Roadside Vegetation Management Research – 2009 Report

ANNUAL REPORT

May 27, 2009

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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: Basal Timing Study on Mixed Tree Species; Grass-Safe Herbicide Mixes for Woody Vegetation Control; Response of Black Locust, Red Oak, and Tulip Poplar to Foliar Applications of DPX-KJM44; Comparing Grass-Safe Herbicides for Converting Canada Thistle Infested Crownvetch to Formula L; Response of Fineleaf Fescues to Herbicides Applied During Establishment; Implementing Japanese Knotweed Removal and Conversion to Grasses; Efficacy of Kixor™ for Selective Postemergence Application; Options for Postemergence Kochia Control; Selective Control of Dicots using DPX-KJM44; Further Evaluation of Alternatives to Diuron for Kochia Control; and Native Seed Mix Establishment Implementation.

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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 2008 season: BASF Specialty Products, Bayer Environmental Sciences, E.I. DuPont de Nemours & Co., and Ernst Conservation Seeds, Inc.

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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

These reports are available by request from the authors, and are available online in portable document format (PDF) at http://rvm.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 product name, active ingredients, formulation, and manufacturer information for products referred to in this report. E=emulsion, EC=emulsifiable concentrate, ME=microencapsulated, S=water soluble, WDG=water-dispersible granules.

Trade Name	Active Ingredients	Formulation	Manufacturer
Accord Concentrate	glyphosate	4 S	DowAgroSciences LLC
Arborchem Basal Oil	diluent	---	Arborchem Products, Inc.
Aquaneat	glyphosate	4 S	Nufarm Turf & Specialty
Arsenal	imazapyr	2 S	BASF Specialty Products
Banvel	dicamba	4 S	Arysta LifeScience LLC
BAS800H (Kixor)	saflufenacil	70 WDG, 2.8 S, 1 EC	BASF Specialty Products
BAS8020H	saflufenacil + imazapic	34 + 36 WDG	BASF Specialty Products
Credit Extra	glyphosate	3 S	Nufarm Turf & Specialty
DPX-KJM44	aminocyclopyrachlor	80 WDG	E.I. DuPont de Nemours & Co.
Edict	pyraflufen ethyl	0.18 S	Nichino, Inc
Endurance	prodiamine	65 WDG	Syngenta Crop Protection, Inc.
Escort, Escort XP	metsulfuron methyl	60 WDG	E.I. DuPont de Nemours & Co.
Garlon 3A	triclopyr amine	3 S	DowAgroSciences LLC
Garlon 4	triclopyr ester	4 EC	DowAgroSciences LLC
GlyPro Plus	glyphosate	3 S	DowAgroSciences LLC
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.
Milestone VM	aminopyralid	2 S	DowAgroSciences LLC
Oust Extra	sulfometuron + metsulfuron	56.25 + 15 WDG	E.I DuPont de Nemours & Co.
Overdrive	dicamba + diflufenzopyr	70 WDG	BASF Specialty Products
Payload	flumioxazin	51 WDG	Valent Professional Products
Pendulum AQ	pendimethalin	3.8 ME	BASF Specialty Products
Plateau	imazapic	2 S	BASF Specialty Products
RoundUp	glyphosate	3 S	Monsanto
RoundUp PRO Conc	glyphosate	3.7 S	Monsanto
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.
Tordon 101M	picloram + 2,4-D	0.54 + 2 S	DowAgroSciences LLC
Tordon K	picloram	2 S	DowAgroSciences LLC
Transline	clopyralid	3 S	DowAgroSciences LLC
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
Weedestroy	2,4-D	3.8 S	Nufarm Turf & Specialty

BASAL TIMING STUDY ON MIXED TREE SPECIES

Herbicide trade and common chemical names: Garlon 4 (*triclopyr*, ester formulation)
Plant common and scientific names: big tooth aspen (*Populus grandidentata*), black birch (*Betula lenta*), black cherry (*Prunus serotina*), gray birch (*Betula populifolia*), green ash (*Fraxinus pennsylvanica*), hemlock (*Tsuga canadensis*), pignut hickory (*Carya glabra*), pin cherry (*Prunus pensylvanica*), quaking aspen (*Populus tremuloides*), red maple (*Acer rubrum*), red oak (*Quercus rubra*), sassafras (*Sassafras albidum*), white oak (*Quercus alba*)

ABSTRACT

Basal bark applications are commonly used for selective control of undesirable woody plants. In some PennDOT districts, contract applicators perform basal bark treatments upon completion of the Krenite/sidetrim season, which occurs at the onset of significant fall color and early dormancy (i.e., November). However, the November application date falls outside of current operational recommendations. The objective of this trial was to evaluate different timings for basal bark application and further define the effective application window for mixed-species brush. Brush control results from three Garlon 4 basal application dates (March, August, and November) were compared at two locations in Pennsylvania. Garlon 4 was selected because it is a common herbicide for the control of mixed tree species via basal treatment. Results showed that regardless of application timing, end-of-season control of red maple, black cherry, pin cherry, black birch, bigtooth aspen, trembling aspen, white oak, sassafras, and pignut hickory was excellent. Alternatively, there were significant differences in control among timings for green ash and red oak, as well as hemlock. Hemlock control was unacceptable at all timings; however, unlike oak and ash, hemlock is not currently listed among species controlled by Garlon 4. The November application produced significantly lower control ratings for green ash and red oak, each at one location. Control among species generally improved or remained constant from the first rating, in June, to the second rating in September. By September, control of all species except hemlock was greater than 77 percent, regardless of timing. Among the species studied, green ash and red oak may be problematic when the application window is extended to late fall. However, control of most common species with Garlon 4 is acceptable to excellent when applied in November using the extended basal bark application window. Therefore, contract applicators could be utilized in off-periods during the year in order to perform selective brush control.

