Escort XP (*metsulfuron methyl*), Krenite S (fosamine), MAT28 or KJM44 (*aminocyclopyrachlor*).
Plant common and scientific names: black locust (*Robinia pseudoacacia*), red oak (*Quercus rubra*), tulip poplar (*Liriodendron tulipifera*).

ABSTRACT

Aminocyclopyrachlor (MAT28, Dupont Crop Protection) is an experimental herbicide that was evaluated for control of black locust using foliar treatments. Treaments included three rates of aminocyclopyrachlor alone or in combination with standard broadleaf and brush control products for roadside management including Escort XP, Arsenal, or Krenite S. Rates of aminocyclopyrachlor ranged from 1 to 3 oz/ac. All treatments effectively controlled black locust.

INTRODUCTION

Aminocyclopyrachlor (MAT28, DuPont Crop Protection) is a broad-spectrum herbicide with selectivity to grasses, belonging to the new chemical class of pyrimidine carboxylic acids. In this trial, aminocyclopyrachlor was evaluated for use in foliar treatment alone or in combination with standard broadleaf and brush control products in control of black locust.

MATERIALS AND METHODS

The foliar trial targeted black locust along a recently constructed section of I-99 near State College, PA. The study was arranged in a completely randomized design with twelve treatments, with each treatment applied to five trees, ranging from 6 to 10 ft tall. The treatment volume for each tree was derived using estimated canopy area and a target application rate of 50 gal/ac. Treatments included an untreated check; 1 oz/ac aminocyclopyrachlor alone, or combined with either 0.5 oz/ac Escort, 4 oz/ac Arsenal, or 192 oz/ac Krenite S; 2 oz/ac aminocyclopyrachlor alone, or combined with either 1 oz/ac Escort, 4 oz/ac Arsenal, or 192 oz/ac Krenite S; 3 oz/ac aminocyclopyrachlor alone, or combined with 1.5 oz/ac Escort; and 128 oz/ac glyphosate. All herbicide treatments included methylated vegetable oil at 1.00 percent, v/v. Treatments were applied on July 4, 2008 using a CO_2-powered backpack sprayer equipped with a spray wand, TeeJet adjustable ConeJet nozzle, and X-6 tip. Percent control was visually rated September 10, 2008 and July 6, 2009, 68 and 367 days after treatment, DAT. The presence of first-year root sprouts was evaluated within a 10-ft proximity to the treated stems.

RESULTS AND DISCUSSION

All foliar treatments provided excellent control of black locust (100 percent), and no root sprouts were observed in the treated area. Trials conducted in 2007 compared similar treatments on black locust, red oak, and tulip poplar[1]. Black locust was controlled (99 to 100 percent), as well as tulip poplar (91 to 100 percent) and red oak (98 to 100 percent), with rates as low as 1 oz/ac aminocyclopyrachlor.

CONCLUSIONS

It is apparent that aminocyclopyrachlor has the ability to control a variety of tree species using foliar applications. Even the lowest rate of 1 oz/ac aminocyclopyrachlor provided complete control of black locust in this study.

MANAGEMENT IMPLICATIONS

DuPont Crop Protection, the manufacturer of this new chemistry, has recently announced the possible release of four products in 2010 that contain the active ingredient, aminocyclopyrachlor. Two of these premixes are well suited for brush control application. Streamline™ is a premix of aminocyclopyrachlor and Escort. Viewpoint™ is a premix of aminocyclopyrachlor, Escort, and Arsenal.

The small quantities of product necessary for control help from an operational perspective. It eases the transport and mixing, offers an opportunity to utilize injection systems, plus enhances production and safety to those using the product. These products, when labeled, will offer useful additions to the line of herbicides appropriate to the PennDOT weed and brush program. The new class of chemistry may provide an opportunity to alleviate the development of resistant biotypes by broadening the selection of products available for this application. More work is needed to determine the effectiveness of aminocyclopyrachlor on a variety of species, prescription rates of application, and possible tank mixes.

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[1] Response of black locust, red oak, and tulip poplar to foliar applications of DPX-KJM44. 2009. Roadside Vegetation Management Research - 2009 Report. http://vm.cas.psu.edu/2009/final2009.pdf

RESPONSE OF WOODY SPECIES TO CUT SURFACE APPLICATIONS OF AMINOPYRACHLOR

Herbicide trade and common chemical names: Garlon 4 (*triclopyr*), KJM44 (*aminocyclopyrachlor*), Stalker (*imazapyr*).
Plant common and scientific names: bigtooth aspen (*Populus grandidentata*), green ash (*Fraxinus pennsylvanica*), pin cherry (*Prunus pensylvanica L. f.*).

ABSTRACT

Aminocyclopyrachlor (KJM44, DuPont Crop Protection) is an experimental herbicide tested for efficacy on green ash, pin cherry, and bigtooth aspen for cut surface application. All three species were effectively controlled. Only one stump of green ash out of 10 replicates at the lowest rate of 2.5 percent v/v KJM44 produced resprouts. This research represents an initial evaluation of this product under a cut surface application regime. Additional research is required before this product would be labeled for this application method.

INTRODUCTION

Aminocyclopyrachlor (KJM44, DuPont Crop Protection) is an experimental broad-spectrum herbicide with selectivity to grasses, belonging to the new chemical class of pyrimidine carboxylic acids. It is a synthetic auxin that has both foliar and soil activity on a variety of broadleaf weed and brush species[1/]. In this trial, KJM44 (aminocyclopyrachlor) was evaluated for use in cut surface treatment of green ash, pin cherry, and bigtooth aspen.

MATERIALS AND METHODS

Cut surface treatments were applied to green ash, pin cherry, and bigtooth aspen within the infield of the SR 22/219S ramp in Ebensburg, PA. The trial was a completely randomized design with eight treatments and ten replications per species. Stems were up to 6 inches in diameter with some targets consisting of multiple stems. Treatments included an untreated check; 2.5, 5, 10, or 15 percent v/v KJM44; 30 percent v/v Garlon 4; 20 percent v/v Garlon 4 plus 1 percent v/v Stalker; or 10 percent v/v KJM44 plus 1 percent v/v Stalker. All treatments were diluted in commercial basal oil[2/]. Treatments were applied to stumps immediately after cutting on September 19 or 22, 2008, using a CO_2-powered sprayer equipped with a Spraying Systems 30 GunJet, TeeJet adjustable ConeJet nozzle, and Y-2 tip.

Stems were rated 297 and 362 days after treatment (DAT) for the presence of first-year resprouts from the stump. The initial stem diameter(s), as well as the diameter of all resprouts and their maximum height, were recorded, where present.

[1/] Rick, S.K., Turner, R.G. and Meredith, J.H. 2008. *Biology review of aminocyclopyrachlor.* Retrieved March 15, 2009 from http://www.weeds.iastate.edu/NCWSS2008/abstracts/202.pdf.
[2/] Arborchem Basal Oil (Arborchem Products, Mechanicsburg, PA).

RESULTS AND DISCUSSION

The cut surface trials yielded only one stump with sprouts among all the treated stems, regardless of treatment or species. Among treatments, resprouts occurred on a single green ash stump using the lowest rate of KJM44, 2.5 percent v/v. The untreated stumps of each species resprouted at the following percentages: green ash (100 percent), bigtooth aspen (70 percent), and pin cherry (30 percent).

Aminocyclopyrachlor has demonstrated its potential for use in cut surface applications. One concern discovered during the implementation of the trial was the limited solubility of KJM44 in basal oil. The KJM44 was difficult to mix with basal oil at the higher concentrations (e.g., 10 to 15 percent v/v) tested in this study.

CONCLUSIONS

Aminocyclopyrachlor has proven to be a candidate for a variety of broadleaf weed and brush control applications, including cut surface treatments. Since KJM44 has not been released to the market, it is uncertain whether the material will be labeled for cut surface application. Additional testing and evaluation of possible compatibility issues with the diluent will be required.

MANAGEMENT IMPLICATIONS

In 2010, DuPont Crop Protection is expected to make aminocyclopyrachlor available in several premix options for foliar weed and brush, turf growth regulator, and bareground weed control in non-crop areas. At this point, it is unknown whether any product combinations will be suitable or labeled for cut surface application.

KIXOR™/BAS80003H FOR SELECTIVE CONTOL OF KOCHIA AND MARESTAIL IN ROADSIDE TURF

Herbicide trade and common chemical names: BAS80003H/ Kixor™ (*saflufenacil*), Overdrive (*dicamba + diflufenzopyr*), Vista (*fluroxypyr*)
Plant common and scientific names: bluegrass (*Poa* spp.), Canada thistle (*Cirsium arvense*), common burdock (*Arctium minus*), common ragweed (*Ambrosia artemiisifolia*), dandelion (*Taraxacum officinale*), fine fescue (*Festuca rubra*), kochia (*Kochia scoparia*), marestail (*Conyza canadensis*), orchardgrass (*Dactylis glomerata*), plantain (*Plantago* spp.), plumeless thistle (*Carduus acanthoides*), tall fescue (*Festuca arundinacea*), wild carrot (*Daucus carota*).

ABSTRACT

BAS800/ Kixor™ is a new herbicide, intended for contact and residual control of broadleaf weeds, currently in development by the BASF Corporation. BAS80003H, the emulsifiable concentrate, was evaluated alone and in combination with Overdrive and Vista, both synthetic auxins, for selective weed control, targeting kochia and marestail, and for safety to roadside turf. At 6 days after treatment, DAT, treatments including BAS80003H caused significantly greater injury to kochia (67 to 87 percent) and marestail (90 to 99 percent) than Overdrive or Vista alone. The addition of BAS80003H significantly improved control provided by both Overdrive and Vista at 14 DAT; however, there were no significant differences in kochia control (58 to 73 percent) among the treatments containing BAS80003H. BAS80003H at the lower rate of 2.85 oz/ac combined with Overdrive resulted in limited and unacceptable control of kochia at 37 percent. All BAS80003H treatments provided excellent marestail control (90 to 100 percent). None of the treatments caused noteworthy injury to turf at 28 DAT. At 57 DAT, no significant differences in kochia cover were observed among treatments; however, all reduced kochia significantly compared to the untreated check. Overall, Kixor™ has proven effective as a selective, post-emergence treatment for control of both kochia and marestail; for resilient species like kochia, rates of 5.7 oz/ac or more tended to provide better control, and high carrier volumes (e.g., 40 to 50 gal/ac) are also expected to increase control.

INTRODUCTION

BAS800/ Kixor™ is a new herbicide, developed by the BASF Corporation, that has been approved for agricultural use but is currently in development for release to the non-crop market. Kixor™ is intended for foliar and residual control of broadleaf weeds. *Saflufenacil*, the active ingredient in Kixor™, is a protoporphyrinogen-IX-oxidase (PPO) inhibitor belonging to the pyrimidinedione class of chemistry. Translocated primarily through the xylem, Kixor™ is absorbed by plant roots, shoots, and leaves. Kixor™ is intended for use alone or mixed with glyphosate for broad-spectrum control of dicot weeds and grasses, including those resistant to glyphosate and ALS-inhibitors. Most perennial grass species appear to be tolerant of Kixor™[1/].

[1/] BASF Agricultural Products. 2008. Kixor Herbicide Worldwide Technical Brochure.

BAS80003H, an emulsifiable concentrate, was evaluated alone and in combination with Overdrive and Vista, both synthetic auxins, for selective weed control, targeting kochia and marestail, and for safety to roadside turf.

MATERIALS AND METHODS

The trial was established in the interior of the median at the I-99/SR26 interchange in Bellefonte, PA. Plots 9 by 15 ft in size were arranged in a randomized complete block design with three replications. Treatments were as follows: BAS80003H alone at either 2.85, 5.7, or 11.4 oz/ac; BAS80003H at 2.85 oz/ac plus either Overdrive at 4 or Vista at 16 oz/ac; BAS80003H at 5.7 plus Overdrive at 4 oz/ac; Overdrive alone at 4 oz/ac; and Vista alone at 16 oz/ac. All treatments included methylated seed oil at 1.0 percent v/v, except for an untreated check. Treatments were applied on June 10, 2009, using a CO_2-powered backpack sprayer with 9-ft boom, equipped with six TeeJet 8002 VS tips at 25 psi. The targeted application rate was 20 gal/ac.

The plots were rated on June 10, 16, and 24, July 8, and August 6, 2009, which correspond to 0, 6, 14, 28, and 57 days after treatment, DAT, respectively. Total, kochia (KCHSC), and marestail (ERICA) cover were assessed at 0, 28, and 57 DAT. Percent injury (0 = no injury, 50 = moderate injury/defoliation, 100 = death) and percent control (0 = no control and 100 = complete control) were determined at 6 and 14 DAT, respectively. Cover ratings were given in the place of percent control beyond 14 DAT due to regrowth of small kochia seedlings and potential germination of new plants. Turf injury was rated 28 DAT (0 = no injury and 10 = death). Total vegetative cover ratings are reported for control plots.

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 Fisher's Protected LSD.

RESULTS AND DISCUSSION

Plots were selected to encompass both kochia, which was growing in the bareground area immediately inside the guiderail, and turf cover. The average kochia height at the time of application was 2.5 in, with larger plants reaching 4 to 5 in. Other weedy broadleaf species present included Canada thistle, common burdock, common ragweed, dandelion, plantain, plumeless thistle, and wild carrot. Turf was a mix of tall fescue, fine fescue, an unidentified bluegrass species, and orchardgrass. At 6 DAT, all treatments containing BAS80003H produced significantly higher injury to kochia (67 to 87 percent) and marestail (90 to 99 percent) than either Overdrive or Vista alone (Table 1). Therefore, BAS80003H appears to cause more rapid injury symptoms than the synthetic auxins. Kochia control was also poorest for Overdrive and Vista alone (13 and 17 percent, respectively) at 14 DAT. The addition of BAS80003H significantly improved the performance of both Overdrive and Vista. There were no significant differences in kochia control (58 to 73 percent) among the treatments containing BAS80003H, except for BAS80003H at the lower rate of 2.85 oz/ac combined with Overdrive (37 percent). Though none of the treatments was strong against kochia at 14 DAT, all BAS80003H treatments provided excellent marestail control (90 to 100 percent). None of the treatments caused noteworthy injury to turf at 28 DAT. The treatments produced statistically similar kochia cover at 28 DAT (1 to 5 percent) and 57 DAT (3 to 9 percent), although all treatments had significantly less kochia cover than the untreated check. For marestail, Vista alone had significantly higher cover (4 percent) than all other treatments (0 to 1 percent) at 57 DAT; however, the addition of BAS80003H decreased cover to 1 percent.

CONCLUSIONS

Higher carrier volumes (i.e., greater than 20 gal/ac) should increase kochia control beyond the maximum of 73 percent observed here. Good coverage is essential for optimal control of hardy species like kochia. Control ratings (14 DAT) were equal to or lower than injury ratings (6 DAT) since some kochia plants appeared to recover from the initial injury. The addition of BAS80003H increased initial injury and control compared to Overdrive and Vista applied alone, but kochia cover was not significantly different among the treatments at 28 or 57 DAT. For marestail control, BAS80003H significantly improved the initial performance of both Overdrive and Vista. BAS80003H appeared safe to the grass species present at rates up to 11.4 oz/ac.

MANAGEMENT IMPLICATIONS

Kixor™ has proven effective as a selective, post-emergence treatment for control of both kochia and marestail; for resilient species like kochia, rates of 5.7 oz/ac or more tended to provide better control, and higher carrier volumes (e.g., 40 to 50 gal/ac) are also expected to increase control. Kixor™ also appears to be safe to common cool-season industrial turfgrasses at rates up to 11.4 oz/ac. In order to provide broad-spectrum control, Kixor™ may be combined with *glyphosate*[2/]. It is currently unknown when Kixor™ will be available to the non-crop market.

[2/] BASF Agricultural Products. 2008. Kixor Herbicide Worldwide Technical Brochure.

Table 1. Total, kochia ("KCHSC"), and marestail ("ERICA") visual ratings were collected on June 10, 16, and 24, July 8, and August 6, 2009, which correspond to 0, 6, 14 28, and 57 days after treatment, DAT, respectively. Treatments were applied to a roadside guiderail location in Bellefonte, PA on June 10, 2009. All treatments included methylated seed oil at 1.0 percent v/v, except for the untreated check. Each value is the mean of three replications. Differences between means were considered statistically significant at $p \leq 0.05$. ns = not significant.

		0 DAT			6 DAT		14 DAT		28 DAT			57 DAT	
		Total	KCHSC	ERICA	KCHSC	ERICA	KCHSC	ERICA	KCHSC	ERICA	TURF	KCHSC	ERICA
Treatment	Rate		Cover		Injury		Control		Cover	Cover	Injury	Cover	
	oz/ac	%											
untreated	---	65	14	2	0	0	0	0	12	3	0	17	4
BAS 80003H	2.85	53	9	3	77	90	60	93	5	0	0	9	0
BAS 80003H	5.7	55	6	1	87	99	72	100	2	0	0	6	0
BAS 80003H	11.4	57	12	1	83	98	68	100	5	0	0	9	0
Overdrive	4	42	6	2	43	43	13	17	4	1	0	4	1
BAS 80003H Overdrive	2.85 4	47	7	1	67	98	37	99	4	0	7	7	0
BAS 80003H Overdrive	5.7 4	65	9	1	67	99	58	100	4	0	0	7	0
Vista	16	58	8	2	37	15	17	10	5	2	7	3	4
BAS 80003H Vista	2.85 16	53	10	2	73	91	73	90	1	0	0	8	1
Protected LSD		ns	ns	ns	15	12	18	15	5	2	ns	7	3

COMPARISON OF JAPANESE KNOTWEED CONTROL METHODS

Herbicide trade and common chemical names: AquaMaster, AquaNeat, Rodeo, Roundup, Roundup Pro Concentrate (*glyphosate*).
Plant common and scientific names: Japanese knotweed (*Polygonum cuspidatum* = *Fallopia japonica*).

ABSTRACT

Japanese knotweed is an invasive herbaceous perennial that invades roadsides and riparian areas, becoming a visibility hazard for motorists, destroying pavement as it spreads, and resulting in control strategy problems when arising and spreading near bodies of water. Three Japanese knotweed control methods were established as a demonstration of the methods and efficacy. The three treatment scenarios were: (1) mechanical cutting or (2) "chemical mowing" on July 2, followed by a foliar application of glyphosate to regrowth on September 15, 2008; and (3) an injection treatment using glyphosate. All three operations provided greater than 90 percent reduction of the knotweed stand the subsequent year at 261 days after treatment, DAT. Each method carries its own constraints including terrain limitations, application time limitations, and rate. Foliar treatments provide practical time management benefits, whereas mechanical cutting can be limited by terrain, access and injection can be time consuming, and application rate limitations are readily reached.

INTRODUCTION

Japanese knotweed (knotweed) is a rhizomatous, herbaceous perennial native to East Asia. The plant spreads vigorously, forming dense monotypic stands up to 10 ft tall. Knotweed is problematic when close to the roadway because it reduces sight distance and can penetrate asphalt. These plants are prone to spread to or from adjacent properties and often occur near waterways.

Treatment of knotweed growing adjacent to surface water is difficult because it is necessary to ensure the herbicide does not contact the water. The use of successive foliar or mechanical then foliar treatment combinations during the same growing season is recommended for initial control of knotweed[1/]. A mechanical cutting (targeting June 1) or foliar herbicide treatment (targeting late April through May) will deplete root reserves, regain sight distance (if needed), reduce height of the stand, and prevent seed production. The diminished stand makes a subsequent late-season foliar treatment easier. Glyphosate has been demonstrated to effectively control knotweed during late summer to killing frost.[2/] Another option is the use of an injection system. Undiluted glyphosate is administered to each stem using a calibrated injection unit; however, this method requires use of an herbicide labeled for injection. The injection unit

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[1/] Factsheet 5: Managing Japanese Knotweed and Giant Knotweed on Roadsides. 2005. http://vm.cas.psu.edu/Publications/FS_5_POLCU.pdf
[2/] Control of Japanese Knotweed with Late-Season Foliar Herbicide Applications. 2006. Roadside Vegetation Management Research Report – Nineteenth Year Report. http://vm.cas.psu.edu/2005/final2005.pdf

applies a prescribed dosage of glyphosate into each stem through a needle and metered trigger pistol. Several glyphosate products have received the required supplemental labeling, including: AquaNeat, AquaMaster, Roundup Pro Concentrate, Roundup, and Rodeo.

This demonstration compares the knotweed control methods available for a variety of settings, including near surface water.

MATERIALS AND METHODS

This demonstration was located at a park-n-ride near the intersection of SR 202/SR 29 in Chester County, PA. Four plots were established to evaluate the success of three treatments compared to an untreated check. Plot size varied from 408 to 420 sq ft. Treatments included two sequential foliar applications, July 2 and September 15 (dual spray); a mechanical cutting on July 2, followed by a September 15 foliar application (cut then spray); and individual stem injection on September 15. Roundup Pro Concentrate, a surfactant-loaded product, was applied at 104 oz/ac for all foliar herbicide treatments. Foliar treatments were applied using a motorized backpack sprayer equipped with a Spraying Systems 30 GunJet, TeeJet adjustable ConeJet nozzle, and X-18 tip. The targeted carrier volume was 300 gal/ac. The injection treatment targeted stems greater than 0.25 in using a JK Injection System[3/] with a short, late-season needle calibrated for 5 mL/stem. A total of 920 mL undiluted AquaNeat was used during the injection treatment. This would equate to 25.2 gal/ac if an entire acre were treated. The dual-spray and cut-then-spray plots were observed for injury symptoms, knotweed height, and presence of flowers on September 15, 2008, 75 days after treatment, DAT, and all treatments were evaluated for percent reduction in knotweed cover and percent cover by knotweed sprouts on June 3, 2009, 261 DAT.

RESULTS AND DISCUSSION

As of September 15, 2008, glyphosate-treated knotweed had some chlorotic and necrotic leaves but was mostly green, ranging from 8 to 10 ft in height. Knotweed height was reduced to 3 or 4 ft by the July cutting treatment, which made follow-up treatment easier; however, the targeted application rate of 300 gal/ac was excessive for the limited foliar area of this stand. Flowering occurred with the glyphosate-treated knotweed but not for the July cutting treatment.

The site was visited on June 3, 2009, 261 DAT, to evaluate all treatments. The front portion of each plot had been eliminated due to unforeseen construction activity. However, enough knotweed remained to provide a fair assessment of each treatment. The dual-spray plot resulted in 99 percent reduction in knotweed cover and 1 percent cover by knotweed sprouts up to 3 ft tall. The cut-then-spray plot resulted in 90 percent reduction in knotweed cover and 1 percent cover by knotweed sprouts up to 4 ft tall. Lastly, the injection treatment had 99 percent reduction in knotweed cover and 1 percent cover by knotweed sprouts up to 4 ft tall. However, injection was a tedious method that took approximately 50 minutes, compared to 5 minutes to treat similar areas using foliar sprays.

[3/] JK Injection Systems, JK International, LLC, Snohomish, WA.
http://www.jkinjectiontools.com

CONCLUSIONS

All three methods resulted in significant reduction of the knotweed stand. The dual-spray treatment is a practical approach to address larger areas that can be targeted with foliar sprays. The cut-then-spray method is an alternative where terrain allows for mowing, or brush saws could be used. This is an especially viable approach near water. Reduction of the stand height allows for a lower carrier volume follow-up treatment and therefore reduces the potential for herbicide to move off-target and into water. The injection method also provides a low-profile alternative to high-volume foliar applications. It is a time-consuming application and limited to treating smaller infestations. More herbicide is applied on a per-acre basis and caution must be used to avoid exceeding the label limits of herbicide applied on a per-acre basis.

MANAGEMENT IMPLICATIONS

The use of either dual-spray or cut-then-spray methods provides an efficient approach to knotweed management. Glyphosate or standard weed and brush herbicides, like Garlon 3A or Vanquish plus Escort XP, are options for the early herbicide treatment. This treatment can be incorporated into ongoing herbicide applications from late April through May. This herbicide treatment will restore sight distance and stunt the knotweed. Mowing should be targeted during June or early July to allow the knotweed enough time to regain sufficient growth for an herbicide application but prevent it from reaching mature height and producing seed. Glyphosate can then be applied to previously treated or cut knotweed from August 1 to the first killing frost. Glyphosate is the most effective herbicide for the subsequent follow-up treatment using either method[4/]. In the long term, competitive grass groundcover should be seeded to suppress regrowth of knotweed from existing rhizomes.[5/] At this point, only selective, broadleaf herbicides should be used for treatment in order to preserve the desirable grasses.

[4/] Control of Japanese Knotweed with Late-Season Foliar Herbicide Applications. 2006. Roadside Vegetation Management Research Report – Nineteenth Year Report. http://vm.cas.psu.edu/2005/final2005.pdf

[5/] Update: Replacing a Giant Knotweed Infestation With Fineleaf Fescues. 2006. Roadside Vegetation Management Research Report – Nineteenth Year Report. http://vm.cas.psu.edu/2005/final2005.pdf

JAPANESE KNOTWEED CONTROLLED WITH GLYPHOSATE OR TRICLOPYR APPLIED SEQUENTIALLY OR FOLLOWING CUTTING

Herbicide trade and common chemical names: Aquaneat (*glyphosate*), Garlon 3A (*triclopyr*)
Plant common and scientific names: Japanese knotweed (*Polygonum cuspidatum* = *Fallopia japonica*)

ABSTRACT

While glyphosate provides a standard for Japanese knotweed control, the effectiveness of triclopyr against this herbaceous perennial plant has been questioned. Japanese knotweed was managed with five different two-operation treatments in 2008 and evaluated in 2009. Cutting alone reduced height and increased stem density but resulted in no significant difference in fresh weight biomass compared to untreated plots. Glyphosate (3 lb ae/ac) applied twice, in July and September at 3 qt/ac; or applied in September at 3 qt/ac following a June cutting, resulted in the least amount of regrowth and lowest stem densities. Triclopyr (3 lb ae/ac) applied at a rate of 4 qt/ac in the same treatment scenario as glyphosate resulted in significantly higher stem densities than glyphosate treatments but fresh weights that were higher yet not significantly different. Therefore, triclopyr offers a useful alternative to glyphosate when the preservation of desirable grasses is a priority.

INTRODUCTION

Japanese knotweed is a rhizomatous, herbaceous perennial that grows in tall, dense stands that impede motorist sight distance and access to roadside areas. Previous trials have demonstrated the utility of glyphosate applied to intact knotweed late in the growing season[1], in addition to well-developed knotweed regrowth[2] following a June cutting. Glyphosate has no soil activity, has aquatic labeling, and is familiar to consumers. It is also non-selective, so care is required to limit injury to non-target plants. In previous trials, single applications of triclopyr have been ineffective against knotweed[1]. However, triclopyr is largely safe to grasses and is available in aquatic-labeled products. Therefore, development of a viable control program using triclopyr would provide reduced environmental risk, similar to glyphosate, in addition to a grass-safe option that would facilitate establishment of desirable groundcover. The objective of this trial was to evaluate triclopyr in a two-operation treatment to determine its effectiveness relative to glyphosate.

MATERIALS AND METHODS

The study was located at Milton State Park, an island in the West Branch of the Susquehanna River, between Milton and West Milton, PA. Plots were 15 by 25 ft, arranged in a

[1] Gover, A.E., et al. 2005. Control of Japanese Knotweed with Late-season Foliar Herbicide Applications. Roadside Vegetation Management Research Report – 19th Year Report. Pages 20-22. http://vm.cas.psu.edu/2005/final2005.pdf

[2] Johnson, J.M., et al. 2007. Evaluation of Herbicides for Control of Japanese Knotweed. Proceedings of the Northeast Weed Science Society. 61: 74-75. (http://www.newss.org/proceedings/proceedings_2007.pdf)

randomized complete block with three replications. The treatments included an untreated control, cutting twice, cutting followed by application of Aquaneat at 3 qt/ac or Garlon 3A at 4 qt/ac, or two applications of Aquaneat at 3 qt/ac or Garlon 3A at 4 qt/ac. The twice-cut plots were cut to the ground June 18 and July 21, 2008; the cut-then-spray plots were cut to the ground June 18 and sprayed September 30, 2008; and the twice-sprayed plots were treated July 21 and September 30, 2008. The July herbicide treatments were applied at a total volume of 185 gal/ac, and the September treatments to regrowth were applied in a total of 92 gal/ac. Each application included surfactant[3] at 2 qt/ac. The herbicide treatments were mixed for each plot and applied with a CO_2-powered sprayer equipped with a TeeJet #5500 Adjustable ConeJet nozzle with an X-18 tip for the July applications and an X-12 tip for the September applications. The intact knotweed canopy heights ranged from 7 to 13 ft. Two of the replications were on the east side of a wide north-south trail and received more light. These plots had 10 to 13 ft canopies. The third replication was on the west side of the trail, was shaded in the afternoon, and had 7 to 8 ft canopies. After cutting, the knotweed in the September-sprayed plots regrew to 3 to 5 ft.

Initial stem counts were taken for each plot in a 5 by 5 ft sub-plot prior to initiation of treatments on May 18, 2008. Response data included a visual rating of percent canopy reduction on May 8, 2009, and a fresh weight harvest and stem count of the sub-plot on June 2, 2009. Data were subjected to analysis of variance. Four plots in one of the replications were lost due to a tree fall, so means comparisons had to account for unequal replication.

RESULTS AND DISCUSSION

Knotweed response to the 2008 treatments is summarized in Table 1. There were no significant differences between pre-treatment stem counts. The untreated plots averaged 13 stems/square yard (SY) on May 22, 2008 and 12 stems/SY with 9.9 lb fresh wt/SY on June 2, 2009. The twice-cut plots changed from 16 to 23 stems/SY after treatment, were rated at 30 percent canopy reduction, and averaged a fresh weight of 8.9 lb/SY on June 2, 2009. The stem density in the twice-cut plots was significantly higher than in the untreated, but the fresh weights were not significantly different. Therefore, the cutting regimen created a shorter, denser stand of knotweed the following season.

The herbicide-treated plots averaged 90 to 99 percent canopy reduction on May 8, 2009, with no significant differences among the four treatments. All herbicide treatments resulted in significantly greater canopy reduction than the twice-cut treatment and significantly reduced fresh weight harvest compared to no treatment or cutting alone. The Garlon 3A-treated plots (2.5, 2.4 lb/SY) averaged more fresh weight than the Aquaneat plots (0.6, 0.3 lb/SY), but there were no significant differences among the herbicide treatments. Post-treatment stem counts revealed higher stem densities among Garlon 3A-treated plots than Aquaneat-treated plots with no significant difference compared to untreated plots.

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[3] Competitor® Modified Vegetable Oil, Wilbur Ellis Company.

CONCLUSIONS

Both glyphosate and triclopyr provided good control of Japanese knotweed. Contrary to the poor results produced by a single, early-September triclopyr application[4], triclopyr was effective as part of a two-step control operation. There appeared to be a relative increase in biomass in triclopyr-treated plots compared to glyphosate-treated plots between the May 8 visual rating and the June 2 sub-plot harvest; however, visual ratings of canopy reduction were not collected during that time interval. This trial was repeated in 2009, and 2010 data collection will include multiple visual ratings and stem counts, as well as a later fresh weight harvest to determine if triclopyr-treated plots show more regrowth than glyphosate-treated plots through the season.

MANAGEMENT IMPLICATIONS

In a multiple-operation control program, triclopyr provides a useful alternative to glyphosate. This provides managers two aquatic-labeled, low soil-residue herbicide options. Triclopyr provides the option to selectively suppress knotweed while preserving grasses, which facilitates reclamation of knotweed infestations through a program of grass seeding and selective herbicide follow-up treatments.

[4] Gover, A.E., et al. 2005. Control of Japanese Knotweed with Late-season Foliar Herbicide Applications. Roadside Vegetation Management Research Report – 19th Year Report. Pages 20-22. http://vm.cas.psu.edu/2005/final2005.pdf

Table 1. Japanese knotweed was subjected to two control operations during 2008. Twice-cut plots were cut June 18 and July 21. Twice-sprayed plots were treated July 21 and September 30, and cut-then-spray plots were treated June 18 and September 30. Pre-treatment stem counts were taken May 18, 2008, and post-treatment stem counts were taken June 2, 2009. Percent canopy reduction was rated May 8, and sub-plot fresh weight was measured June 2, 2009. Column means followed by the same letter are not significantly different according to Fisher's Protected LSD test. A single LSD value could not be used due to unequal replications because four plots were lost due to a tree fall. Means are the average of two or three replications. SY = square yards.

Treatment	May 18, 2008 Stem Count	May 8, 2009 Canopy Reduction	June 2, 2009 Stem Count	June 2, 2009 Fresh Weight
	Stems/SY	%	Stems/SY	lb/SY
Untreated	13	0 c	12 b	9.9 a
Cut twice	16	30 b	23 a	8.9 a
Aquaneat 2X	13	99 a	2 c	0.6 b
Garlon 3A 2X	15	90 a	8 b	2.5 b
Cut/Aquaneat	12	90 a	1 c	0.3 b
Cut/Garlon 3A	15	94 a	11 b	2.4 b

SELECTIVE WEED CONTROL IN TURF

Herbicide trade and common chemical names: Garlon 3A (*triclopyr*), Milestone VM (*aminopyralid*), Milestone VM Plus (*aminopyralid* + *triclopyr*), Overdrive (*dicamba* + *diflufenzopyr)*.

Plant common and scientific names: common evening-primrose (*Oenothera biennis*), crownvetch (*Coronilla varia*), yellow nutsedge (*Cyperus esculentus*), yellow rocket (*Barbarea vulgaris*), yellow woodsorrel (*oxalis stricta*).

ABSTRACT

The common use of crownvetch as a low-maintenance ground cover in difficult terrain and poor soil quality sites along roadways has resulted in the mechanical and natural spread of crownvetch seed into adjacent low-maintenance turf sites. Selective herbicides are commonly employed to eliminate the crownvetch on these sites and to prevent further invasive spread into the roadway right-of-way. This demonstration project was designed to provide a side-by-side comparison of the efficacy of three post-emergence herbicide treatments with aminopyralid, the active ingredient in Milestone VM applied to a stand of crownvetch and adjacent turf in fall 2008. Milestone VM at 7 oz/ac (equivalent to 1.75 oz aminopyralid/ac) was compared with both Milestone VM Plus at 128 oz/ac (1.6 oz aminopyralid/ac plus 16 oz triclopyr/ac) and the combination of Milestone at 7 oz/ac with Overdrive at 4 oz/ac. The treatments were evaluated the following season, 238 days after treatment, DAT, for vegetative cover in the crownvetch stand and damage to turf. All herbicides provided complete control of crownvetch and safety to tall fescue; however, broadleaf weeds, mostly yellow rocket with 35 percent vegetative cover, was present on the areas treated with Milestone VM alone. Both the combination of Milestone VM and Overdrive or Milestone VM Plus alone resulted in 5 percent or less vegetative cover. Milestone VM is a valuable tool for selective weed control on the roadside; however, combinations such as Garlon 3A or Overdrive would be helpful in providing broad spectrum control and preventing release of herbicide-tolerant species such as plants in the mustard family.

INTRODUCTION

Small patches of crownvetch have appeared on areas of the roadside right-of-way that originally had been seeded to grasses. Although crownvetch has been widely utilized as a low-maintenance groundcover, its presence in turf is undesirable and likely results from improper cleaning of hydroseeding units. In other words, residual crownvetch seeds can effectively contaminate a hydroseeder and grass mix, leading to immediate weed problems. Aminopyralid, the active ingredient in Milestone VM, has shown excellent activity against crownvetch and other broadleaf weeds. However, Milestone VM alone has shown weakness against weeds in the mustard family. Therefore, Milestone VM is typically mixed with other broadleaf chemistry to improve its spectrum of control. As another option, Milestone VM Plus is a premix of aminopyralid and triclopyr, the active ingredient in Garlon 3A.

This project represents a side-by-side demonstration of aminopyralid-containing herbicides alone or as a combination or tank-mixed version to show the effective control of crownvetch and other broadleaf weeds, as well as safety to turf.