INTRODUCTION

Basal bark applications are commonly used for selective control of undesirable woody plants. This technique involves herbicide application to the lower 6 to 18 inches of individual woody stems via backpack sprayer. Applications are normally made in the dormant season because stems are more accessible in the absence of foliage and living groundcover. However, treatment should be avoided when snow cover prevents direct spray contact with the base of the plants. Additionally, target stems should be less than 6 inches in diameter. For larger trees, other methods are recommended, such as hack-and-squirt or injection.

In some PennDOT districts, contract applicators perform basal bark treatments upon completion of the Krenite/sidetrim season, which occurs at the onset of significant fall color and early dormancy (i.e., November). However, previous field experience by the Penn State

Vegetation Management research group suggests that mid to late fall may not be an effective time period for basal bark application. Current operational recommendations by the Penn State Vegetation Management employ basal bark applications from January to fall color. If late fall applications are proven equally effective, they would provide a means to retain contractors and accomplish brush control with little aesthetic impact.

The objective of this trial was to evaluate different timings for basal bark application and further define the effective application window for mixed-species brush. Brush control results from three Garlon 4 basal application dates were compared at two locations in Pennsylvania. Garlon 4 was selected because it is a common herbicide for the control of mixed tree species via basal treatment.

MATERIALS AND METHODS

Experimental sites were established along a cut slope on the ramp shoulder of I-81 N, Exit 155 near Dorrance, PA (Luzerne Co.) and in the median of I-80 E, Seg. 1264 near Woodland, PA (Clearfield Co.). Treatments included an untreated check and three basal bark application timings, August, November, and March, in a randomized complete block design with three replications. The solution used was 25% v/v Garlon 4 (triclopyr, ester formulation) and 75% v/v Arborchem Basal Oil with colorant added. This solution was applied using standard backpack sprayers or a CO_2-powered backpack sprayer operating between 20 and 40 psi. All were equipped with an ultra low volume wand, adjustable conejet nozzle, and Y-2 tip. Applications targeted the lower 6 to 12 inches of stems, which ranged in size from 0.5 to 6 inches diameter at the base.

At the Luzerne site, twelve 75-by-50-ft plots were located beyond the edge of the mowline on the cut slope. Applications were made on August 11 and November 8, 2007 and March 25, 2008. Target species included green ash, pignut hickory, pin cherry, big tooth aspen, gray birch, red maple, red oak, sassafras, and white oak. Percent control by species was evaluated on June 3 and September 24, 2008.

At the Woodland site, twelve 75-by-30-ft plots were located in the median. Applications were made on August 10 and November 14, 2007 and March 24, 2008. Target species included black and gray birch, black cherry, green ash, hemlock, quaking aspen, red oak, sugar maple, and white oak. Percent control by species was evaluated on June 5 and September 17, 2008. 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

Control ratings for the Luzerne and Woodland sites are shown in Tables 1 and 2, respectively. Some species were present at only one site and/or were not present in all plots. Regardless of application timing, end-of-season control of red maple, black cherry, pin cherry, black birch, bigtooth aspen, trembling aspen, white oak, sassafras, and pignut hickory was excellent. Alternatively, there were significant differences in control among timings for green ash and red oak, as well as hemlock. Hemlock control was unacceptable at all timings; however, unlike oak and ash, hemlock is not currently listed among species controlled by Garlon 4.

Green ash control at the first rating date, June 3, was significantly lower for the November timing (78 percent) compared to the August (100 percent) and March (97 percent) applications at

Luzerne but increased to 99 percent by the second rating in September. At Woodland, green ash control was initially only 55 percent for the November timing but increased to 88 percent by the September rating. However, control for the November timing remained significantly lower than the 100 percent control provided by both the August and March timings.

Red oak control was significantly lower for the November application at Luzerne. End-of-season control at Luzerne was 78 percent for the November timing and 98 and 99 percent for the August and March timings, respectively. Red oak control was lower, but not significantly different, for both the August (77 percent) and November (78 percent) applications relative to the March timing (96 percent) at Woodland.