MATERIALS AND METHODS

The treatments were applied along the off-ramp of the SR 476N/SR30 interchange near Radnor, PA and included 7 oz/ac Milestone VM alone, 7 oz/ac Milestone VM combined with 4 oz/ac Overdrive, and 128 oz/ac Milestone VM Plus alone. All treatments included 0.5 percent v/v CWC 90 surfactant. The treated area was an embankment of crownvetch and included a stand of tall fescue along the length of the plots. The area was divided into three plots that varied in size from 3,900 to 4,100 sq ft. Each treatment was applied to a single plot. The targeted carrier volume was 80 gal/ac. Treatments were applied on October 8, 2008, using a hydraulic sprayer, equipped with a piston pump, hose, and TeeJet Lawn Spray Gun with Spraying Systems 25670-1.5 tip. Visual ratings of turf injury and percent vegetative cover were taken June 3, 2009, 238 days after treatment, DAT.

RESULTS AND DISCUSSION

At 238 DAT, all treatments had completely eliminated the crownvetch, and no turf injury was evident among the treatments. The 7 oz/ac Milestone VM treatment area contained 35 percent vegetative cover, 7 oz/ac Milestone VM combined with 4 oz/ac Overdrive had 5 percent cover, and 128 oz/ac Milestone VM Plus had 1 percent cover. The Milestone VM alone plot was dominated by yellow rocket with lesser amounts of yellow woodsorrel and yellow nutsedge. Species common to the other treatments included prickly lettuce and common evening-primrose.

CONCLUSIONS

Aminopyralid was effective for control of crownvetch but released yellow rocket when used alone. Aminopyralid is known for weakness against yellow rocket and other members of the mustard (*Brassicaceae*) family. Aminopyralid alone at 7 oz/ac and in combination with either triclopyr, the active ingredient in Garlon 3A, or Overdrive was safe to tall fescue. The addition of either triclopyr or Overdrive to Milestone VM also provided a better spectrum of control in the following growing season.

MANAGEMENT IMPLICATIONS

Milestone VM has caused significant, long-term injury to crownvetch and dramatic initial, but temporary, injury to Canada thistle in other studies.[1/] Therefore, Milestone VM is a valuable tool for selective weed control on the roadside. Milestone VM should be used in combination with another broadleaf herbicide, such as Garlon 3A or Overdrive, to broaden its control spectrum and avoid releasing tolerant species, such as plants in the mustard family. Milestone VM tank mixes can be used to selectively target crownvetch in established turf or to eliminate a crownvetch stand in preparation for conversion to grasses. The treatment of Milestone VM Plus at 128 oz/ac used in this demonstration is equivalent to a tank mix of Milestone VM with Garlon 3A at 6.4 and 43 oz/ac, respectively.

[1/] Comparing grass-Safe Herbicides for Converting Canada thistle Infested Crownvetch to Formula L. 2009. Roadside Vegetation Management Research – 2009 Report.

The Milestone VM and Milestone VM Plus labels contain precautionary statements. These include not applying within the root zone of desirable trees, avoiding drift to desirable broadleaf plants, and applying only on perennial grass stands that are well established. Nevertheless, products and tank mixes containing aminopyralid can be used safely and effectively for broadleaf weed control to established perennial grasses on the roadside. When reseeding or converting an area to grasses, Milestone VM or Garlon 3A should be applied at least 15 days prior to seeding and Overdrive (dicamba) at least 30 days prior to ensure germination of the grasses is not inhibited by the herbicide.[2/]

[2/] Effect on Grass Seed Establishment and Weed Control With Several Broadleaf Herbicides. 2008. Roadside Vegetation Management Research Report – 2008 Report.

AMINOCYCLOPYRACHLOR FOR BAREGROUND AND SUPPRESSION OF KOCHIA

Herbicide trade and common chemical names: Authority (*sulfentrazone*), Chateau (*flumioxazin*), Krovar (*bromacil + diuron*), Karmex (*diuron*), Landmark (*sulfometuron + chlorsulfuron*), MAT28 (*aminocyclopyrachlor*), Oust (*sulfometuron*), Oust Extra (*sulfometuron + metsulfuron*), Roundup (*glyphosate*).

Plant common and scientific names: barnyardgrass (*Echinochloa crus-galli*), Canada thistle (*Cirsium arvense*), common ragweed (*Ambrosia artemisiifolia*), kochia (*Kochia scoparia*), marestail (*Conyza canadensis*), prostrate knotweed (*Polygonum aviculare*), yellow foxtail (*Setaria glauca*).

ABSTRACT

MAT28 was applied alone and in combination with other bareground herbicides to evaluate its effectiveness for total vegetation control, and specifically, for control of the herbicide-resistant species kochia and marestail. By 85 days after treatment, DAT, plots treated with MAT28 alone had significantly higher total cover (20 to 30 percent) than plots treated with MAT28 plus an additional broad-spectrum component (1 to 14 percent). Therefore, MAT28 is not suitable alone as a bareground product. In the interval between 85 and 121 DAT, total cover increased the most on plots treated with MAT28 plus a sulfonylurea herbicide (e.g., Oust, Oust Extra, Landmark), except for the treatment containing Authority (*sulfentrazone*), which remained the lowest at 3 percent. Kochia cover followed the same trend, resulting in lower kochia cover on plots treated with MAT28 alone than when combined with a sulfonylurea component. It is likely that competition from other plant species was responsible for kochia suppression in the MAT28 alone treatments. Of the tank mixes, the combination of MAT28 at 7.5 oz/ac plus Oust at 3 oz/ac with either Karmex at 16, Chateau at 10, or Authority at 8 oz/ac provided the best control of kochia through 168 days (0 to 1 percent kochia cover) as well as total vegetation control (5 to 9 percent cover). By end of season, the MAT28 only plots were dominated by annual grasses, mostly yellow foxtail and barnyardgrass. Marestail was present throughout the site, but pressure was not great enough to result in any significant differences among treatments.

INTRODUCTION

Kochia is one of the most challenging species to control in roadside bareground areas. This annual, broadleaf species thrives in harsh environments, reaches heights over 6 ft, and has developed widespread resistance to ALS- and photosystem II inhibitors[1]. Isolated reports of biotypes resistant to synthetic auxins[1] (populations located in Montana, North Dakota, Idaho), glyphosate[1] (Kansas), and diuron[2] (North Dakota, Minnesota) have also been confirmed. Therefore, new chemistry is needed to help control this troublesome weed. MAT28 (*aminocyclopyrachlor*) is being promoted as a broad-spectrum herbicide with selectivity to grasses, belonging to the new chemical class "pyrimidine carboxylic acids." It should be noted that KJM44 was an early-stage experimental formulation of the same active ingredient. MAT28

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[1] Heap, I. International Survey of Herbicide Resistant Weeds. Accessed March 2, 2009 <www.weedscience.com>.

[2] Mengistu et al. 2005. A psbA mutation in Kochia scoparia (L) Schrad from railroad rights-of-way with resistance to diuron, tebuthiuron and metribuzin. Pest Manag Sci 61, 1035-1042.

is in development by DuPont and has shown the potential to control resistant kochia biotypes; it is currently thought to act as an auxin mimic. In addition to kochia, MAT28 provides both postemergence and soil residual activity on many annual and perennial broadleaf weeds and brush species.

MAT28 was applied alone and in combination with other bareground herbicides to evaluate its effectiveness for total vegetation control, and specifically, for control of kochia and marestail, another annual weed with herbicide-resistant biotypes[1].

MATERIALS AND METHODS

The trial was established along the median guiderail of I-99 in Altoona, PA. Plots 4 by 25 ft in size were arranged in a randomized complete block design with three replications. Treatments were as follows: MAT28 alone at either 5.8, 7.5, or 9.2 oz/ac; MAT28 at 6.0 oz/ac mixed with Oust Extra at 4.0 oz/ac; MAT28 mixed with Landmark at three respective dosage combinations, 5.8 plus 3.4, 7.5 plus 4.5, and 9.2 plus 5.6 oz/ac; MAT28 at 7.5 oz/ac plus Oust at 3 oz/ac mixed with either Karmex at 16, Chateau at 10, or Authority at 8 oz/ac; and Krovar at 128 oz/ac. All treatments included Roundup (4 lb ae/gal) at 64 oz/ac and nonionic surfactant at 0.25 percent v/v, except for an untreated check. Treatments were applied on April 27, 2009 using a CO_2-powered backpack sprayer with ULV wand, equipped with a Floodjet 10 nozzle at 29 psi. The targeted application rate was 30 gal/ac.

Total, kochia, and marestail percent cover were visually rated on May 18 (21 days after treatment, DAT), May 30 (33 DAT), July 21 (85 DAT), August 26 (121 DAT), and October 12, 2009 (168 DAT). A final 360 DAT rating is scheduled for late spring 2010.

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 Fisher's Protected LSD.

RESULTS AND DISCUSSION

A white precipitate formed when mixing MAT28 plus Landmark; however, it did not appear to interfere with the broadcasting of the treatment. Kochia, Canada thistle, prostrate knotweed, and common ragweed were present at the time of application. All treatments reduced total cover to less than 1 percent by 21 DAT (Table 1). By 85 DAT, plots treated with MAT28 alone had significantly higher total cover (20 to 30 percent) than plots that received an additional broad-spectrum component (1 to 14 percent). Therefore, MAT28 is not suitable alone as a bareground product. There were no significant differences in kochia cover (0 to 7 percent) or marestail cover (0 percent for all treatments and untreated check; data not shown) at 85 DAT. In the interval between 85 and 121 DAT, total cover increased the greatest amount on plots treated with MAT28 plus a sulfonylurea herbicide (e.g., Oust, Oust Extra, Landmark), except for the treatment containing Authority (*sulfentrazone*), which remained the lowest at 3 percent. Kochia cover followed the same trend, with MAT28 alone treatments at 0 to 2 percent and MAT28 mixes ranging from 0 to 10 percent. It is likely that competition from other plant species was responsible for kochia suppression in the MAT28 alone treatments. Of the tank mixes, the combination of MAT28 at 7.5 oz/ac plus Oust at 3 oz/ac with either Karmex at 16, Chateau at 10, or Authority at 8 oz/ac provided the best control of kochia through 168 days (0 to 1 percent kochia cover) as well as total vegetation control (5 to 9 percent cover). These three treatments provided equal or better control than the standard, Krovar at 128 oz/ac. By end of season, the MAT28 only plots were dominated by annual grasses, mostly yellow foxtail and barnyardgrass.

Marestail was present throughout the site, but pressure was not great enough to result in any significant differences among treatments.

CONCLUSIONS

MAT28 did not provide acceptable total vegetation control when used alone. Its selectivity to grasses, in this case weedy annual species such as yellow foxtail and barnyardgrass, demonstrates the need for tank-mix partners to supplement its spectrum of control. The combination of MAT28 with a bona fide broad-spectrum sulfonylurea component decreased total cover but simultaneously released kochia. This suggests that kochia at the site may be resistant to ALS-inhibitors. The best bareground performance, for both kochia and total vegetation control, resulted from the combination of MAT28 with Oust plus either Karmex (*diuron*), Chateau (*flumioxazin*), or Authority (*sulfentrzone*). In fact, the reduced rate of Karmex used in the MAT28/Oust treatment (i.e., 16 oz/ac relative to the standard operational rate of 128 oz/ac) still provided excellent kochia control through end of season. However, the 16 oz/ac rate used in this study was the result of an error in the original treatment list. The minimum label rate is 5 lb/ac for bareground; use of lower rates may encourage the development of resistant weeds.

MANAGEMENT IMPLICATIONS

MAT28 offers great potential as a tank-mix partner for bareground weed control, especially for control of resistant weed species. The release of MAT28 to the noncrop market is currently anticipated for late 2010; however, availability will be limited to four premixed herbicides. DuPont's PlainviewTM, a combination of MAT28 and Landmark, is the most suitable of the four products for total vegetation control, pending EPA approval. For the best suppression of kochia and other resistant species, Plainview^{TM} should be applied in combination with *diuron*, *flumioxazin,* or *sulfentrazone*.

Table 1. Total, kochia ("KCHSC"), and marestail ("ERICA") percent cover were visually rated on May 18 (21 days after treatment, DAT), May 30 (33 DAT), July 21 (85 DAT), August 26 (121 DAT), and October 12, 2009 (168 DAT). Treatments were applied to a roadside guiderail location in Altoona, PA on April 27, 2009. Each value is the mean of three replications. Differences between means were considered statistically significant at $p \leq 0.05$. ns = not significant.

		21 DAT		85 DAT		121 DAT		168 DAT		
Product	Rate	Total	KCHSC	Total	KCHSC	Total	KCHSC	Total	KCHSC	ERICA
	oz/ac	% Cover								
untreated	---	15	8	33	7	23	7	22	5	2
Roundup	64	1	0	43	2	42	2	42	3	2
MAT28	5.8	0	0	30	1	32	2	25	1	0
MAT28	7.5	0	0	20	1	27	1	27	2	0
MAT28	9.2	1	0	28	0	30	0	32	0	0
MAT28 Oust Extra	6 4	0	0	4	3	12	10	13	9	2
MAT28 Landmark	5.8 3.4	0	0	14	4	22	6	13	8	0
MAT28 Landmark	7.5 4.5	0	0	3	3	11	7	13	11	0
MAT28 Landmark	9.2 5.6	0	0	5	2	16	8	11	8	0
MAT28 Oust Karmex	7.5 3 16	0	0	4	0	11	2	8	1	0
MAT28 Oust Chateau	7.5 3 10	0	0	2	0	16	0	9	0	0
MAT28 Oust Authority	7.5 3 8	0	0	1	0	3	1	5	1	0
Krovar	128	0	0	6	0	15	1	18	1	0
Protected LSD		ns	ns	14	ns	17	6	15	6	ns

INDAZIFLAM/AE1170437 FOR BAREGROUND AND SUPPRESSION OF KOCHIA

Herbicde trade and common chemical names: AE1170437 (*indaziflam*), Karmex (*diuron*), Oust (*sulfometuron*), Oust Extra (*sulfometuron + metsulfuron*), Roundup (*glyphosate*), Simazine – 4 lb ae/gal (*simazine*).

Plant common and scientific names: Canada bluegrass (*Poa compressa*), Canada thistle (*Cirsium arvense*), kochia (*Kochia scoparia*), orchardgrass (*Dactylis glomerata*), plumeless thistle (*Carduus acanthoides*), prickly lettuce (*Lactuca serriola)*, wild carrot (*Daucus carota*), yellow foxtail (*Setaria glauca*).

ABSTRACT

AE1170437 (*indaziflam*) is a nonselective, broad-spectrum herbicide currently in development by Bayer Crop and Environmental Sciences. The potential use of indaziflam in bareground areas, specifically kochia-infested sites was evaluated. AE1170437 was applied in the early season either alone or in combination with several common bareground herbicides. Glyphosate was included in all treatments as a post-emergence component. At 134 days after application, kochia dominated regrowth on treated plots, and all treated plots had significantly less total cover (2 to 6 percent) than Roundup alone (11 percent). For the three rates of AE1170437 tested (ie, 3.5, 7, and 10 oz/ac), kochia cover ranged from 4 to 6 percent, with no significant differences among the dosages. Overall, Karmex in combination either with AE1170437 (at 80 plus 7 oz/ac) or with Oust Extra (at 128 plus 4 oz/ac) resulted in the lowest kochia cover. Therefore, it appears that *diuron* was the most effective material tested against kochia. In fact, Karmex at 128 oz/ac plus Oust Extra at 4 oz/ac produced significantly lower kochia cover at end of season than AE1170437 at 7 oz/ac plus Oust Extra at 3 oz/ac. However, AE1170437 provided excellent total vegetation control and may serve as a rotation option to help prevent further herbicide resistance issues, pending EPA approval and registration.

INTRODUCTION

AE1170437 (*indaziflam*) is a nonselective, broad-spectrum herbicide currently in development by Bayer Crop and Environmental Sciences. A member of the new chemical class "alkylazines," *indaziflam* provides pre-emergence control of annual grasses and broadleaf weeds and can be combined with post-emergence herbicides. It provides residual control with a relatively low application rate, affecting germinating seeds. The herbicide acts on meristematic growth and inhibits cell wall biosynthesis[1].

The potential use of AE1170437 in bareground areas, specifically kochia-infested sites, was evaluated. AE1170437 was applied in the early season either alone or in combination with several common bareground herbicides. Glyphosate was included in all treatments as a post-emergence component.

[1] Myers, D.F., et al. 2009. Indaziflam/BCS-AA10717-A New Herbicide for Pre-Emergent Control of Grasses and Broadleaf Weeds for Turf and Ornamentals. WSSA Meeting Abstracts, No. 386.

MATERIALS AND METHODS

The trial was established along the median guiderail of the SR322/SR26 interchange in State College, PA. Plots 6 by 15 ft in size were arranged in a randomized complete block design with three replications. Treatments were as follows: AE1170437 alone at 3.5, 7, or 10 oz/ac; AE1170437 at 7 oz/ac rate mixed with either Oust, Karmex, simazine (4 lb ae/gal), or Oust Extra at 3, 80, 64, or 3 oz/ac, respectively; and Oust plus Karmex at 4 plus 128 oz/ac. Roundup at 96 oz/ac was applied alone and included with all treatments, except for an untreated check. Treatments were applied on May 19, 2009, using a CO_2-powered backpack sprayer with 6-ft boom, equipped with four 8003 VS tips at 26 psi. The targeted application rate was 32 gal/ac.

Ratings included total and kochia cover on May 19 (0 days after treatment, DAT), kochia control (0 = no injury, 100 = death) and total cover (control plots only) June 17 (30 DAT), kochia cover and total cover (control plots only) July 20 and August 17 (63 DAT and 91 DAT, respectively) and total, kochia, and annual grass cover on September 29, 2009 (134 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 Fisher's Protected LSD.

RESULTS AND DISCUSSION

Kochia was up to 2 inches tall at the time of application. Other species present included yellow foxtail, Canada bluegrass, prickly lettuce, plumeless thistle, Canada thistle, orchardgrass, and wild carrot. All treatments provided excellent initial kochia control at 30 DAT, ranging from 97 to 100 percent, which was significantly better than Roundup alone at 89 percent (Table 1). At 63 DAT, the treatments had effectively maintained kochia cover at 2 percent or less. However, by 91 DAT, only treatments containing Karmex had significantly lower kochia cover (1 to 2 percent) than Roundup alone (6 percent). At 134 DAT, kochia dominated regrowth on treated plots, and all treated plots had significantly less total cover (2 to 6 percent) than Roundup alone (11 percent), except for AE1170437 plus Oust (7 percent). For the three rates of AE1170437 tested (i.e., 3.5, 7, and 10 oz/ac), kochia cover ranged from 4 to 6 percent, with no significant differences among rates. Kochia cover ranged from 2 to 7 percent for the AE1170437 mixes. Only the two treatments containing Karmex provided significantly less kochia cover (2 percent) than Roundup alone (7 percent). All treatments completely controlled annual grasses compared to Roundup alone, which had 5 percent annual grass cover.

Some kochia seedlings escaped the initial treatments; however, the carrier volume used in this study was lower at 32 gal/ac than those used in standard DOT operations (i.e., 50 gal/ac or more). Therefore, the higher carrier volumes used operationally should provide better coverage and kochia control.

CONCLUSIONS

At end of season, an increase in AE1170437 dosage from 3.5 to 10 oz/ac provided no additional kochia control. Overall, Karmex in combination either with AE1170437 (at 80 plus 7 oz/ac) or with Oust Extra (at 128 plus 4 oz/ac) resulted in the lowest kochia cover. Therefore, it appears that *diuron* was the most effective material tested against kochia. In fact, Karmex at 128 oz/ac plus Oust Extra at 4 oz/ac produced significantly lower kochia cover at end of season than AE1170437 at 7 oz/ac plus Oust Extra at 3 oz/ac. However, AE1170437 provided excellent total vegetation control and may serve as a rotation option to help prevent further herbicide resistance issues, pending EPA approval and registration.

MANAGEMENT IMPLICATIONS

Bayer anticipates marketing the first products based on *indaziflam* in 2011, assuming that regulatory approval is granted. In testing to date, AE1170437 has shown utility as a bareground material, providing non-selective, broad-spectrum control.

Table 1. Visual ratings of total, kochia ("KCHSC"), and annual grass ("A. Grass") vegetative cover, as well as kochia control, according to treatment. Early-season treatments were applied to a roadside guiderail location on May 19, 2009. Ratings were collected on May 19 (0 days after treatment, DAT), June 17 (30 DAT), July 20 (63 DAT), August 17 (91 DAT) and total, kochia, and September 29, 2009 (134 DAT). Control was evaluated on a scale of 0 to 100, where 0 = no control and 100 = plant death. Each value is the mean of three replications. Differences between means were considered statistically significant at $p \leq 0.05$. ns = not significant.

		0 DAT		30 DAT	63 DAT	91 DAT	134 DAT		
Product	Rate	Total Cover	KCHSC Cover	KCHSC Control	KCHSC Cover	KCHSC Cover	Total Cover	KCHSC Cover	A.Grass Cover
	oz/ac	%							
Untreated	---	4	2	0	7	9	20	9	4
Roundup	96	5	5	89	3	6	11	7	5
AE1170437	3.5	5	3	98	2	6	6	6	0
AE1170437	7	4	3	99	1	4	5	4	0
AE1170437	10	5	3	98	1	5	6	5	0
AE1170437 Oust	7 3	4	4	99	1	4	5	5	0
AE1170437 Karmex	7 80	4	3	99	0	2	2	2	0
AE1170437 Simazine	7 64	3	3	99	1	4	4	4	0
AE1170437 Oust Extra	7 3	5	3	97	2	6	7	7	0
Oust Extra Karmex	4 128	5	3	100	0	1	3	2	0
Protected LSD		ns	ns	5	2	3	4	3	2

SUPPRESSION OF ANNUAL GRASSES ALONG HIGHWAY GUIDERAILS

Herbicide trade and common chemical names: Aquaneat (*glyphosate*), Authority (*sulfentrazone*), Karmex XP (*diuron*), Landmark XP (*sulfometuron + chlorsulfuron*), Matrix (*rimsulfuron*), Oust Extra (*sulfometuron + metsulfuron*), Pendulum AC (*pendimethalin*), Plateau (*imazapic*), Proclipse (*prodiamine*), Surflan (*oryzalin*), Throttle XP (*sulfometuron + chlorsulfuron + sulfentrazone*), Velpar DF (*hexazinone*).

Plant common and scientific names: barnyardgrass (*Echinochloa crus-galli* (L.) Beauv.), fall panicum (*Panicum dichotomiflorum* Michx.), giant foxtail (*Setaria faberi* Herrm.), large crabgrass (*Digitaria sanguinalis* (L.) Scop.), orchardgrass (*Dactylis glomerata* L.), reed canarygrass (*Phalaris arundinacea* L.), smooth brome (*Bromus inermis* Leyss.), smooth crabgrass (*Digitaria ischaemum* (Schreb.) Schreb. Ex Muhl.), yellow foxtail (*Setaria pumila* (Poir.) Roemer & J.A. Schultes).

ABSTRACT

Control of late-season, annual grasses is a persistent challenge in many bareground areas, where herbicide treatments typically occur in early spring. The residual herbicide activity has often diminished enough by late summer that weed seeds can germinate and vegetation quickly establishes. A trial was replicated at two sites to test the addition of several preemergence grass herbicides to the standard bareground herbicide mix of Landmark XP and Karmex XP. The treatments included a dual application, where herbicides were applied twice during the season. This treatment involved the application of Throttle XP at 8, Oust Extra at 2, and Karmex XP at 96 oz/ac followed nearly two months later by an application of Throttle XP at 4.5, Oust Extra at 1, and Velpar DF at 16 oz/ac. Although no statistical differences in annual grass control were found among the treatments, there was a trend. The addition of Surflan at rates of 128 or 192 oz/ac to the Landmark XP plus Karmex XP mix as well as the dual application consistently performed better than the other treatments.

INTRODUCTION

Annual grasses, such as foxtail (*Setaria* spp.), plague roadside bareground weed control areas because they continue to germinate throughout the growing season. Herbicides chosen for bareground weed control are selected in part based on the length of their half-life, or persistence in the environment. Half-lives of some products or active ingredients tested include: Karmex XP (90 days, d), *sulfometuron* (20-28 d), *sulfentrazone* (121-302 d), Pendulum AC (44 d), and Surflan (20-128 d)[1/]. However, temperature extremes, photodegradation, and runoff further limit the residual life and efficacy of herbicides in bareground settings. Along with the logistic complication and cost of scheduling multiple herbicide applications, these factors make effective season-long control of annual grasses difficult.

The typical herbicide program for bareground areas consists of a broad-spectrum component, such as Landmark XP, and a residual herbicide, such as Karmex XP. Since annual grasses must establish from seed, several preemergence grass herbicides were evaluated in combination with Landmark XP and Karmex XP for total vegetation control at two locations.

[1/] Senseman, S.A. et al. 2007. Herbicide Handbook Ninth Edition. Weed Science Society of America. Lawrence, KS.

The treatments included a dual application, where herbicides were applied twice during the season. This treatment involved the application of Throttle XP at 8, Oust Extra at 2, and Karmex XP at 96 oz/ac followed nearly two months later by an application of Throttle XP at 4.5, Oust Extra at 1, and Velpar DF at 16 oz/ac.

MATERIALS AND METHODS

The trial was established at guiderail locations along SR221 in Washington County and Fox Hollow Road in Centre County, PA, using a randomized complete block design with three replications. Ten herbicide treatments and an untreated check were applied to 25-by-4-ft plots. The herbicide combinations (oz/ac) included Landmark XP at 4.5 plus Karmex XP at 128 alone, or combined with either Pendulum AC at 134, Surflan at 128 or 192, Proclipse at 36, Plateau at 12, Matrix at 4, or Authority at 8 oz/ac; Landmark XP at 4.5 plus Karmex XP at 240; and a dual application treatment, consisting initially of Throttle XP at 8, Oust Extra at 2, and Karmex XP at 96 followed up with a second application of Throttle XP at 4.5, Oust Extra at 1, and Velpar DF at 16. Aquaneat at 48 oz/ac, for post-emergence activity, and 0.25% v/v CWC 90, non-ionic surfactant, were included in all herbicide treatments. Treatments were applied using a CO_2-powered hand-held sprayer equipped with a single off-center tip targeting 40 gal/ac on May 15 and May 27, 2009, at the Washington and Centre sites, respectively. The second application of the dual application treatment was applied on July 10 or 20, 2009, at the Washington and Centre sites, respectively. Plots were visually evaluated for total cover approximately 0, 60, and 120 days after treatment (DAT) and for annual grass cover at 120 DAT. Predominant grass species at Washington included smooth brome, reed canarygrass, giant foxtail, fall panicum, orchardgrass, and barnyardgrass. The Centre site was inhabited by the following grass species: giant foxtail, yellow foxtail, smooth crabgrass, large crabgrass, barnyardgrass, and orchardgrass.

RESULTS AND DISCUSSION

By September (120 DAT), untreated plots averaged 68 and 83 percent total vegetative cover and 2 and 12 percent annual grass cover at the Washington and Centre sites, respectively. Treated plots ranged from 1 to 34 percent total and 0 to 14 percent annual grass cover at Washington. At Centre, treatments produced between 1 and 32 percent total and 0 and 8 percent annual grass cover. Treatments containing Pendulum AC, Plateau, or Matrix provided the poorest total vegetation control, with differences most pronounced at the Washington site. There were no significant differences in annual grass cover at either site; however, the addition of Surflan (either rate) and the dual application tended to produce the best results.

CONCLUSIONS

Among the preemergence herbicides evaluated, Surflan maintained excellent weed control in combination with Landmark XP and Karmex XP. The lesser rate of 128 oz/ac Surflan, by label, provides between 4 and 8 months control of germinating seeds, while 192 oz/ac Surflan provides 8 to 12 months of control. This level of control was apparent within the studies conducted at both locations. The dual application (Throttle XP at 8, Oust Extra at 2, and Karmex XP at 96 oz/ac, followed almost 2 months later with a treatment of Throttle XP at 4.5, Oust Extra at 1, and Velpar DF at 16 oz/ac) also provided robust total vegetation control but would add significant cost to an operational treatment by requiring two site visits during the growing season.

MANAGEMENT IMPLICATIONS

The addition of Surflan to a base mixture of Landmark XP plus Karmex XP or utilization of dual applications provided the best results among the treatments evaluated in the present study, but both approaches have drawbacks. Surflan (active ingredient, oryzalin) is not available under the current state herbicide contract. The present retail price was quoted at nearly $48.00/gallon[2/]. This would add significant cost to any bareground mix. A standard bareground mix investigated in this study would be Landmark XP at 4.5, Karmex XP at 128, and AquaNeat at 48 oz/ac for $65.55/ac. The addition of Surflan (128 oz = $48.00/ac) would add significant cost to the mix compared to Plateau (12 oz = $18.70/ac)[3/]. Oryzalin may also undermine public perception of the roadside spray program due to its bright orange color and potential to cause short-term staining (i.e., days or more) of pavement and other treated surfaces, such as guiderails. The dual application requires a second visit to treat the site, which adds additional labor to the operational cost.

Overall, both the use of Surflan as a preemergence component and the dual application have shown the potential to help control late-season annual grasses in bareground areas. Due to the additional costs involved, these approaches should be used to target high-profile and problematic sites.

[2/] Cost of $47.80/gallon in 2.5 gallon container quoted January 2010 by Arborchem, Inc., Mechanicsburg, PA. Price quote was for Oryzalin 4 Pro manufactured by Quali-Pro, Raleigh, NC. Generic equivalent of Surflan AS.

[3/] Cost for products obtained from 2008 PA State Herbicide Contract, except Landmark XP (2006 PA State Herbicide Contract).

Table 1: Percent total vegetative and annual grass cover ratings at 120 days after treatment, DAT. Treatments were applied May 15 and May 27, 2009 at the Washington and Centre County sites, respectively. Each value is the mean of three replications.

		Washington Co.		Centre Co.	
treatment[1/]	application rate	Total Cover	Annual Grass Cover	Total Cover	Annual Grass Cover
	oz/ac	%			
untreated	---	68	2	83	12
Landmark XP Karmex XP	4.5 128	12	4	10	7
Landmark XP Karmex XP	4.5 240	18	3	7	3
Pendulum AC[2/]	134	30	5	32	3
Surflan[2/]	128	8	0	11	1
Surflan[2/]	192	4	0	8	0
Proclipse[2/]	36	24	8	13	1
Plateau[2/]	12	34	4	10	6
Matrix[2/]	4	30	14	13	8
Authority[2/]	8	13	6	10	6
Throttle XP[3/] Oust Extra Karmex XP	8 2 96	1	1	1	1
Protected LSD (p=0.05)		28	n.s.	24	n.s.

[1/] All treatments included Aquaneat at 48 oz/ac and 0.25% v/v CWC 90 non-ionic surfactant.

[2/] Treatment additionally includes Landmark XP at 4.5 and Karmex XP at 128 oz/ac as a base component to tank mix.

[3/] Treatment had additional (dual) application made on July 10 or July 20, 2009, at Washington and Centre County sites, respectively. Treatment included Throttle XP at 4.5, Oust Extra at 1, and Velpar DF at 16 oz/ac.

EVALUATION OF TURF GROWTH REGULATOR COMBINATIONS

Herbicide trade and common chemical names: Embark (*mefluidide*), Escort XP (*metsulfuron*), Glyphomate 41 (*glyphosate*), Journey (*imazapic* + *glyphosate*), Overdrive (*dicamba* + *diflufenzopyr*), Panoramic (*imazapic*), Plateau (*imazapic*).

Plant common and scientific names: crownvetch (*Coronilla varia*), dandelion (*Taraxacum officinale*), tall fescue (*Festuca arundinacea*, FESAR), Kentucky bluegrass (*Poa pratensis*, POAPR), orchardgrass (*Dactylis glomerata*), sulphur cinquefoil (*Potentilla recta*), wild carrot (*Daucus carota*).

ABSTRACT

Panoramic represents a generic brand of *imazapic* that may offer a cost effective alternative if it is as operationally effective compared to Plateau brand herbicide, which is presently used in bareground and turf growth regulator programs by the Pennsylvania Department of Transportation (PennDOT). Trials were established to compare and evaluate the effectiveness and safety of Panoramic, Plateau, and other tank mixes in turf growth regulator programs. No treatments caused unacceptable injury to turf. The addition of Overdrive to a growth regulator tended to improve broadleaf weed control. All treatments reduced tall fescue (FESAR) height through 33 days after treatment (DAT) relative to the untreated plots; however, there were not significant differences among treatments. By 64 DAT, growth of FESAR was no different between treated areas and the untreated check. Kentucky bluegrass (POAPR) seedheads were present on the site at the time of application, and all treatments reduced seedhead numbers. *Imazapic* treatments reduced FESAR seedhead emergence by 95 to 99 percent. Overall, Plateau and Panoramic appear comparable when used as a turf growth regulator.

INTRODUCTION

Panoramic is a generic brand of *imazapic* sold by Alligare, LLC. Plateau is manufactured by BASF and has been used in recent years by the Pennsylvania Department of Transportation in both bareground and turf growth regulator applications. Both are liquid formulations containing 2 lb *imazapic*/gal. Questions about the quality and effectiveness of the generic versus brand name products arose when Panoramic was substituted for Plateau on the PA State Herbicide contract in 2008. The unknowns surrounding the manufacturing process of the generics led to the debate on whether they were comparable to the familiar brand name products. Journey (0.75 lb *imazapic* + 1.5 lb *glyphosate*/gal) is considered a brand name product and an alternative product choice labeled for use in non-crop, turf growth regulator applications. Glyphomate 41 plus Overdrive was included among the treatments to compare *glyphosate* against *imazapic* for regulating turf growth. Glyphomate 41 is also labeled for growth and seedhead suppression of grasses on roadside rights-of-way. Lastly, Embark plus Escort was included as the standard treatment for this application.

Trials were established to compare and evaluate the effectiveness and safety of Panoramic, Plateau, Journey, and other tank mixes in turf growth regulator programs.

MATERIALS AND METHODS

Two replicated trials were established. The first trial was located within the interchange of SR22/I-99 near Duncansville, PA, and the second within the median of SR322 near the Oak Hall, PA exit. Plots 6 by 15 ft in size were arranged in a randomized complete block design with three replications. Treatments included Plateau or Panoramic at 2 oz/ac alone and combined with Overdrive at 8 oz/ac, Glyphomate 41 at 6 oz/ac or Journey at 4 oz/ac combined with Overdrive at 8 oz/ac, Embark at 8 oz/ac plus Escort XP at 0.125 oz/ac, and an untreated check. All herbicide treatments, except surfactant-loaded Glyphomate 41 plus Overdrive, contained 0.25 percent v/v CWC Surfactant 90. Treatments were applied April 27, 2009 (Duncansville) and April 28, 2009 (Oak Hall), using a CO_2-powered backpack sprayer equipped with a 6 ft boom and four 8003VS tips operating at 29 psi. The carrier volume was 35 gal/ac.

The Duncansville site was evaluated for percent grass cover on April 27, 2009, 0 days after treatment, DAT; phytotoxicity, percent seedhead reduction of Kentucky bluegrass (POAPR), average and maximum height of tall fescue (FESAR), and percent broadleaf control on May 14 and 30, 17 and 33 DAT; and phytotoxicity, average and maximum height (FESAR) on June 30, 64 DAT.

Oak Hall was rated for percent grass cover on April 28, 2009, 0 DAT; phytotoxicity, average and maximum height (FESAR) on May 14, 16 DAT; phytotoxicity on May 28, 30 DAT; and average and maximum height (FESAR and POAPR) and percent seedhead reduction (FESAR) on July 1, 64 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 Fisher's Protected LSD.