It is unclear why green ash and red oak responded differently to the November timing than other species, which were effectively controlled regardless of application date. Generally, downward sap movement in the phloem is expected to cease after leaf drop. Therefore, herbicides applied in late fall (i.e., November), after leaf senescense, may not move into the roots; conversely, herbicides applied late in the growing season (i.e., August), while plants are still photosynthesizing, are expected to move into the roots with sugars exported from the canopy for storage. One factor that separates oak and ash, as well as hickory, from the other species is their ring-porous wood structure. In spring, ring-porous trees produce wood with wide, open vessels and are able to quickly transport large quantities of sap upward through the xylem. It is possible that oak and ash were able to produce an initial flush of growth, leafing out before the herbicide was able to move and chemically girdle the stems. Control generally increased from the first rating in June to the second rating in September, indicating that the herbicide became more effective with time.

Among species, the March timing tended to be more effective than the November timing. March application is advantageous because it decreases the time for potential herbicide degradation between application and active growth. In order for the herbicide to act, the target stem must be actively growing; therefore, herbicides applied in November do not act until the following season and can potentially degrade over winter.

Other factors that affect the efficacy of basal bark applications are the stem diameter, bark texture/thickness, and the presence of multiple stems. For example, stems over 6 inches in diameter may not be controlled regardless of the rate of application. In addition, the thick bark of oak trees tends to resist penetration of the herbicide. Therefore, trees with larger stem diameter or thick bark require more spray coverage than smaller trees with smooth bark. Plants with multiple stems, such as gray birch, may also be problematic due to the large amount of stem surface area and vascular tissue present.

CONCLUSIONS

Control among species tended to either improve or remain constant from the first rating, in June, to the second rating in September. By September, control of all species except hemlock was acceptable, at greater than 77 percent, regardless of timing. Among the species studied, green ash and red oak may be problematic when the application window is extended to late fall. Future work could involve trials with tagged stems, focusing on difficult species such as red oak, green ash, and hemlock.

MANAGEMENT IMPLICATIONS

Control of most common species with Garlon 4 is acceptable to excellent, even when applied in November using the extended basal bark application window. Therefore, contract applicators can be utilized in off-periods during the year in order to perform selective brush control.

Table 1. Control ratings resulting from three basal bark application timings (August 11 and November 8, 2007 and March 25, 2008) at Luzerne, PA. A solution of 25% v/v Garlon 4 and 75% v/v basal oil was applied via backpack sprayer, targeting the lower 6 to 12 inches of stems. The first and second ratings, separated by a "/", represent evaluations made on June 3 and September 24, 2008, respectively. Different letters after a rating indicate values that are significantly different ($p \leq 0.05$).

Species	Red Maple	Pin Cherry	Gray Birch	Bigtooth Aspen	Green Ash	Red Oak	Sassafras	Pignut Hickory
Timing	-- % Control --							
August	100 / 100	99 / 95	92 / 99	100 / 100	100a / 99	99a / 98a	100 / 100	96 / 98
November	100 / 100	100 / 98	62 / 86	74 / 100	78b / 99	70b / 78b	100 / 100	99 / 99
March	100 / 100	99 / 99	82 / 98	75 / 100	97a / 100	99a / 99a	100 / 100	94 / 95

Table 2. Control ratings resulting from three basal bark application timings (August 10 and November 14, 2007 and March 24, 2008) at Woodland, PA. A solution of 25% v/v Garlon 4 and 75% v/v basal oil was applied via backpack sprayer, targeting the lower 6 to 12 inches of stems. The first and second ratings, separated by a "/", represent evaluations made on June 5 and September 17, 2008, respectively. Different letters after a rating indicate values that are significantly different ($p \leq 0.05$).

Species	Red Maple	Black Cherry	Black Birch	Trembling Aspen	Green Ash	Red Oak	White Oak	Hemlock
Timing	-- % Control --							
August	99 / 100	74 / 100	--- / 100	100 / 100	100a / 100a	72 / 77	99 / 97	5b / 5
November	87 / 99	95 / 100	--- / 100	100 / 100	55c / 88b	87 / 78	93 / 100	0c / 0
March	94 / 99	93 / 95	50 / 100	98 / 100	93b / 100a	96 / 96	96 / 100	20a / 22

GRASS-SAFE HERBICIDE MIXES FOR WOODY VEGETATION CONTROL

Herbicide trade and common chemical names: Escort, Escort XP (*metsulfuron methyl*), Garlon 3A (*triclopyr*), Milestone VM (*aminopyralid*), Overdrive (*dicamba + diflufenzopyr*), Tordon 101M (*picloram + 2,4-D)*, Vanquish (*dicamba-glycolamine*).

Plant common and scientific names: creeping red fescue (*Festuca rubra* ssp. *rubra*), Kentucky bluegrass (*Poa pratensis*), Morrow's honeysuckle (*Lonicera morrowii*, LONMO), multiflora rose (*Rosa multiflora*, ROSMU), border privet (*Ligustrum obtusifolium*, LIGOB), tall fescue (*Festuca arundinacea*), Tartarian honeysuckle (*Lonicera tatarica*, LONTA).

ABSTRACT

September-applied herbicide mixtures were compared with Garlon 3A plus Escort XP for efficacy in controlling woody vegetation and safety to grasses. Control of Morrow's honeysuckle, multiflora rose, and border privet was evaluated 27, 236, and 363 days after treatment (DAT) in State College, PA. Morrow's honeysuckle control was evaluated at 28, 226, and 360 DAT in Indiana, PA. Garlon 3A plus Vanquish plus Milestone VM and Garlon 3A plus Tordon 101M were rated the highest for control across all species at both sites. Garlon 3A plus Escort XP was effective against multiflora rose and border privet, but ineffective against Morrow's honeysuckle. Although slight injury symptoms were noted, no treatments provided unacceptable injury to the turf.

INTRODUCTION

The objective of the weed and brush program is to suppress encroaching brush and broadleaf weeds while maintaining the integrity of the existing grass groundcover. The combination of Garlon 3A plus Escort XP is a standard mix for most PennDOT districts. This combination has shown weakness in control of exotic shrub honeysuckle (*Lonicera* spp.)[1/]. Escort has also been shown to inhibit desirable roadside grass species[2/]. The alternative mixtures tested in this experiment retained Garlon 3A but replaced Escort XP with growth regulator herbicides that have been demonstrated to be safe to grasses.

MATERIALS AND METHODS

Brush Treatments

Trial sites were located at Toftrees in State College, PA (Centre Co.) and along SR 422 E at the SR 286 off-ramp near Indiana, PA (Indiana Co.). Eight treatments and an untreated check were arranged in a randomized complete block design (RCBD) with three replications. Treatments were applied as an 8-ft-high pattern to 45-ft-long plots at the State College site using a CO_2-powered backpack sprayer equipped with a TeeJet XP20L BoomJet nozzle delivering 30

[1/] Johnson, J.M., A.E. Gover, T.L. Harpster, and L.J. Kuhns. 2005. Evaluation of herbicides for control of lonicera species. Proc. NEWSS, 59:18-19.

[2/] Gover, A.E. L.J. Kuhns, and D.A. Batey. 1994. Effect of application date on response of tall and fine fescues to applications of metsulfuron methyl or chlorsulfuron. Proc. NEWSS, 48: 31-33.

gal/ac at 40 psi. At the Indiana site, individual shrubs within plots approximately 25 by 30 ft in size were selectively treated using CO_2-powered backpack sprayers with spray wands equipped with TeeJet Adjustable ConeJet nozzles with X-12 tips targeting 100 gal/ac at 30 psi. Treatments were completed on September 13 and 17, 2007 at the State College and Indiana sites, respectively. The treatments included an untreated check; 64 oz/ac Garlon 3A alone or combined with 1 oz/ac Escort XP, 32 oz/ac Vanquish, 7 oz/ac Milestone VM, 8 oz/ac Overdrive, or 64 oz/ac Tordon 101M; 32 oz/ac Garlon 3A plus 7 oz/ac Milestone VM and either 32 oz/ac Vanquish or 8 oz/ac Overdrive. Activator 90 non-ionic surfactant was added to all treatments at 0.25% v/v.

Target species at State College included Morrow's honeysuckle (identified as Tartarian honeysuckle in the preliminary report), multiflora rose, and border privet. Control evaluations were taken October 10, 2007, May 6, 2008, and September 10, 2008, or 27, 236, and 363 DAT, respectively. Percent control of Morrow's honeysuckle at the Indiana, PA site was evaluated on October 15, 2007, April 30, 2008, and September 11, 2008, or 28, 226, and 360 DAT, respectively.

Turf Injury Treatments

Turf injury trial sites were located at the Oak Hall interchange of SR 322 in State College and the SR 22/SR 99 interchange near Duncansville, PA. The same treatments applied to the brush sites were applied to 6-by-15-ft plots using a CO_2-powered backpack sprayer equipped with a 6-ft boom and 8006VS tips delivering100 gal/ac at 35 psi. Treatments were completed on October 22 and 30, 2007 at the Oak Hall and Duncansville sites, respectively. The turf canopy height at the time of treatment averaged 4 inches with some plants reaching 8 inches. The turf species at both sites included tall fescue and Kentucky bluegrass, while creeping red fescue was an additional component at the Oak Hall site.

At the Oak Hall site percent total vegetative cover and cover by turf were evaluated October 25, 2007 (3 DAT) while injury to the turf was evaluated December 11, 2007 (50 DAT). A final evaluation including percent total vegetative cover, cover by turf, and turf injury was made on April 28, 2008 (189 DAT).

At the Duncansville site percent total vegetative cover and cover by turf were evaluated October 30, 2007 (0 DAT), while injury to the turf was evaluated December 11, 2007 (42 DAT). A final evaluation including percent total vegetative cover, cover by turf, and turf injury was made on April 28, 2008 (181 DAT). Injury ratings were assigned values on a scale of 0 to 10, where 0 = no injury; 5 = moderate injury, some chlorosis; and 10 = dead.

RESULTS AND DISCUSSION

Brush Treatments

Injury symptoms evaluated 27 DAT on Morrow's honeysuckle and border privet at the State College site were highest with Garlon 3A plus Tordon 101M. The percent injury was 95 and 98 percent, respectively, for this treatment. Other herbicide treatments ranged from 45 to 63 percent injury for Morrow's honeysuckle and 50 to 83 percent injury for border privet. All treatments resulted in 98 percent injury on multiflora rose, except Garlon 3A plus Milestone VM at 95 percent. A year after treatment, Garlon 3A plus Vanquish plus Milestone VM or Garlon

3A plus Tordon 101M were among the best treatments at controlling all three species. Control values ranged from 60 to 92 percent for Garlon 3A plus Vanquish plus Milestone VM and between 63 and 87 percent for Garlon 3A plus Tordon 101M treatments.