RESULTS AND DISCUSSION

The Duncansville site was a mixed stand of FESAR and POAPR. Average turf height was 6 in with some plants up to 9 in tall at time of application. Some POAPR seedheads were beginning to emerge, but FESAR seedheads were not yet in "boot stage." Ideally this application, within a mixed stand of FESAR and POAPR, targets seedhead suppression of the FESAR because it achieves undesirable heights. Broadleaf species present at the site included sulphur cinquefoil, wild carrot, dandelion, and crownvetch. All treatments caused limited, but acceptable, phytotoxicity to the turf at 17 DAT, ranging from 2 to 3 (0 to 10 scale), which was significantly higher than the untreated check. Broadleaf weed control ranged from 40 to 89 percent for the treatments. Plateau and Panoramic offered almost identical control to the standard Embark plus Escort XP combination (42, 40, and 40 percent, respectively). Treatments containing Overdrive provided the highest broadleaf weed control, from 65 to 89 percent (Table 1). The average height of FESAR was statistically similar for all treatments (7 to 8 in) but significantly lower than the untreated (10 in). POAPR seedheads emerged following application. Although the treatments produced average reductions ranging from 17 to 88 percent, there were no significant differences due to high variability among replicate plots (Table 2).

Plateau, Glyphomate 41 plus Overdrive, and Embark plus Escort XP caused the highest phytotoxicity (3) at 33 DAT, while all other treatments ranged from 1 to 2. Treatments offered statistically similar broadleaf weed control from 45 to 93 percent (Table 1). Treatments resulted in similar heights of 6 to 7 in, compared to the 10 in height of the untreated check. There were no significant differences in POAPR seedhead reduction among treatments (25 to 63 percent)

(Table 2). By 64 DAT, the average height of FESAR ranged from 11 to 15 in for all treatments, with untreated at 12 in.

The Oak Hall site was comprised of a mixed stand of FESAR, orchardgrass, and limited amount of POAPR. Broadleaf weeds were minimal and included mostly dandelion. By 16 DAT, phytotoxicity to the turf ranged from 0 to 1, and average FESAR heights (8 to 9 in) were not significantly different among treatments, including the untreated check. Phytotoxicity remained acceptable at 30 DAT for all treatments, ranging from 1 to 3. By 64 DAT, the treatment effect appeared to be wearing off. At this time, the average FESAR heights were similar, between 17 and 21 in. FESAR seedhead reduction was 95 to 99 percent for all treatments, except Glyphomate plus Overdrive and Embark plus Escort XP, at 0 and 76 percent, respectively.

CONCLUSIONS

Treatment results were variable, but all treatments were safe to turf. The addition of Overdrive tended to improve broadleaf weed control compared to using a turf growth regulator alone. The height of FESAR was similarly controlled by all treatments and, for the most part, significantly lower than the untreated plots up to 33 DAT. By 64 DAT, growth of FESAR was no different between treated areas and the untreated check. Although POAPR seedhead reduction was similar for all treatments, the emergence of POAPR seedheads prior to application may have caused the wide variability in seedhead inhibition that was observed. *Imazapic* treatments provided excellent inhibition of FESAR seedhead emergence.

MANAGEMENT IMPLICATIONS

Plateau and Panoramic provide comparable results when used as a turf growth regulator. These products are safe to K31 tall fescue at a rate of up to 2 oz/ac. Higher rates may result in excessive turf injury or mortality. The addition of a non-ionic surfactant is recommended, though methylated seed oil should be avoided, according to product labeling. Overdrive or another selective broadleaf weed control component is recommended for tank mixes to control unwanted weeds. Panoramic and Plateau appear equivalent in effectiveness to the standard Embark plus Escort XP used in this study and could be a possible substitute for this application. Journey plus Overdrive also offered similar results and would provide a viable alternative. Based on the lack of FESAR seedhead inhibition, the Glyphomate 41 plus Overdrive combination needs further investigation before its suggested use.

Table 1: Visual phytotoxicity ratings on turf and broadleaf weed control efficacy ratings for each treatment. Treatments were applied April 27 and April 28, 2009, at Duncansville and Oak Hall, respectively. Ratings were collected May 14 (16 days after treatment, DAT) and May 28 (30 DAT) for Oak Hall and May 14 and 30 (17 and 33 DAT) for Duncansville. Phytotoxicity was evaluated on a scale of 0 to 10, where "0" = no visible symptoms, "5" = moderate chlorosis, some necrosis, "10" = dead. Each value is the mean of three replications. Differences between means were considered statistically significant at $p \leq 0.05$. ns = not significant.

		Phytotoxicity				Broadleaf Control	
		Oak Hall		Duncansville		Duncansville	
Treatment	Rate	16 DAT	30 DAT	17 DAT	33 DAT	17 DAT	33 DAT
	oz/ac	-----0 to10 scale------				------%------	
Untreated	---	0	0	0	0	0	0
Plateau	2	0	1	2	3	42	45
Panoramic	2	1	2	2	2	40	74
Plateau Overdrive	2 8	1	2	2	1	65	66
Panoramic Overdrive	2 8	1	3	2	1	79	81
Glyphomate 41 Overdrive	6 8	0	1	3	3	80	80
Journey Overdrive	4 8	0	3	2	1	89	93
Embark Escort XP	8 0.125	1	2	3	3	40	66
LSD (p=0.05)		ns	1	1	1	51	48

Table 2: Visual ratings of average tall fescue (FESAR) height and Kentucky bluegrass (POAPR) seedhead reduction, according to treatment. Treatments were applied April 27 and April 28, 2009, at Duncansville and Oak Hall, respectively. Ratings were collected May 14 (16 days after treatment, DAT) and July 1 (64 DAT) for Oak Hall and May 14 and 30 (17 and 33 DAT) for Duncansville. Each value is the mean of three replications. Differences between means were considered statistically significant at $p \leq 0.05$. ns = not significant.

		FESAR Average Height				Seedhead Reduction	
		Oak Hall		Duncansville		Duncansville	
Treatment	Rate	16 DAT	64 DAT	17 DAT	33 DAT	17 DAT	33 DAT
	oz/ac	------in------				------%------	
Untreated	---	9	20	10	10	0	0
Plateau	2	8	21	7	6	17	50
Panoramic	2	8	19	8	7	55	42
Plateau Overdrive	2 8	8	19	8	6	72	42
Panoramic Overdrive	2 8	8	17	8	7	37	25
Glyphomate 41 Overdrive	6 8	9	20	8	7	48	63
Journey Overdrive	4 8	8	21	8	7	88	50
Embark Escort XP	8 0.125	8	17	7	7	67	50
LSD (p=0.05)		ns	ns	1	1	ns	ns

INVESTIGATING HERBICIDES FOR COMBINED WEED AND BRUSH PLUS PLANT GROWTH REGULATOR APPLICATIONS

Herbicide trade and common chemical names: Escort XP (*metsulfuron*), Journey (*imazapic* + *glyphosate*), MAT28 (*aminocyclopyrachlor*), Milestone VM (*aminopyralid*), Telar XP (*chlorsulfuron*), Vanquish (*dicamba-glycolamine*).

Plant common and scientific names: annual sowthistle (*Sonchus oleraceus*), birdsfoot trefoil (*Lotus corniculatus*), Canada thistle (*Cirsium arvense*), common milkweed (*Asclepias syriaca*), crownvetch (*Coronilla varia*), fine fescue (*Festuca* spp.), giant foxtail (*Setaria faberi*), goldenrod (*Solidago* spp.), Kentucky bluegrass (*Poa pratensis*), orchardgrass (*Dactylis glomerata*), poison hemlock (*Conium maculatum*), quackgrass (*Elymus repens*), smooth brome (*Bromus inermis*), spotted knapweed (*Centaurea stoebe*), tall fescue (*Lolium arundinaceum*), wild carrot (*Daucus carota*), wild grape (*Vitis* spp.), yellow rocket (*Barbarea vulgaris*).

ABSTRACT

Roadside vegetation management employs selective weed and brush herbicides and plant growth regulator (PGR) treatments in an effort to manage grass seedhead and growth while preventing broadleaf weed release in the early spring. This research was designed to investigate the efficacy of tank mixing a new product (aminocyclopyrachlor) as an alternative for brush and broadleaf control as well as new commercial premixes of this chemistry with standard turf PGR products. Two operational, non-replicated demonstrations were established consisting of four broadleaf herbicide and plant growth regulator mixes to determine their control on woody and herbaceous broadleaf species and suppression and safety to turf within an industrial turf stand. Two treatments contained MAT28 (aminocyclopyrachlor) plus either Escort XP or Telar XP. These treatments were meant to mimic premixes that are expected to be commercially available in 2010. Two additional treatments, Journey plus Vanquish and Escort XP plus Milestone VM, were also tested. All four treatments provided some level of seedhead inhibition, regulation of turf height, and broadleaf weed control. Milestone VM plus Escort XP offered the best overall control. However, some turf discoloration was expected and occurred at an Escort XP rate of 0.5 oz/ac. It is questionable whether mixes containing MAT28 would outperform the existing standard mix of 6 oz/ac Embark 2S, 0.25 oz/ac Escort XP, 24 oz/ac Garlon 3A, and 24 oz/ac Vanquish.

INTRODUCTION

Plant growth regulator (PGR) and selective weed and brush (W/B) applications are two independent PennDOT programs. The PGR program is applied in early spring to prevent seed head development of the grasses and reduce leaf growth. The addition of broadleaf products is necessary to prevent the less vigorous grasses from being overrun by untreated weeds. A standard mixture is 6 oz/ac Embark 2S plus 0.25 oz/ac Escort XP. In addition, a broadleaf component is added to control a broader spectrum of weed species. A typical combination may include; 24 oz/ac Garlon 3A plus 24 oz/ac Vanquish. This combination is implemented in hard to mow areas or to reduce mowing cycles. A W/B program has two distinct objectives, to control herbaceous broadleaf weeds and brush. Usually both objectives are achieved using a tank mix of products suited for either target.

MAT28, or aminocyclopyrachlor, is a new active ingredient developed by DuPont. The herbicide is a synthetic auxin within a class of herbicides known as pyrimidine carboxylic acids. It controls a wide spectrum of broadleaf weeds, vines, and brush species, while selective to grasses at low rates. It has soil activity with a potential half-life of 4 months.

Two commercially available premixes containing aminocyclopyrachlor will be on the market in 2010 and are anticipated to be suitable for plant growth regulation and dicot weed control in industrial turf. Perspective™ contains aminocyclopyrachlor and Telar XP. Streamline™ contains aminocyclopyrachlor and Escort XP. Telar or Escort at 0.5 oz/ac are effective as plant growth regulators as previously reported [1/2/].

Demonstration plots were established to evaluate the effectiveness of MAT28 in combination with Escort XP or Telar XP as a turf growth regulator and for both short- and long-term broadleaf weed control. These mixes mimic the components of the proposed commercial mixes to be available in 2010. It was hypothesized that the residual activity of MAT28 would substantially suppress growth of broadleaf weeds and brush throughout the season, thus eliminating the need for follow-up treatments later in the season. In addition, two alternate mixes were evaluated. Journey plus Vanquish and Escort XP plus Milestone VM contain ingredients that would provide plant growth regulation, broadleaf weed control, and residual soil activity.

Reduction in tall fescue seed heads and vegetative growth, potential phytotoxicity to the turf, and broadleaf weed control data were collected at both locations. Tall fescue is the most widely targeted grass species in PennDOT's PGR program. Evaluating the success of PGR effects on this species will determine the usefulness of the treatment. The short-term and residual broadleaf weed control was also an important criterion used in measuring the performance of each treatment.

MATERIALS AND METHODS

Two, nearly identical but separate, operational demonstrations were established within the median of SR70 near Claysville, PA, and along the shoulder of I-99 near State College, PA. On April 24, 2009, four 1-acre plots were established at the Claysville location by applying a rate of 35 gallons per acre, GPA, using a hydraulic spray truck, Norstar spray head, and pattern width of 34 ft. On May 7, 2009, four half-acre plots were established at State College by applying a rate of 10 GPA, utilizing a Surflo electric pump, radiarc spray head, and pattern width of 15 ft. A single treatment was applied within each plot. Treatments included 1.88 oz/ac MAT28 plus 0.5 oz/ac Escort XP; 2.5 oz/ac MAT28 plus 0.66 oz/ac Telar XP; 4 oz/ac Journey plus 32 oz/ac Vanquish; and 0.5 oz/ac Escort XP plus 7 oz/ac Milestone VM. All treatments included 0.25% v/v CWC Surfactant 90.

Treatment evaluations and observations were recorded at the Claysville site, including phytotoxicity, turf and weed species composition, seedhead suppression, turf height, and broadleaf weed control, on May 15, June 5, July 10, and September 11, 2009 (21, 42, 77, or 140

[1/] Response of Tall Fescue to Fall or Spring Applications of Plant Growth Regulator Treatments. 1994. Roadside Vegetation Management Research Report – Eighth Year Report. http://vm.cas.psu.edu/1993/1993/final1993.pdf

[2/] The Effect of Application Timing on the Activity of Plant Growth Regulators Applied to Tall Fescue. 1991. Roadside Vegetation Management Research Report – Fifth Year Report. http://vm.cas.psu.edu/1990/1990/final1990.pdf days after treatment, DAT, respectively). At State College observations were recorded on May 22, June 19, and September 17, 2009 (15, 43, or 133 DAT, respectively).

Predominant grass and broadleaf species at the Claysville site included: smooth brome, tall fescue, Kentucky bluegrass, fine fescue, quackgrass, giant foxtail, crownvetch, Canada thistle, poison hemlock, wild carrot, common milkweed, yellow rocket, annual sowthistle, and wild grape.

The State College site was inhabited by: tall fescue, Kentucky bluegrass, orchardgrass, quackgrass, smooth brome, orchardgrass, birdsfoot trefoil, Canada thistle, crownvetch, wild carrot, spotted knapweed, annual sowthistle, wild carrot, and yellow rocket.

RESULTS AND DISCUSSION

These treatments were designed as demonstrations and not replicated. Some general conclusions can be drawn from the observations from which a fully replicated experiment can be conducted in the future using the future premix products to better define efficacy.

At 21 DAT, all treatments at the Claysville location produced a reduction in tall fescue height. The foliar height of tall fescue averaged from 9 to 11 in, which was lower than the untreated areas (18 in). By 42 DAT, all treatments, except Journey plus Vanquish, continued to control average tall fescue foliar height. Treated tall fescue on average remained 4 to 6 in shorter than untreated areas. Tall fescue seedheads were reduced by 80 percent for all treatments, except MAT28 plus Telar XP (50 percent).

Excellent grass seedhead suppression was found through 77 DAT, for Escort XP plus Milestone VM treatments. In addition, Journey plus Vanquish or MAT28 plus Escort XP also showed continued seedhead suppression, while MAT28 plus Telar XP did not provide acceptable seedhead suppression by 77 DAT.

Limited phytotoxicity was observed with Journey plus Vanquish and Escort XP plus Milestone VM, while no phytotoxicity was observed with treatments containing MAT28 plus Escort XP or Telar XP.

Journey plus Vanquish or MAT28 plus Escort XP provided moderate levels of broadleaf weed control from 77 to 140 DAT. MAT28 plus Telar XP and Escort XP plus Milestone VM showed excellent broadleaf weed control during these later ratings.

The State College site showed reduced average tall fescue foliar height for all treatments at both 15 and 43 DAT, with treatments averaging 8 to 12 in, untreated (16 in), and 10 to 13 in, untreated (20 in), respectively. No tall fescue seedheads were observed at 15 DAT for treated plots. In contrast seedheads were just emerging within untreated areas. At 43 DAT, no tall fescue seedheads developed within the Journey plus Vanquish plot; few seed heads were found within the Milestone VM plus Escort plot; and notes insufficiently record this data for the MAT28 plots, but it was apparent seedheads were not completely prevented. MAT28 plus Escort XP was the only treatment to verge on unacceptable, but temporary injury to the turf. The best broadleaf weed control was observed with Escort XP plus Milestone VM. Journey plus Vanquish seemed to provide the least effective control of the broadleaf species present. A lower carrier volume of 10 GPA, added weed pressure, and abundance of legumes (e.g., birdsfoot trefoil and crownvetch) may explain the overall reduced broadleaf weed control observed at this site.

CONCLUSIONS

All treatments, except MAT28 plus Telar XP, provided acceptable levels of seedhead inhibition. Treatments containing 0.5 oz/ac Escort XP may cause noticeable injury to the desirable turf, but the turf seems to recover. Overall, the Escort XP plus Milestone VM treatment provided the best broadleaf weed control over the length of the demonstration. Journey plus Vanquish provided excellent short-term broadleaf weed control. The overall lower weed control observed with Journey plus Vanquish may have been due to the abundance of birdsfoot trefoil and crownvetch present at the State College site. The active ingredient, imazapic, found in Journey is weak on legumes, like birdsfoot trefoil.

Broadleaf weed control improved over time with treatments containing MAT28. However, treatments containing MAT28 did not outperform the other mixes tested. Unfortunately, increasing the rates of MAT28 beyond what was investigated would create issues with the premixes that are being offered. The amounts of Escort XP or Telar XP found within the premixes would begin to exceed safe application rates on turf.

MANAGEMENT IMPLICATIONS

Streamline™ or Perspective™ may offer options for general broadleaf weed control and turf growth regulation. Opportunities to utilize these products will rely on the labeling offered when they become commercially available. The new products should be experimentally evaluated prior to adoption to assure their efficacy is similar or better than what was observed in this demonstration. Milestone VM plus Escort XP also offers an excellent option for this application. However, some turf discoloration is expected at this 0.5 oz/ac rate of Escort XP. It is doubtful whether these mixes have any advantage over existing standard mix of Embark 2S, Escort XP, Garlon 3A, and Vanquish.

NATIVE SEED MIX ESTABLISHMENT IMPLEMENTATION – YEAR TWO

<u>Plant common and scientific names</u>: autumn bentgrass (*Agrostis perennans*), big bluestem (*Andropogon gerardii*), black-eyed susan (*Rudbeckia hirta*), brown-eyed susan (*Rudbeckia triloba*), butterfly weed (*Asclepias tuberosa*), Canada wildrye (*Elymus canadensis*), crownvetch (*Coronilla varia*), early goldenrod (*Solidago juncea*), fine fescue (*Festuca rubra*), giant foxtail (*Setaria faberi*), gray beardtongue (*Penstemon canescens*), Indiangrass (*Sorghastrum nutans*), little bluestem (*Schizachyrium scoparius*), ox eye sunflower (*Heliopsis helianthoides*), partridge pea (*Chamaecrista fasciculata*), spring oats (*Avena sativa*), switchgrass (*Panicum virgatum*), wild senna (*Senna hebecarpa*)

ABSTRACT

Formula N, a native warm-season grass mix, was broadcast and hydroseeded at two sites in 2008. At both locations, most plants were still in the seedling or juvenile stages two years after seeding. Native cover was sparse, except for a few isolated patches with greater than one seedling per square foot. Therefore, native grasses and forbs failed to provide sufficient cover for erosion control after two years. An evaluation is planned for the third year after seeding in order to provide a more comprehensive, long-term evaluation of the success of Formula N. Results to date have confirmed the slow establishment rates expected with warm-season grasses but also provide encouragement, considering the steep, gravelly soils at both sites.