Morrow's honeysuckle treated at the Indiana site had the greatest injury symptoms occurring with Garlon 3A plus Vanquish, Overdrive, or Tordon 101M; or Garlon 3A plus Vanquish plus Milestone VM treatments. These resulted in 91 to 98 percent injury when evaluated 28 DAT. A year after treatment, Garlon 3A plus Vanquish plus Milestone VM, Garlon 3A plus Overdrive, or Garlon 3A plus Tordon 101M provided the best control. Control using these treatments ranged from 90 to 98 percent. All other herbicide treatments had control ratings from 28 to 75 percent.

Turf Treatments

The turf cover at the Oak Hall site averaged from 61 to 94 percent at the initiation of the study and 91 to 97 percent at the Duncansville location. Injury ratings were "0" for all turf plots except two as evaluated 50 and 42 DAT at Oak Hall and Duncansville, respectively. The Garlon 3A plus Escort XP treatments each had one plot that was given a "3" rating, meaning that the treated plot was slightly off color compared to the untreated plot. A subsequent evaluation of total vegetative cover, turf cover, and turf injury was made on April 28, 2008 at both locations. Several plots across both sites containing Overdrive in the treatment were given a "3" rating.

CONCLUSIONS

Garlon 3A plus Tordon 101M or Garlon 3A plus Vanquish plus Milestone VM were among the best mixtures at controlling the targeted species at all carrier volumes. However, Tordon 101M is a "Restricted Use" product, and Department policy is to *refrain* from using such products. The Garlon 3A plus Vanquish plus Milestone VM combination was also effective at controlling the brush species encountered. This tank mix yielded better results for controlling Morrow's honeysuckle than the standard Garlon 3A plus Escort XP mixture used by PennDOT while providing similar control of multiflora rose and border privet. Although slight injury symptoms were noted, no treatments provided unacceptable injury to the turf.

MANAGEMENT IMPLICATIONS

Garlon 3A plus Escort XP does not provide acceptable control of exotic shrub honeysuckle. Garlon 3A plus Vanquish plus Milestone VM would provide roadside managers with an alternative mix that will provide equivalent control on most brush species plus demonstrates superior control of exotic shrub honeysuckle.

Table 1: Summary of percent injury, by species, for brush treated September 13 or 17, 2007, and evaluated October 10 or 15, 2007, 27 or 28 days after treatment (DAT), respectively. Species evaluated included Morrow's honeysuckle (*Lonicera morrowii*, LONMO), multiflora rose (*Rosa multiflora*, ROSMU), and border privet (*Ligustrum obtusifolium*, LIGXX). Two plots at the State College site were eliminated from the statistics due to anomalies found during the rating. ROSMU was not present in all plots. Otherwise, the injury values are the mean of three replications.

Product[1/]	Rate	Indiana LONMO[2/] Injury	---------------State College--------------- LONMO Injury	ROSMU Injury	LIGXX Injury
	(oz/ac)	(---------------------------%---------------------------)			
Untreated	---	---	0 c	0 c	0 e
Garlon 3A	64	45	50 b	98 a	50 d
Garlon 3A Escort XP	64 1	73	45 b	98 a	83 b
Garlon 3A Vanquish	64 32	95	50 b	98 a	57 cd
Garlon 3A Milestone VM	64 7	78	63 b	95 b	50 d
Garlon 3A Vanquish Milestone VM	32 32 7	96	63 b	98 a	60 c
Garlon 3A Overdrive	64 8	91	50 b	98 a	57 cd
Garlon 3A Overdrive Milestone VM	32 8 7	82	60 b	98 a	63 c
Garlon 3A Tordon 101M	64 64	98	95 a	98 a	98 a
Protected LSD (p=0.05)		13	---	---	---

[1/] A single LSD value could not be calculated for injury on species present at the State College site because of missing data. Values followed by the same letter are not significantly different according to Fisher's LSD at p=0.05 significance level.
[2/] LONMO at Indiana site was treated using a carrier volume of 100 gal/ac. The State College treatments used a carrier volume of 30 gal/ac.

Table 2: Percent control of brush species using foliar applied herbicides. Herbicides were applied September 13, 2007 to mixed brush including Morrow's honeysuckle (*Lonicera morrowi*, LONMO), multiflora rose (*Rosa multiflora*, ROSMU), or border privet (*Ligustrum obtusifolium*, LIGOB) in State College, PA; and September 17, 2007 to LONMO in Indiana, PA. The State College site was treated with a vertical, broadcast pattern using a carrier volume of 30 gal/ac (GPA) while individual shrubs were targeted at the Indiana site using a carrier volume of 100 GPA. Final evaluations of percent control were taken in September 2008. Each value is the mean of three replications. ROSMU was not present in all plots, so a single LSD value cannot be reported.