INTRODUCTION

Warm-season grass plantings often require several years to establish. Formula N (Table 1) is a native warm-season grass mix currently under evaluation as an alternative to Formula C. Formula C has been criticized due to the tendency for its crownvetch component to become invasive. In 2008, two application methods, hydroseeding and broadcasting, were employed to demonstrate the versatility of Formula N as an alternative seed mix. Additional background information, including an explanation of the components in Formula N, is provided in the Roadside Vegetation Management Research Twenty-Third Year Report[1]. Results from the second year after seeding are reported here.

MATERIALS AND METHODS

The native seed mix implementation had been established in 2008 at two locations, along I-80W in Montour County and at a stockpile along SR56 near Homer City, PA. Both sites had a steeply graded slope with poor, erosion-prone soil. In Montour County, half of the site was broadcast and the other half hydroseeded with Formula N on April 29. In addition to broadcast and hydroseeding application of Formula N, Formula C, at 19 lb/ac crownvetch and 24 lb/ac annual ryegrass, was also hydroseeded in Homer City on April 30. Amendments were applied according to PennDOT Pub. 408, section 804 specifications. Hydroseeding was performed as a one-step process, in which seed, mulch, and soil amendments were mixed and applied together

[1] Johnson et al. 2009. Native Seed Mix Establishment Implementation. Roadside Vegetation Management Research Report. Twenty-Third Year Report.

as a slurry. Floc-Lock tackifier (Lesco) was added to the hydroseed mixture at a rate of 3 lb/acre. Broadcast plots were not mulched.

The Montour County and Homer City sites were evaluated for establishment success in 2008 and re-evaluated in late-summer 2009.

RESULTS AND DISCUSSION

Results from the first year (2008) rating have been reported previously[1]. Aside from what appeared to be minor additional germination of warm-season grasses, there was little change in the second year. At Montour County, the effects of fertilization, which enhanced the stand of existing fine fescue, were even more apparent than in 2008. Although only little bluestem was identified in 2008, big bluestem and switchgrass seedlings were found on the broadcast area in 2009. Partridge pea, an annual legume, was also growing on the site; therefore, it is likely that some seed had remained dormant through 2008.

Establishment at Homer city was slightly more encouraging than at Montour County, similar to results from 2008, and the broadcast plot had a higher density of desirable grasses than the hydroseeded plot.

CONCLUSIONS

At both locations, most plants were still in the seedling or juvenile stages. Establishment at Homer City was visually better overall than at Montour County, though there were some isolated patches of good seedling density (i.e., greater than one plant per square foot) in the broadcast plot of the latter site. Therefore, native grasses and forbs failed to provide uniformly sufficient cover for erosion control after two years. In a similar study, which was installed on three newly constructed roadside sites in West Virginia, native warm-season grasses were also slow to establish[2]. Native cover was nearly zero at all sites until the third growing season, even though plots had been prepared through tillage to a depth of 2 in, with half of each site receiving fertilizer. Among the native species seeded, big bluestem, Indiangrass, brown-eyed susan, and wild senna established, whereas early goldenrod, butterfly weed, and gray beardtongue did not. At the end of the third season, native cover averaged 0, 24, and 25 percent among the three locations. The authors did not suggest why native species may have failed to establish on one of the three sites.

An evaluation is planned for the third year after seeding at Homer City and Montour County in order to provide a more comprehensive, long-term evaluation of the success of Formula N. Results to date have confirmed the slow establishment rates expected with warm-season grasses but also provide encouragement, considering the steep, gravelly soils at both sites.

MANAGEMENT IMPLICATIONS

The warm-season grass species used in this implementation will require more than two seasons to establish in poor roadside soils.

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[2] Skousen, J.G., and Venable, C.L. 2008. Establishing Native Plants on Newly Constructed and Older, Reclaimed Sites along West Virginia Highways. Land Degrad. Develop. 19, 388-396.

Table 1. Formula N seed mix for the Montour County and Homer City slope rehabilitation projects. Components followed by an "*" are reported as lb/ac pure live seed (PLS). PLS = % germination x % purity / 100.

Common name	Scientific name	lb/ac
big bluestem	*Andropogon gerardii*	5.3*
little bluestem	*Schizachyrium scoparius*	5.3*
Indiangrass	*Sorghastrum nutans*	5.3*
switchgrass	*Panicum virgatum*	1.1*
Canada wildrye	*Elymus canadensis*	5.3*
autumn bentgrass	*Agrostis perennans*	11
spring oats	*Avena sativa*	64
partridge pea	*Chamaecrista fasciculata*	2.1
black-eyed susan	*Rudbeckia hirta*	0.53
ox eye sunflower	*Heliopsis helianthoides*	0.53
Total		100

PERENNIAL WILDFLOWER MIX DEMONSTRATION

Herbicide trade and common chemical names: Aquaneat, (*glyphosate*), Assure II (*quizalofop*), Plateau (*imazapic*), Roundup (*glyphosate*)

Plant common and scientific names: annual gaillardia (*Gaillardia pulchella*), bachelor's button (*Centaurea cyanus*), big bluestem (*Andropogon gerardii*), black-eyed susan (*Rudbeckia hirta*), blue false indigo (*Baptisia australis*), broomsedge (*Andropogon virginicus*), common milkweed (*Asclepias syriaca*), corn poppy (*Papaver rhoeas*), cornflower (*Centaurea cyanus*), cosmos (*Cosmos bipinnatus*), crabgrass (*Digitaria* spp.), crownvetch (*Coronilla varia*), foxtail (*Setaria* spp.), Illinois bundleflower (*Desmanthus illinoensis*), Indiangrass (*Sorghastrum nutans*), lance-leaved coreopsis (*Coreopsis lanceolata*), little bluestem (*Schizachyrium scoparium*), nimblewill (*Muhlenbergia schreberi*), partridge pea (*Chamaecrista fasciculata*), perennial blue flax (*Linum perenne*), perennial gaillardia (*Gaillardia aristata*), rocket larkspur (*Delphinium ajacis*), shasta daisy (*Chrysanthemum maximum*), sideoats grama (*Bouteloua curtipendula*), spotted knapweed (*Centaurea maculosa*), sweet alyssum (*Lobularia maritime*), tall plains coreopsis (*Coreopsis tinctoria*), teasel (*Dipsacus fullonum*), wild carrot (*Daucus carota*)

ABSTRACT

Wildflower plantings enhance roadside aesthetics; however, long-term beds often provide inconsistent results. Annual species require extensive inputs for establishment and maintenance, and perennial beds often become quickly infested with weeds. A demonstration was established to compare two Plateau-tolerant, perennial wildflower mixes with a standard annual wildflower seeding. Trials were established in the median of I-80, one mile west of the I-80/I-81 interchange (Luzerne County) at opposite ends (i.e., East and West) within the footprint of a previously established but inactive flower bed, which was not planted in the year preceding the study. The East and West sections were approximately 1.5 and 0.75 ac in size, respectively. The site was prepared with an Aquaneat treatment in September 2008 and seeded with the three mixes, in both the East and West sections, in March 2009. Half of each plot was fertilized with sulfur-coated urea at 80 lb N/ac, while the East end was sliced by dragging an inoperative seeder across the bed and using the discs to incorporate both seed and fertilizer. A site visit on August 27, 2009 revealed that both sections had been mowed by PennDOT's contractor. There was evidence of wild carrot throughout the site with some patches of milkweed. A few flower remnants were present in the residue from the annual mix. Black-eyed susan flower heads were found on the perennial plots. No other identifiable parts were found in the mowing residue. This trial is an ongoing study and will require several years of monitoring to evaluate establishment success.

INTRODUCTION

Roadside aesthetics are an integral aspect of vegetation management. Among beautification projects, wildflower plantings have one of the greatest impacts on public perception. However, establishment and maintenance of annual wildflower beds can require extensive time and material inputs. On the other hand, perennial flower beds are often infested with broadleaf weeds and fail to perform within one to two years after establishment. In response to this problem, Ernst Conservation Seeds, Inc. (Ernst) has developed herbicide-tolerant perennial mixes.

A Plateau-tolerant, perennial, native wildflower mix (Table 1), and a wildflower mix plus native grasses have been developed (Table 2). The mixes can grow 3-4 ft in height; therefore, they should be planted in an area where they will not impede sight distance. Ernst suggests that a Plateau treatment can be applied pre- or post-emergence in the planting year and repeated in subsequent years. The mixes are expected to persist for approximately ten years with annual maintenance consisting of dormant mowing and Plateau application, if needed.

At this time a standard protocol for wildflower planting and establishment is employed by PennDOT based on previous research by Penn State Vegetation Management from 1989 through 1994. The protocol emphasizes several main steps. First, managers should reduce bed footprints to a manageable size; a small, showy, weed-free planting is more aesthetically pleasing than a large, overgrown weed patch. Second, pre-plant weed control, such as *glyphosate*, should be applied in late summer or fall when other herbicide programs have ended. When possible, tilling in the spring can also help to diminish weed pressure. Beds should be seeded in March with a simple mix of reliable annual species (e.g., corn poppy, black-eyed susan, cosmos)[1]. For areas of low fertility, slow-release fertilizer can be applied at a rate of 80 to 120 lb N/ac/yr. In fertile soils, yearly addition of nitrogen is not necessary[2], but soil testing should be employed to determine site-specific nutrient requirements. During the season, Assure II can be applied for post-emergence control of annual and perennial grasses as needed. Finally, beds should be mowed at the end of summer or early fall, and glyphosate can be applied beginning two weeks after mowing. This annual cycle is then repeated with a spring seeding.

A demonstration was established to compare the standard annual wildflower method and the two Plateau-tolerant, perennial seed mixes. The effects of fertilization and seed incorporation on each of the mixes were also observed.

MATERIALS AND METHODS

The wildflower demonstration was established in the median of I-80, one mile west of the I-80/I-81 interchange (Luzerne County). This location presently includes a previously established flower bed of approximately 6 ac. Maintenance of the existing flower bed followed an annual program of site preparation with Roundup at 3 qts/ac after greenup and prior to seeding, reseeding of existing plots with an annual mix at 12 lb/ac, and weed control using Assure II at 8 oz/ac in the period from mid-July to early August. The present demonstration was established at opposite ends (i.e., East and West) of the previous flower bed, which was not planted in the year preceding the study. The East and West sections were approximately 1.5 and 0.75 ac in size, respectively.

The two sections were prepared on September 17, 2008, the fall before seeding, with a mix of 104 oz/ac Aquaneat plus 8 oz/ac NuFilm IR surfactant. The treatment was applied using a John Bean Sprayer equipped with Superjet Spray Gun and D-8 orifice tip, targeting 50 gal/ac. Three seed mixes were tested within each section: a perennial wildflower mix, a perennial

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[1] Gover et al. 1990. Wildflower Species Evaluation. Roadside Vegetation Management Research Report. Fourth Year Report.

[2] Gover et al. 1994. Effect of Nitrogen Fertilizer on the Establishment of an Annual Wildflower Mix. Roadside Vegetation Management Research Report. Eighth Year Report.

wildflower mix with warm-season grasses, and an annual wildflower mix (Tables 1, 2, and 3, respectively). Seed was broadcast on March 12, 2009, at a rate of 12.5 lb PLS/ac for the perennial mixes and 12 lb/ac for the annual mix. Sulfur-coated urea (39-0-0) was applied to half of each plot at a rate of 80 lb N/ac. After seeding, the plots on the East end were dragged in the east-west direction with an Olathe seeder disconnected from the PTO, creating approximately half-in deep slicing. Plots on the West end were not sliced.

RESULTS AND DISCUSSION

The wildflower bed had not been seeded by PennDOT in 2008. Species present prior to the September 2008 glyphosate application included wild carrot, common milkweed, crownvetch, crabgrass, foxtail, broomsedge, spotted knapweed, and teasel. A site visit on August 27, 2009 revealed that both sections had been mowed by PennDOT's contractor. There was evidence of wild carrot throughout the site with some patches of milkweed. A few flower remnants were present in the residue from the annual mix. Black-eyed susan flower heads were found on the perennial plots. No other identifiable parts were found in the mowing residue.

CONCLUSIONS

This trial is an ongoing study and will require several years of monitoring to evaluate establishment success. Of the perennial species planted, it appears that black-eyed susan flowered in the first year. It is anticipated that many of the other perennial species would not have bloomed in 2009. Re-establishment of annual wildflowers is not planned for 2010.

MANAGEMENT IMPLICATIONS

Recommendations cannot be made until the mixes are given at least two to three years to establish.

Table 1. Perennial wildflower mix from Ernst Conservation Seeds. All rates in PLS (pure live seed) = % germination x % purity / 100. Cost of the mix was $27.66 per lb PLS, as of February 2009.

Common Name	Scientific Name	Seeding Rates	
		% of total	lb/ac
partridge pea	*Chamaecrista fasciculata*	15	1.8
bachelor's button/tall mixed cornflower	*Centaurea cyanus*	14	1.7
perennial blue flax	*Linum perenne*	13	1.6
lance-leaved coreopsis	*Coreopsis lanceolata*	12	1.5
Illinois bundleflower	*Desmanthus illinoensis*	12	1.5
perennial gaillardia	*Gaillardia aristata*	10	1.2
shasta daisy	*Chrysanthemum maximum*	7.8	0.98
annual gaillardia (Indian blanket)	*Gaillardia pulchella*	7.8	0.98
black-eyed susan	*Rudbeckia hirta*	7.8	0.98
blue false indigo	*Baptisia australis*	2.0	0.25
Total		100	12.5

Table 2. Perennial wildflower mix with warm-season grasses from Ernst Conservation Seeds. All rates in PLS (pure live seed) = % germination x % purity / 100. Cost of the mix was $20.41 per lb PLS, as of February 2009.

Common Name	Scientific Name	Seeding Rates	
		% of total	lb/ac
little bluestem	*Schizachyrium scoparium*	22	2.8
sideoats grama	*Bouteloua curtipendula*	9	1.1
Indiangrass	*Sorghastrum nutans*	9	1.1
nimblewill	*Muhlenbergia schreberi*	8	1.0
big bluestem	*Andropogon gerardii*	5	0.63
partridge pea	*Chamaecrista fasciculata*	7	0.88
perennial blue flax	*Linum perenne*	6	0.75
bachelor's button/tall mixed cornflower	*Centaurea cyanus*	7	0.88
lance-leaved coreopsis	*Coreopsis lanceolata*	6	0.75
Illinois bundleflower	*Desmanthus illinoensis*	4	0.50
perennial gaillardia	*Gaillardia aristata*	5	0.63
shasta daisy	*Chrysanthemum maximum*	3	0.38
annual gaillardia (Indian blanket)	*Gaillardia pulchella*	2	0.25
black-eyed susan	*Rudbeckia hirta*	6	0.75
blue false indigo	*Baptisia australis*	1	0.13
Total		100	12.5

Table 3. Annual wildflower mix. Cost of the mix was $16.19 per lb bulk, as of February 2009.

Common Name	Scientific Name	Seeding Rates	
		% of total	lb/ac
cosmos	*Cosmos bipinnatus*	44	5.28
rocket larkspur	*Delphinium ajacis*	22	2.64
cornflower	*Centaurea cyanus*	14	1.68
sweet alyssum	*Lobularia maritima*	7.0	0.84
corn poppy	*Papaver rhoeas*	6.5	0.78
tall plains coreopsis	*Coreopsis tinctoria*	6.5	0.78
Total		100	12

SITE AND SOIL QUALITY EFFECTS ON NATIVE GRASS ESTABLISHMENT

<u>Plant common and scientific names:</u> big bluestem (*Andropogon gerardii*), black-eyed susan (*Rudbeckia hirta*), bull thistle (*Cirsium vulgare*), crownvetch (*Coronilla varia*), fine fescue (*Festuca rubra*), goldenrod (*Solidago spp.*), Indiangrass (*Sorghastrum nutans*), Kentucky bluegrass (*Poa pratensis*), quackgrass (*Agropyron repens*), orchardgrass (*Dactylis glomerata*), spotted knapweed (*Centaurea maculosa*), switchgrass (*Panicum virgatum*), tall fescue (*Festuca arundinacea*)

ABSTRACT

Revegetation with native warm-season grasses (WSG) offers the potential to establish self-sustaining, non-invasive groundcover; however, WSG are slower to establish than cool-season grasses (CSG), limiting their immediate utility as erosion control and competitive cover. WSG are generally more dependent on mycorrhizal symbioses than CSG; therefore, insufficient mycorrhizal inoculum in the soil may limit their growth on disturbed sites where topsoil has been removed. Rates of mycorrhizal root infection were characterized among established WSG and CSG species occurring at two planting sites. Soils differed between the two sites; while one location was a fertile, thriving site, the other stand was located on an infertile, steep slope composed of high pH soil with little organic matter. Due to methodological limitations, no differences in root colonization were detected among species or between sites. Overall, root viability appeared lower for the harsher, infertile sites, which is expected. Such infertile sites are likely phosphorus-limited and may benefit from the incorporation of mycorrhizal inoculum into seeding protocols; however, further research is necessary to determine whether WSG species will benefit from inoculation in the field and, if so, to evaluate the benefits of different inoculum sources.

INTRODUCTION

For revegetation of poor quality sites, native warm-season grasses (WSG), such as big bluestem, indiangrass, and switchgrass, provide a viable alternative to naturalized groundcovers like crownvetch. However, WSG may take several years to establish and provide acceptable groundcover in order to meet requirements for erosion control. Alternatively, cool-season grasses (CSG) used for revegetation, such as tall and fine fescues, can establish in the first season after planting. While CSG produce rapid initial aboveground growth and spread, WSG tend to invest in a more extensive root system. The increased belowground growth promotes water and nutrient uptake, and as a result, WSG are generally more drought-tolerant and grow better in poor soils than CSG; WSG also provide excellent erosion control, due to their deep root systems, once established.