Product	Application Rate	Indiana LONMO Control	--------------State College-------------- LONMO Control	ROSMU Control	LIGOB Control
	oz/ac	----------------------------%----------------------------			
Untreated	---	0	0	0 c	0
Garlon 3A	64	28	12	33 bc	12
Garlon 3A Escort XP	64 1	67	33	75 ab	93
Garlon 3A Vanquish	64 32	66	17	5 c	55
Garlon 3A Milestone VM	64 7	73	62	38 bc	72
Garlon 3A Vanquish Milestone VM	32 32 7	98	60	92 a	60
Garlon 3A Overdrive	64 8	90	20	5 c	42
Garlon 3A Overdrive Milestone VM	32 8 7	75	35	33 bc	42
Garlon 3A Tordon 101M	64 64	93	87	58 ab	63
Protected LSD (p=0.05)		19	41	---	42

RESPONSE OF BLACK LOCUST, RED OAK, AND TULIP POPLAR TO FOLIAR APPLICATIONS OF DPX-KJM44

Herbicide trade and common chemical names: Aquaneat (glyphosate), Arsenal (imazapyr), DPX-KJM44 (aminocyclopyrachlor), Escort XP (metsulfuron), Krenite S (fosamine).
Plant common and scientific names: black locust (*Robinia pseudoacacia*, ROBPS), red oak (*Quercus rubra*, QUERU), tulip poplar (*Liriodendron tulipifera*, LIRTU).

ABSTRACT

DPX-KJM44 (proposed common name, *aminocyclopyrachlor*) is an experimental herbicide that was evaluated for control of three brush species using foliar treatments. Multiple rates of DPX-KJM44 and four commonly used brush herbicides were compared in controlling black locust, red oak, and tulip poplar. Rates of DPX-KJM44 ranged from 1.25 oz/ac to 6.25 oz/ac. The three species were effectively controlled by all treatments with control ranging from 85 to 100 percent.

INTRODUCTION

DPX-KJM44 (proposed common name, *aminocyclopyrachlor*) is an experimental herbicide under development by DuPont. It is a synthetic auxin that has both foliar and soil activity on a variety of broadleaf weed and brush species[1/]. Control of three tree species was evaluated in the field using multiple rates of DPX-KJM44 in comparison with commonly applied brush control products. The three species were chosen based on their individual characteristics. Notably, black locust is a weedy, leguminous, root-suckering species; oaks are widespread targets on roadside settings; and tulip poplars are not very responsive to Escort XP, a common component of PennDOT's weed and brush program.

MATERIALS AND METHODS

Two trials investigating DPX-KJM44 were established along a forest road within the Stone Valley Experimental Forest near McAlevy's Fort, PA on tulip poplar and red oak. A third trial was conducted along an unopened section of I-99 near State College, PA targeting black locust. Treatments included an untreated check; 1.25, 2.5, 3.75, 4.38, 5, or 6.25 oz/ac DPX-KJM44; 48 oz/ac Arsenal (2 lb/gal); 2 oz/ac Escort XP; 192 oz/ac Krenite S; or 96 oz/ac Aquaneat. All treatments included a methylated seed oil surfactant at 1 percent, v/v. A completely randomized experimental design with five replications was employed with each treated stem serving as a replicate. Fifty-five individual trees or clusters ranging from 6 to 10 ft tall were tagged and measured to determine average canopy width. Dosage for each tree or cluster was calculated based on the canopy area and applied at a volume of 100 gal/ac (GPA) for oak and tulip poplar or 50 GPA for black locust. Treatments were applied using a CO_2-powered, single-nozzle sprayer with a spray wand and TeeJet adjustable ConeJet nozzle and X-6 or X-12 tip. Black

[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.

locust and red oak were treated August 28 and 31, 2007, respectively, while tulip poplar was sprayed September 5, 2007.

Visual ratings of percent injury to the canopy were taken October 1 or 2, 2007, 34 or 32 days after treatment (DAT) for black locust and red oak. Tulip poplar injury was evaluated September 26, 2007 (21 DAT). Percent control was evaluated June 17, 2008 (294 DAT) for black locust; June 20, 2008 (294 DAT) for red oak; and June 20, 2008 (289 DAT) for tulip poplar.

RESULTS AND DISCUSSION

The three species were effectively controlled by all treatments. In 2008, black locust control ranged from 93 to 100 percent, red oak control ranged from 98 to 100 percent, and tulip poplar control ranged from 85 to 100 percent. Control for DPX-KJM44 treatments was 99 to 100 percent for black locust, 98 to 100 percent for red oak, and 91 to 100 percent for tulip poplar.

CONCLUSIONS

All three species were effectively controlled by all treatments. Even at the lowest rates, DPX-KJM44 provided excellent control of the species tested.

MANAGEMENT IMPLICATIONS

DPX-KJM44, if registered and labeled for right-of-way application, may be a valuable addition to the products currently used by PennDOT for the weed and brush program. New chemistry that demonstrates enhanced control, broadens the spectrum of activity, and helps alleviate the development of resistant biotypes is always needed. Continued work with this product is required to determine the efficacy on other species, proper rates of application, and potential tank mixes.