The roots of both WSG and CSG host arbuscular mycorrhizal fungal associations, which help plants acquire nutrients and water in exchange for carbohydrates, which are supplied to the fungus from the plant[1]. Research shows that WSG are generally more dependent on mycorrhizal symbioses than CSG and will produce greater aboveground biomass when colonized[2]. In order for roots to be colonized, either mycorrhizal spores, fungal hyphae, or already infected roots

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[1] Hartnett, D.C., and Wilson, W.T. 2002. Plant and Soil 244: 319-331.
[2] Wilson, W.T., and Hartnett, D.C. 1998. American Journal of Botany 85: 1732-1738.

must be present in the soil[3]. Soil disturbance, including construction, can lower rates of "infectivity," the ability of the soil to colonize plant roots, by removing mycorrhizal propagules. The presence of sufficient mycorrhizal inoculum may be a significant factor in the establishment of native grasses and could help explain why WSG are more successful on some sites than others. Therefore, WSG may receive greater direct benefit than CSG from the addition of mycorrhizal propagules as a soil supplement during seeding.

Rates of mycorrhizal root infection were characterized among established WSG and CSG species occurring at two planting sites. Soils differed between the two sites; while one location was a fertile, thriving site, the other stand was located on an infertile, steep slope composed of high pH soil with little organic matter. Presumably, the latter site either currently or historically had low relative amounts of mycorrhizal propagules. The objective of the current study was to compare rates of colonization among WSG and CSG species inhabiting the same site and soil type, as well as between soil types (i.e., fertile and infertile), for species occurring at both sites. Rates of infection were expected to be higher for WSG than CSG at both sites, due to higher dependence of WSG species on mycorrhizal associations. Since WSG were established at both sites, though densities were not as high at the infertile site, infection was not expected to be significantly different among soil types for individual species.

MATERIALS AND METHODS

Roots and soil samples were collected from two WSG plantings located in State College, PA. A fertile site was located along Orchard Road ("Orchard") on the campus of Penn State University. This planting was established in the late 1990s and contained a mix of switchgrass, big bluestem, and indiangrass. CSG species adjacent to the planting were tall fescue, fine fescue, Kentucky bluegrass, and orchardgrass. WSG were well established in the deep, fertile soil but had been invaded by quackgrass, a weedy perennial CSG species. A second, poorer site was an east facing fill area with an approximately 50 percent slope, located at the interchange of SR 322/SR220 ("Interchange"). The infertile substrate was limestone spoil with a clay layer about 2 in thick, overlain by gravel. The site had been seeded in 2000 to a WSG mix consisting of big bluestem, little bluestem, indiangrass, and switchgrass[4]; however, big bluestem and indiangrass were the only desirable species remaining at the time of the current study. CSG species present were tall and fine fescue. Several broadleaf species had also spread onto the site, including crownvetch, spotted knapweed, and goldenrod. WSG density was lower at the Interchange site than at Orchard Road. Roots were collected at both sites on June 9, 2009. For WSG species, root samples were obtained by excavating a one-foot diameter column of soil around the crown and harvesting individual roots. Roots from two stems were sampled and homogenized for each species. Due to apparently low initial viability, duplicate samples were collected for Indiangrass and big bluestem from the interchange on June 23, 2009. For CSG species, a homogenous area of turf was located and excavated in two locations per species on June 9, 2009. Root samples were washed in water and preserved in 50% ethanol until analysis. In order to assess mycorrhizal infection, roots were cleared in KOH and stained with trypan blue. Mycorrhizal percent root colonization (= infected root length / total root length x 100%) was determined using the modified gridline-intersect technique[5]. Due to the low viability of the root samples, 27

[3] Smith, S.E., and Read, D.J. 1996. Mycorrhizal Symbiosis, Second Edition. Academic Press.
[4] Gover et al. 2003. Roadside Vegetation Management Research Report – Sixteenth Year.
[5] Koide, R.T., and Mooney, H.A. 1987. *New Phytologist* 107: 173-182.

to 100 points were counted per sample, though 100 points is desirable. A composite soil sample was collected from each site and submitted to Penn State Agricultural Analytical Services for basic fertility analysis.

RESULTS AND DISCUSSION

Soil test results are shown in Table 1. Soil phosphorus (P) levels were optimum for the Orchard site and far below optimum for the Interchange site. In soils with low P levels, mycorrhizal associations are especially beneficial for nutrient acquisition. Soil pH greatly exceeded optimum for the Interchange site, with no reserve acidity and 80 percent saturation of the cation exchange capacity by calcium, which further suggests P limitation. During sample collection, it was apparent that root growth at the Interchange site was limited in depth due to the occurrence of the shallow clay layer. WSG are well-suited to such infertile sites but require several years to establish, during which weed control is an issue. WSG at the interchange site were competing with several aggressive, non-native broadleaf species, including crownvetch and spotted knapweed.

Microscopic examination of root samples revealed that the majority of the roots that had been collected were dead. Since only the stele (vascular tissue in the center of the root) and epidermis (outer layer of cells) remained on dead and decaying roots, mycorrhizal infection rates could not be determined for the non-viable portion of the sample. Infected roots were recognized by the presence of blue-stained mycorrhizal structures in the root cortex, which is a thick layer of cells used for storage and transport located between the stele and epidermis. Table 2 shows the results for total root counts and the number of infected, or colonized, roots. Ideally, 100 points are counted per sample (i.e., "total"); however, due to the low viability of roots, total counts for many samples were less than 100. Generally, it appeared that the viability of roots was lower at the Interchange site; this is expected given the harsher soil conditions and low fertility at that location. Infection rates for WSG and CSG species varied from 30 to 44% and 47 to 49% at the interchange, respectively. Lower infection rates for WSGs may have resulted from the low root viability; if dead roots that had lost their cortex were mistakenly counted as viable, estimated percent infection rates would be lower than actual values. At the Orchard site, infection rates were 43 to 65% for WSG and 48 to 64% for CSG. Again, there was no apparent difference among the two growth habits in infection rates; however, the low viability of samples limited detection of differences.

Roots had been collected from the area near the root crown (i.e., within 1 ft) for WSG species, in order to confirm that the roots belonged to the targeted plant species, since the stands were composed of mixed species, including weeds. If only desirable WSG were present, it would be possible to take a sample of roots from several areas within the stand to estimate a colonization rate for the stand, rather than individual species. However, both of the sites in this study contained weedy species throughout.

CONCLUSIONS

Low root viability limited any ability to detect differences among growth habits and between field sites, so additional samples were not collected. In a greenhouse study, Wilson and Hartnett grew plants from seed in both nonsterile soil and steam-pasteurized soil inoculated with arbuscular mycorrhizal spores. They reported percent root colonization values as follows: big bluestem 50.2, switchgrass 61.4, indiangrass 44.7, orchardgrass 41.2, tall fescue 23.2, and

Kentucky bluegrass 17.2[6]. Their results are similar to the results reported here for WSGs, though they reported lower colonization rates for CSG. Wilson and Hartnett also found that big bluestem, switchgrass, and indiangrass were significantly more responsive to mycorrhizal infection. This means that the dry mass of mycorrhizal plants was significantly greater than that of noninoculated plants. Conversely, the CSG species orchardgrass and Kentucky bluegrass were not responsive to inoculation; however, tall fescue biomass was positively but weakly correlated with mycorrhizal infection. Therefore, mycorrhizal inoculation may provide some benefit for CSG in addition to WSG.

Future work could utilize soil bioassays to estimate the amount of mycorrhizal propagules and infectivity of a soil[7]. Generally, one or more soils are collected, and a species such as corn (a WSG species) is sown in replicate containers of each soil. The corn is harvested, roots are cleared and stained, and mycorrhizal root infection is assessed, similarly to the present study. However, since the corn plants are young and vigorously growing, root viability is high, and dead roots therefore do not interfere with the counting process.

White et al. compared mycorrhizal root colonization and vegetative cover among four inoculation treatments at a roadside prairie restoration site[8]. They found that treatments which received mycorrhizal inoculum had higher root colonization (57 to 60%) compared to an uninoculated control (48%) after 15 months of growth, but inoculation did not detectably improve the establishment of vegetation. By the end of the third growing season, there were no differences in colonization or vegetative cover among treatments. However, soils at the restoration site had high P levels (i.e., 22 ppm), which may have made inoculation less beneficial. The soils at the Orchard and Interchange sites had P levels of 24 and 7 ppm, respectively. It is likely that many of the Commonwealth's road construction sites are in fact P-limited and may benefit from the application of inoculums. Further research is necessary to determine whether WSG species will benefit from inoculation in the field and, if so, to evaluate the benefits of different inoculum sources.

MANAGEMENT IMPLICATIONS

Current seeding protocols and specifications are based on the physiology and requirements of CSG[9] and may need modification to facilitate the success of WSG. The addition of mycorrhizal inoculums, for example, may aid in the establishment of WSG, as well as some CSG. Inoculum is available as commercial mixes, but propagules are also present in soils from corn and other WSG crop species. Therefore, the use of corn or other agricultural soil as an amendment may provide a cost-effective source of inoculum. Other species used by the Commonwealth for revegetation, such as black-eyed susan, have also responded favorably to mycorrhizal colonization; however, weedy species like bull thistle benefitted, as well[10]. Changes to existing specifications, including the addition of microbiological inoculums, may increase establishment of WSG and help provide more immediate benefits for native groundcovers.

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[6] Wilson, W.T., and Hartnett, D.C. 1998. American Journal of Botany 85: 1732-1738.
[7] Djunna, I.A.F., et al. 2009. Ch. 3 - Use of Mycorrhiza Bioassays in Ecological Studies. *In:* Symbiotic Fungi, Soil Biology 18. Varma, A., and Kharkwal, A.C. (eds.), Springer.
[8] White, J.A., et al. 2008. Mycologia 100: 6-11.
[9] PennDOT. Pub 408, Section 804 – Seeding and Soil Supplements.
[10] Wilson, W.T., and Hartnett, D.C. 1998. American Journal of Botany 85: 1732-1738.

Table 1. Soil test results from Orchard Rd, "Orchard," and the SR322/SR220 interchange, "Interchange," in State College, PA. A composite soil sample was collected from each site. CEC = Cation Exchange Capacity, meq/100g = milliequivalents per 100 grams soil, ppm = parts per million.

						Exchangeable Cations		
Site	Soil pH	P	K	Acidity	CEC	K	Mg	Ca
		---- ppm ----		--- meq/100g ---		% Saturation of the CEC		
Orchard	5.6	24	167	6.3	11	3.8	5.8	34
Interchange	8.4	7	130	0	19.4	1.8	18	80

Table 2. Mycorrhizal root colonization for warm-season (W) and cool-season (C) grass species collected from Orchard Rd, "Orchard," and the SR322/SR220 interchange, "Interchange," in State College, PA. Data are the composite of two root samples per species per site. W = warm-season grass, C = cool-season grass, Total = total number of points of root length counted, Infected = number of points infected (colonized) by mycorrhizal fungi, % Infection = number infected / total x 100%. A dashed line denotes a species not present.

	Growth	Interchange			Orchard		
Species	Habit	Total	Infected	**Infection**	Total	Infected	**Infection**
		--- # points ---		**%**	--- # points ---		**%**
big bluestem	W	27	12	**44**	54	23	**43**
indiangrass	W	33	10	**30**	92	54	**59**
switchgrass	W	---	---	---	69	45	**65**
fine fescue	C	96	45	**47**	100	55	**55**
Kentucky bluegrass	C	---	---	---	100	64	**64**
orchardgrass	C	---	---	---	40	19	**48**
tall fescue	C	57	28	**49**	100	64	**64**

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

Plant common and scientific names: annual ryegrass (*Lolium multiflorum*), barnyardgrass (*Echinochloa crus-galli*), big bluestem (*Andropogon gerardii*), cereal rye (*Secale cereale*), crownvetch (*Coronilla varia*), fall panicum (*Panicum dichotomiflorum*), foxtail (*Setaria* spp.), Indiangrass (*Sorghastrum nutans*), little bluestem (*Schizachyrium scoparium*), partridge pea (*Chamaecrista fasciculata),* showy tick-trefoil (*Desmodium canadense*), spring oats (*Avena sativa*), switchgrass (*Panicum virgatum*), Virginia wildrye (*Elymus virginicus*).

ABSTRACT

Revegetation methods that provide rapid establishment and erosion control throughout the year are required for roadside construction and maintenance, presenting a challenge to the development of slower growing, native groundcovers for operational use. A replicated trial was designed to test establishment success of a native seed mix consisting of both grasses and legumes, Formula N, against Formula C, a mix of annual ryegrass and crownvetch used for poor sites and low-maintenance areas. The two mixes were planted on four dates in 2009, February 13, April 23, July 7, and August 21, using current establishment practices per PennDOT Pub 408. As of August 25, 2009, it appeared that, as expected, only the cover crops from the two mixes, annual rye and spring oats, had established. Otherwise, partridge pea, a native annual legume, was the most visible component from either mix. The native warm-season grasses, big bluestem and Indiangrass, were found on a few plots among the seeding times. Virginia wildrye, little bluestem, switchgrass, and showy tick-trefoil, a legume, were not found in any of the plots. The August seeding was not expected to establish prior to winter. Weedy grass species, including foxtails, barnyardgrass, and fall panicum, as well as various broadleaf weeds, were much more abundant than desirable species. The trial is an ongoing study and will require several years of monitoring to evaluate the establishment success of Formula N relative to Formula C from the four seeding dates.

INTRODUCTION

Revegetation of low quality sites, such as those remaining after road construction or maintenance, presents a challenge for environmental managers who must balance the regulatory need for immediate erosion control with the pressure to establish groundcover composed of native plant species. Formula C[1], a crownvetch plus annual ryegrass seed mix, is currently specified for use on newly developed sites or to rehabilitate sloped, difficult-to-mow areas. Crownvetch has successfully been established on the poorest of roadside soils for over 50 years; however, due to its advantageous characteristics, including the capacity to fix atmospheric nitrogen, drought tolerance, and reproduction both by seed and rhizomes, crownvetch is now considered a weedy and "invasive" plant in many settings. In order to provide an alternative to Formula C, previous research has focused on the potential use of native warm-season grasses, such as big bluestem, little bluestem, indiangrass, and switchgrass, as an alternative to

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

naturalized groundcovers like crownvetch[2]. The major drawback to warm-season grasses is their long establishment period, requiring several years to meet groundcover criteria for erosion control. A further complication is the need for an adaptive groundcover that will readily establish from seed throughout the year to correspond with construction schedules, which rarely match optimal planting periods. PennDOT Pub. 408 specifies that the crownvetch portion of Formula C can be seeded anytime except September and October, and annual ryegrass can be planted March 1 to October 15. Warm-season grasses are most successfully seeded in early spring; a late summer (i.e., August to September) planting can result in winter kill of newly germinated seedlings[3].

A trial was designed to test establishment success of a native seed mix, Formula N, against Formula C at four different planting dates, using current establishment practices per PennDOT Pub 408.

MATERIALS AND METHODS

The study was established on the level portion of a fill slope located behind the guiderail on I99 eastbound, west of State College, PA, and immediately west of the Sellers Lane overpass. The site was prepared by ripping and grading on October 16, 2008. Two soil samples were collected, one composite sample and one grab sample from the southeastern corner of the site. Samples were sent to the Penn State Agricultural Analytical Services Laboratory for analysis of pH; Mehlich buffer lime requirement; and phosphorus, potassium, magnesium, and calcium by the Mehlich 3 (ICP) test.

The site footprint, approximately 0.49 ac, was seeded with cereal rye at 8.3 lbs per 1000 square yard (S.Y.) on October 22, 2008, to provide immediate cover. Soil amendments applied with the rye were 46-0-0 urea and 39-0-0 sulfur-coated urea at a rate of 15 and 5.9 lbs per 1000 S.Y., respectively. The site was mulched with straw.

The experiment followed a factorial design, consisting of two seed mixes (i.e., Formula N and Formula C) and four application timing windows (i.e., 1=Nov to Feb, 2=Mar to May, 3=Jun to July, and 4=Aug to Sep). The eight treatments were applied to 20-ft-by-24-ft plots, arranged in a randomized complete block with three replications. Tables 1 and 2 present the components and seeding rates of Formula C and Formula N, respectively. The seed mixes were obtained from Ernst Conservation Seeds, Inc. (Meadville, PA) separately for each treatment. Formula C and N were applied at a rate of 8 lb and 12.8 lb per 1000 S.Y., respectively. Both treatments included pelleted limestone and 20-10-10 fertilizer at 800 and 140 lb per 1000 S.Y., respectively. The Formula N treatment also received 39-0-0 sulfur-coated urea at 49 lb per 1000 S.Y, equivalent to the Pub. 408 specifications for seeding cool-season grasses. All plots were straw mulched after seeding at a rate of 1200 lb per 1000 S.Y.

The first seed timing was applied on February 13, 2009. Spring oats, the temporary cover in the Formula N seed mix, was not included in February seeding since cereal rye had already been seeded as a cover crop on October 22, 2008. With the oats removed, the rate for seeding the remaining components was 6.8 lb per 1000 S.Y. Most plots were saturated with water

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[2]Johnson et al. 2009. Native Seed Mix Establishment Implementation. Roadside Vegetation Management Research Report – Twenty-Third Year Report.

[3]Miller and Dickerson. 1999. The Use of Native Warm Season Grasses for Critical Area Stabilization. Proc. of the 2nd Annual Eastern Native Grass Symposium, pp. 222-228.

resulting in some ice formation on the surface. Plots in the southeastern corner had standing water.

The second timing was applied on April 23, 2009. The soil was very moist to nearly saturated. The seed supplier had failed to pre-mix the crownvetch inoculant for this shipment of seed. Therefore, the inoculant was separately broadcast onto the plots on April 30, 2009.

The third and fourth timings were applied July 7 and August 21, 2009, respectively. Soils were dry on both dates.