Table 1. Percent control of species using foliar applied herbicide treatments. Treatments were made September 5, 2007 to tulip poplar (*Liriodendron tulipifera*, LIRTU), August 28, 2007 to black locust (*Robinia pseudoacacia*, ROBPS), and August 31, 2007 to red oak (*Quercus rubra*, QUERU). LIRTU and QUERU were treated with a carrier volume or 100 gal/ac (GPA), and ROBPS treatments targeted 50 GPA. Final evaluations of percent control were taken June 20, 2008, 289 and 294 days after treatment, DAT, for LIRTU and QUERU, respectively. Percent control of ROBPS was evaluated June 17, 2008, 294 DAT. Each value is the mean of five replications. A few LIRTU trees were lost to road maintenance activities, so a single LSD value cannot be reported.

Treatment	Application Rate	LIRTU	ROBPS	QUERU
	oz/ac	--------------------% Control	--------------------	
Untreated	---	20 b	0	0
KJM44	1.25	95 a	100	98
KJM44	2.5	91 a	99	100
KJM44	3.75	99 a	100	100
KJM44	4.38	100 a	100	100
KJM44	5	99 a	99	100
KJM44	6.25	100 a	100	100
Arsenal	48	99 a	100	100
Escort XP	2	85 a	100	100
Krenite S	192	98 a	100	100
Aquaneat	96	99 a	93	100
Protected LSD (p=0.05)		---	6	2

COMPARING GRASS-SAFE HERBICIDES FOR CONVERTING CANADA THISTLE INFESTED CROWNVETCH TO FORMULA L

Herbicide trade and common chemical names: Milestone VM (*aminopyralid*), Overdrive (*dicamba + diflufenzopyr*), RoundUp Pro Concentrate (*glyphosate*), Tordon K (*picloram*), Transline (*clopyralid*), Vanquish (*dicamba-glycolamine*).

Plant common and scientific names: Canada thistle (*Cirsium arvense,* CIRAR), creeping red fescue (*Festuca rubra*), crownvetch (*Coronilla varia,* CZRVA), hard fescue (*Festuca brevipila*), perennial ryegrass (*Lolium perenne*).

ABSTRACT

Field observations along Pennsylvania roadsides have suggested that a companion relationship between Canada thistle and crownvetch may exist where crownvetch supports the growth and development of Canada thistle colonies. One solution to prevent this relationship and reduce long-term control requirements would be to renovate crownvetch areas into perennial competitive grass zones through selective removal of Canada thistle and crownvetch followed by overseeding and promotion of a grass groundcover. This study tested seven grass-safe herbicides and herbicide combinations for control of Canada thistle and crownvetch accompanied by seeding with a grass mixture at two sites. Treatments were applied October 5 near University Park, PA and October 11, 2007 near St. Clairsville, PA. Degree of injury to the target species was evaluated 31 and 34 days following treatment at the respective sites. Severe injury was observed to both Canada thistle and crownvetch with all treatments. Hard fescue and perennial ryegrass seeded five days after treatment (University Park) and immediately following treatment (St. Clairsville) germinated within the study areas by four weeks after treatment. The crownvetch was almost completely eliminated by all treatments when evaluated in 2008. Percent cover by turf was low, 0 to 12 percent, for the treatments by June 2008. The only treatment to show a reduction in Canada thistle stems at both locations was Milestone VM plus Overdrive.

INTRODUCTION

Crownvetch has been widely used by PennDOT as a conservation planting to provide groundcover and soil stabilization. Unfortunately, Canada thistle, a Pennsylvania noxious weed, has demonstrated an affinity for co-existing with crownvetch. Selectively removing Canada thistle from a crownvetch stand has proven ineffective to date. Previous trials have shown that removing both species with herbicides and replacing the stand with grasses is effective[1/]. Once grasses replace the weed-infested site, routine mowing or broadleaf herbicide treatments must be used to combat further Canada thistle and crownvetch invasion.

Glyphosate and a limited selection of broadleaf-specific chemicals have provided satisfactory results in eliminating both Canada thistle and crownvetch and allowed for seeding immediately after application. This study was conducted to evaluate the efficacy of alternative broadleaf

[1/] Comparing Sequences To Convert Canada Thistle-Infested Crownvetch To A Cool-Season Grass Mixture. 2000. Roadside Vegetation Management Research Report – Fifteenth Year Report. http://vm.cas.psu.edu/2000/final2000.pdf herbicides and herbicide combinations in order to expand and optimize applicator options for control of Canada thistle and crownvetch while providing a safe environment for grass establishment.

MATERIALS AND METHODS

Trials were established along Park Avenue at University Park, PA and in the median of SR 99 N to the south of Exit 10 near St. Clairsville, PA (Bedford Co.). Experimental treatments consisted of RoundUp Pro Concentrate at 96 oz/ac; Milestone VM at 7 oz/ac or Transline at 8 oz/ac alone or combined with Overdrive at 8 oz/ac; Tordon K at 24 oz/ac; Vanquish at 32 oz/ac plus Overdrive at 8 oz/ac; and an untreated check. Activator 90, surfactant was added at 0.25% v/v to all treatments except RoundUp Pro Concentrate.