The trial was evaluated on August 25, 2009, to determine the presence or absence of each species in the seed mixes.

RESULTS AND DISCUSSION

Soil test results are shown in Table 3. Despite the appearance of red-tinted surface water in the southeast corner of the site, a possible indicator of acid runoff, soil pH was slightly basic. Prior to receiving soil amendments, the soil had below optimum phosphorus and potassium levels. Soils were not tested after the application of lime and fertilizer.

As of August 25, 2009, annual ryegrass had germinated on all Formula C plots except for the fourth (August) timing. Crownvetch seedlings were not apparent on any plots. Spring oats, the cover crop in Formula N, had established well from the second (April) timing, and it appeared that seedlings were emerging from the third (July) timing. Virginia wildrye, little bluestem, switchgrass, and showy tick-trefoil, a legume, were not found on any of the plots. Big bluestem seedlings were visible on one plot from each of the first (February) and third timings. Indiangrass had emerged on one plot from each of the second and third timings. Partidge pea, an annual legume, was located on all three of the plots from the first timing and one plot from the second timing. The fourth timing was not expected to establish prior to winter. Weedy grass species, including foxtails, barnyardgrass, and fall panicum, and various broadleaf weeds were much more abundant than desirable species.

CONCLUSIONS

This trial is an ongoing study and will require several years of monitoring to evaluate the establishment success of Formula N relative to Formula C at the four seeding dates. However, after one season, it appeared that only the cover crops, annual rye and spring oats, had established. Otherwise, partridge pea was the most visible component from either mix. Weedy species, both broadleaf and annual, dominated the groundcover.

MANAGEMENT IMPLICATIONS

Recommendations cannot be made until the mixes are given at least two to three years to establish. However, it is clear from the soil testing at this site that the addition of lime to raise soil pH, as prescribed by Pub. 408, was unnecessary. Therefore, soil testing prior to seeding seems to offer a more cost-effective approach to soil amendment than the general specifications currently used.

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

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

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

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

Table 3. Soil test results from the planting site on new I-99 construction, west of State College, PA. A “Composite” sample was collected from multiple points, and the “Grab” sample was collected from the southeast corner of the site. CEC = Cation Exchange Capacity, meq/100g = milliequivalents per 100 grams soil, ppm = parts per million.

						Exchangeable Cations		
Site	Soil pH	P	K	Acidity	CEC	K	Mg	Ca
		---- ppm ----		--- meq/100g ---		% Saturation of the CEC		
Composite	7.8	16	73	0.00	17	1.1	23	76
Grab	7.3	26	110	0.00	9.0	3.1	35	62

GERMINATION OF ANNUAL RYE AND TALL FESCUE IN KNOTWEED INFESTED SOIL

Herbicde trade and common chemical names: Arsenal (*imazapyr*).
Plant common and scientific names: annual ryegrass (*Lolium multiflorum*), creeping red fescue (*Festuca rubra*), giant knotweed (*Polygonum sachalinensis*), Japanese knotweed (*Polygonum cuspidatum*).

ABSTRACT

Establishment of competitive grass groundcover in operational knotweed control sequences has presented a challenge[1]. One potential mechanism behind this challenge is allelopathic interference, inhibition of grass growth and/or germination, by knotweed. As a preliminary assessment of the potential for allelopathic inhibition by Japanese knotweed, fine fescue and annual ryegrass were sown in a controlled environment in soils collected from infested and un-infested ("clean") areas of three established knotweed stands, as well as a control soil (i.e., vermiculite). Germination rates were similar for infested and clean soils, ranging from 61 to 82 percent for fine fescue and 50 to 70 percent for annual ryegrass. Germination in the control ranged from 64 to 70 and 40 to 56 percent for fine fescue and annual ryegrass, respectively. Data were pooled and blocked by site in order to compare the effects of soil type across all locations. There were no significant differences in the germination rates of either species between clean and infested field soils. Therefore, any allelochemicals which may have been present in the soils collected did not impact seed germination rates of fine fescue and annual ryegrass. Future germination trials could involve the application of extracts from living knotweed shoots and rhizomes to sterile soils.

INTRODUCTION

Japanese knotweed is a rhizomatous, herbaceous perennial plant, originally transplanted from East Asia for ornamental use. Due to its aggressive growth and ability to spread via infested fill material, knotweed has become a threat on roadsides and other disturbed areas, crowding out other species to create a monoculture. The dense, spreading stands can exceed 10 ft in height and, therefore, pose a threat to sight distance and safety. Both Japanese knotweed and the related species, giant knotweed, are widely regarded as invasive species.

Previous work has shown that a multi-step approach, based on chemical methods, can effectively control both species of knotweed[2]. Revegetation with grasses is part of the ideal treatment scenario, allowing knotweed resprouts to be retreated with a selective herbicide. In order to eradicate knotweed, annual retreatment may be required for several years. However, establishment of competitive groundcover in operational control sequences has presented a challenge[3].

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[1] Johnson et al. 2009. Implementing Japanese Knotweed Removal and Conversion to Grasses. Roadside Vegetation Management Research Report – Twenty-Third Year Report.

[2] Gover et al. 1999. Evaluation of Giant Knotweed Control and Conversion into Fine Fescues. Roadside Vegetation Management Research Report – Fourteenth Year Report.

[3] Implementing Japanese Knotweed Removal and Conversion to Grasses. 2009. Roadside Vegetation Management Research Report – Twenty-Third Year Report.

Part of the difficulty involved in revegetation of knotweed-infested areas may be a result of allelopathic inhibition. Knotweed produces phenolic compounds in both its above-ground parts and rhizomes. Many of these chemicals are known to be biologically active, potentially inhibiting the growth of other plant species[4]. Unfortunately, the allelopathic properties of knotweed have not been well characterized[5].

As a preliminary assessment of the potential for allelopathic inhibition by Japanese knotweed, grass seeds were sown in soils collected from infested and un-infested areas of three established knotweed stands. Germination rates of two species commonly used in PennDOT's seed mixes, annual rye and tall fescue, were compared among sites and between infested and un-infested soils at each location.

MATERIALS AND METHODS

Soils were collected from three roadside knotweed stands in the vicinity of State College, PA. The sites were as follows: Fox Hollow Rd., near the intersection with Toftrees Ave. (FHA); Fox Hollow Rd., west of the intersection with Orchard Rd. (FHB), and the southwest infield of University Dr. and E. College Ave. (UCI). The FHB site was adjacent to a drainage basin that had previously been treated with Arsenal during late spring or early summer of 2009.

Soils were collected on November 13 from FHA and FHB and on November 30, 2009, from UCI. Knotweed shoots at all sites were brown and senescing. At each location, two composite soil samples were taken to a depth of approximately two inches; one sample, "infested," was collected within the knotweed patch, and another sample, "clean," was collected from adjacent, similar soil with no evidence of knotweed growth. Soils were passed through a 4-mm sieve to remove rocks and detritus. A sample of each field soil (n=6) was also sent to the Penn State Agricultural Analytical Services Laboratory for analysis of pH, Mehlich buffer lime requirement, and for phosphorus, potassium, magnesium, and calcium by the Mehlich 3 (ICP) test.

Annual ryegrass and creeping red ("fine") fescue seed was obtained from Ernst Seeds (Meadville, PA). Germination trays were filled with either the sieved soil or vermiculite (control), and 100 seeds of each species were planted into each tray by manually slit-seeding rows in the soil. Each germination trial was initiated within two weeks of soil collection, and two plantings of 100 seeds each were done per site by soil type combination. The trays were initially watered by immersion and then incubated in hydroponics bays, where they received fluorescent light on plastic-enclosed, elevated tables. Soil moisture was maintained by spraying the trays with water as needed. Soils were incubated for four to seven days to allow germination. Germination rates were determined by counting the visible shoots which appeared within that time period.

Germinations rates were calculated as the number of visible shoots divided by the total number of seeds planted (i.e., 100) multiplied by 100 percent. Germination rates from the two runs were compared among soil types (infested, clean, or control) and blocked by location. Results were considered significant at $p < 0.05$.

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[4] Vrochtova, N., and Sera, B. 2008. Allelopathic Properties of Knotweed Rhizome Extracts. Plant Soil Environ 54, 301-303.

[5] Weston, L.A., et al. 2005. A review of the Biology and Ecology of Three Invasive Perennials in New York State. Plant and Soil 277, 53-69.

RESULTS AND DISCUSSION

Soil test results are shown in Table 1. Soil pH was similar among all sites and ranged from 7.2 to 7.5. Soil phosphorus, potassium, and magnesium levels tended to be higher in knotweed infested soils. It is likely that the extensive root system and dense aboveground growth of knotweed increased acquisition of nutrients from the soil and accumulation in the upper soil profile. Overall, soil properties were relatively similar among the soil types and should not have affected germination rates.

Germination rates for site by soil type combinations are shown in Table 2. Rates were similar for infested and clean soils, ranging from 61 to 82 percent for fine fescue and 50 to 70 percent for annual ryegrass. Germination in the control ranged from 64 to 70 and 40 to 56 percent for fine fescue and annual ryegrass, respectively. Differences among sites in germination rates for both grass species were not significant; therefore, data were pooled and blocked by site in order to compare the effects of soil type across all locations. Table 3 shows the results of germination rates according to soil type. There were no significant differences in fine fescue germination rates; however, annual rye germination rates in the control soil were significantly lower than in the field soil. The control soil, vermiculite, may have yielded the lowest germination rates due to its relative sterility compared to the field soils. The field soils likely contained a microbial population capable of degrading the seed coats and therefore enhancing germination. Potential residual activity from the application of Arsenal at FHB did not appear to significantly influence germination rates of either grass species.

CONCLUSIONS

The data from this preliminary study do not provide evidence that germination of fine fescue and annual ryegrass is inhibited in knotweed infested soil relative to clean (un-infested) soil. Other possible factors that may account for poor grass establishment on knotweed infested sites include failure of seeds to reach mineral soil (i.e., resulting in low germination rates) due to accumulated knotweed residue, seedling competition with surviving knotweed rhizomes for nutrients and water, and lack of sufficient sunlight for growth. There is also the potential that secondary chemicals produced by knotweed inhibit the growth of grass seedlings without directly affecting germination. This is a reasonable possibility since allelochemical concentrations in the soil would likely remain high throughout the growing season. Also supporting this hypothesis, Vrchotova and Sera[3] reported that the length of radicals, hypocotyls, and root-to-shoot ratio were significantly lower for white mustard seeds germinated in extracts of knotweed rhizomes, whereas there were no significant differences in germination rate relative to the control.

Results of the current study are limited to the conclusion that any allelochemicals that may have been present in the soils collected did not impact seed germination rates of fine fescue and annual ryegrass, species commonly used for roadside revegetation. It is also possible that any allelochemicals in soil may have been degraded by microbes in the one- to two-week interval between soil sampling and seed planting. Future germination trials could involve the application of extracts from living knotweed shoots and rhizomes to sterile soils. This would minimize any potential effects resulting from differences in soil properties and ensure that knotweed secondary chemicals are not degraded in the time interval between soil sampling and seed planting.

MANAGEMENT IMPLICATIONS

At this point, it is unclear whether knotweed allelopathically inhibits the establishment of desirable grass species. If allelopathic inhibition can be confirmed, it will be advisable to allow a longer time interval between initial knotweed control efforts and reseeding. Another option, when feasible, would be the removal of knotweed surface residues to prevent leaching of allelochemicals from foliage.

Table 1. Soil test results from sites located in the vicinity of State College, PA: Fox Hollow Rd., near the intersection with Toftrees Ave. (FHA); Fox Hollow Rd., west of the intersection with Orchard Rd. (FHB), and the southwest infield of University Dr. and E. College Ave. (UCI). A composite soil sample was collected from each site. CEC = Cation Exchange Capacity, meq/100g = milliequivalents per 100 grams soil, ppm = parts per million.

				Exchangeable Cations			
Site	Soil Type	Soil pH	Phosphorus	K	Mg	Ca	CEC
			ppm	------------- meq/100g -------------			
FHA	Infested	7.3	30	0.42	1.91	13.2	15.5
FHA	Clean	7.3	32	0.26	1.27	19.8	16.5
FHB	Infested	7.3	89	0.56	2.68	21.8	18.2
FHB	Clean	7.2	35	0.19	1.26	27.5	16.4
UCI	Infested	7.4	62	0.67	3.86	18.3	19.5
UCI	Clean	7.5	46	0.33	2.79	9.92	13.0

Table 2. Germination rates from three knotweed infested sites in the vicinity of State College, PA. Results are presented for fine fescue and annual ryegrass grown in either clean soils (no detectable knotweed biomass), knotweed-infested field soils, or control (vermiculite) soil. Each value represents the mean of two replications.

	Fine Fescue			Annual Ryegrass		
Site	Clean	Infested	Control	Clean	Infested	Control
	------------------------------ % Germination ------------------------------					
FHA	62	68	64	59	61	40
FHB	61	74	64	60	50	40
UCI	80	82	70	70	70	56

Table 3. Germination rates for fine fescue and annual ryegrass grown in either clean soils (no detectable knotweed biomass), knotweed-infested field soils, or control (vermiculite) soil. Each value represents the mean of six replications. Data from three different locations were pooled and blocked by location.

Soil type	Fine Fescue	Annual Ryegrass
	---------- % Germination ----------	
Clean	68	63
Infested	74	60
Control	66	45
Protected LSD (p=0.05)	ns	15

SLOPEMASTER WHITE CLOVER SEED MIX DEMONSTRATION

Plant common and scientific names: chewings fescue (*Festuca rubra*), foxtail millet (*Setaria italica*), hard fescue (*Festuca brevipila*), perennial ryegrass (*Lolium perenne*), sericea lespedeza (*Lespedeza cuneata*), tall fescue (*Festuca arundinacea*), white clover (*Trifolium repens*).

ABSTRACT

Slopemaster is a "Durana," white-clover-based seed mix designed for rapid establishment and erosion control on low-maintenance sites (Pennington Seed, Inc., Madison, GA). Two variations of the Slopemaster mix, one based on fine fescue and the other on tall fescue, were seeded on a new roadside construction area. Both Slopemaster mixes established well, especially the tall fescue blend, with 85 percent cover 109 days after seeding. However, there are several caveats toward potential operational use of the Slopemaster mixes. Firstly, the mixes rely on aggressive, introduced/naturalized species. Furthermore, sericea lespedeza, a component of the tall fescue mix, has been reported as invasive in the Mid-Atlantic region. Finally, white clover has the potential to attract deer and other wildlife to the roadside. Further monitoring is necessary to determine how well the "Durana" clover establishes and persists as a permanent groundcover.

INTRODUCTION

Slopemaster is a "Durana," white-clover-based seed mix designed for rapid establishment and erosion control on low-maintenance sites (Pennington Seed, Inc., Madison, GA). "Durana," a medium-leafed, intermediate-type white clover, is promoted as a durable cover, producing as many as 97 stolons per square foot and capable of fixing up to 150 lb of atmospheric nitrogen per acre per year. "Durana" has been incorporated into two seed mixes. The standard mix consists of 60 percent "Predator" hard fescue, 20 percent "7 Seas" chewings fescue, 10 percent "T-3" perennial ryegrass, and 10 percent "Durana" clover. For full sun and dry sites, a second Slopemaster mix with a combination of 10 percent "Durana" clover with "Greystone" tall fescue, "T-3" perennial ryegrass, sericea lespedeza, and foxtail millet at 70, 10, 5, and 5 percent, respectively, is recommended. These mixes can be planted via drilling, broadcasting, or hydroseeding.

A demonstration was established to evaluate success of the standard, fine fescue-based Slopemaster mix, as well as a Slopemaster mix for full sun/dry conditions, with tall fescue as the main component.

MATERIALS AND METHODS

The trial was installed on the level portion of a fill slope outside of the guiderail on I99 eastbound, west of State College, PA, and immediately west of the Sellers Lane overpass. The Slopemaster mixes were broadcast on April 22, 2009, at a rate of approximately 90 and 125 lb/ac for the standard ("fine fescue") and full sun/dry ("tall fescue") mixes, respectively. The total area seeded to each mix was approximately 2500 sq ft. Soil amendments and mulch were applied according to PennDOT Pub. 408 Specifications, Sections 804 and 805. The plots were evaluated for vegetative cover on August 9, 2009, which corresponds to 109 days after seeding.

RESULTS AND DISCUSSION

As of 109 days after seeding, the fine fescue mix provided about 50 percent cover by desirable species. There was greater cover on the plot seeded to the tall fescue, with about 85 percent cover, mainly tall fescue. Overall, the "Durana" white clover had established better on the plot seeded to the fine fescue mix. It is possible that the thick stand of tall fescue competed with the clover, inhibiting its establishment.

CONCLUSIONS

Both Slopemaster mixes established well, especially the tall fescue blend. However, there are several caveats toward potential operational use of the Slopemaster mixes. First, the mixes rely on introduced/naturalized species to provide rapid cover. These fast-growing, aggressive plants have the tendency to become invasive. Furthermore, sericea lespedeza, also known as Chinese lespedeza, is regarded as highly invasive in some settings[1] and has been reported to be invasive in Pennsylvania and surrounding areas[2]. Finally, white clover provides palatable forage and is especially attractive to deer and elk.[3] Therefore, use of Slopemaster has the potential to attract wildlife to the roadside. Further monitoring is necessary to determine how well the "Durana" clover establishes and persists as a permanent groundcover. If the mixes show continued success, it will be necessary to remove the sericea lespedeza component to permit further usage.

MANAGEMENT IMPLICATIONS

Ongoing evaluation will determine the establishment success of the "Durana" white clover, which is promoted for its long-term ability to fix nitrogen. This nitrogen is expected to become available to the other components of the mixes, providing cost savings by decreasing or eliminating fertilizer requirements. Caution should be exercised when planting potentially invasive species or species that can attract wildlife to the roadside.

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[1] USDA/NRCS. Plant Fact Sheet: Chinese Lespedeza, *Lespedeza cuneata* <http://plants.usda.gov>.
[2] Mid-Atlantic Exotic Pest Plant Council Plant List < http://www.invasive.org/maweeds.cfm> .
[3] USDA/NRCS. Plant Fact Sheet: White Clover, *Trifolium repens* <http://plants.usda.gov>.