At both sites, treatments were applied to 9-by-20-ft plots, arranged in a randomized complete block design with three replications, using a CO_2-powered backpack sprayer with 9 ft boom and equipped with 8002VS tips delivering 20 gal/ac. Herbicides were applied on October 5 and 11, 2007 at the University Park and St. Clairsville sites, respectively. Both sites were broadcast seeded with a grass seed mix containing 52% hard fescue, 35% creeping red fescue, and 10% perennial ryegrass. The St. Clairsville site was seeded immediately after application, while seeding occurred five days after application at the University Park site.

A representative one by one meter subplot was placed within each plot. The number of Canada thistle stems in each subplot was counted at time of treatment. The response of Canada thistle and crownvetch was rated according to foliar injury on a 0 to 10 scale, where 0 = no injury, 5 = moderate defoliation, epinasty, chlorosis, and 10 = complete necrosis or dead, on November 5 and 14, 2007, 31 and 34 days after treatment (DAT) for the University Park and St. Clairsville sites.

Data were collected at the University Park and St. Clairsville sites on June 24 and June 25, 2008, 263 and 258 DAT, respectively. The number of Canada thistle stems within each subplot, percent cover by crownvetch, and cover by turf were rated. Only the University Park site was later revisited. On November 18, 2008, 372 DAT, percent total vegetative cover, percent cover by Canada thistle, crownvetch, and turf were evaluated. All data were subjected to analysis of variance and means were compared using Fisher's protected LSD (p=0.05).

RESULTS AND DISCUSSION

Dramatic injury symptoms were observed for all herbicide treatments at both sites in 2007. Injury to crownvetch and Canada thistle for all treatments ranged from 8 to 10. Crownvetch never recovered, with cover never exceeding 2 percent in 2008 for any treatment while untreated plots had significantly more crownvetch ranging from 42 to 70 percent. There were differences in cover by desirable turfgrass between the two sites but not treatments. The University Park site had average turf cover between 1 and 11 percent by November 2008 for the treatments. While some grasses were observed at the St. Clairsville site, the cover averaged 0 percent for all treatments at the June 2008 rating. No significant differences were observed for the number of Canada thistle stems at either location. The University Park site saw a reduction in stem numbers and by June 2008 average stem numbers were between 1 and 17. The St. Clairsville site resulted in increases in Canada thistle stem numbers for all treatments, except Milestone VM plus Overdrive. A substantial number of Canada thistle stems were found, ranging from 14 to 98, among all treatments with no significant difference at the June 2008 count.

CONCLUSIONS

Herbicide treatments produced significant, long-term injury to the crownvetch present at both sites. The Canada thistle showed dramatic initial but temporary injury. By the second year, Canada thistle stems had re-emerged from the perennial root system with no treatments demonstrating enhanced control. The turf establishment was disappointing. Possible reasons for the poor turf establishment include: close temporal proximity of seeding to herbicide treatment impacted seed germination, the sites were not conducive to the development of these cool-season grasses, and environmental conditions during establishment inhibited growth.

MANAGEMENT IMPLICATIONS

A single herbicide application will not eradicate a Canada thistle stand. However, the fall-applied treatments within this trial will nearly eliminate an established stand of crownvetch. Past work investigating the replacement of crownvetch infested with Canada thistle with a fall seeding of Formula L has been successful[2/]. A couple of weeks should elapse between the initial herbicide treatment and seeding. This will provide some time for the herbicide residues to dissipate. Formula L may not be the best mix of species for all situations. Where soil quality is less than ideal, other grass species selections may be more appropriate. Once the seeding is established, annual monitoring and follow-up herbicide treatments are needed to keep both crownvetch and Canada thistle from getting reestablished.

[2/] Crownvetch To Formula L Conversions Districts 8-0 and 2-0. 1995. Roadside Vegetation Management Research Report – Ninth Year Report. http://vm.cas.psu.edu/1994/1994/final1994.pdf

Table 1. Injury rating comparison for herbicide treatments applied to a Canada thistle (CIRAR) infested crownvetch (CZRVA) stand near University Park, PA on October 5, 2007 and near St. Clairsville, PA on October 11, 2007. Visual ratings of CZRVA and CIRAR injury were taken November 5, 2007 (University Park) and November 14, 2007 (St. Clairsville), 31 and 34 days after treatment, DAT. Injury was rated on a 0 to 10 scale, where '0' = no injury, '5' = moderate defoliation, epinasty, chlorosis, and '10' = completely necrotic, dead. Each value is the mean of three replications.

	Product	University Park, PA		St. Clairsville, PA	
Product	Rate	CZRVA	CIRAR	CZRVA	CIRAR
	oz/ac	---------------------Injury (0-10 scale)---------------------			
RoundUp Pro Conc.	96	8	10	9	10
Milestone VM	7	10	9	9	9
Transline	8	9	8	9	8
Tordon K	24	10	9	9	9
Vanquish Overdrive	32 8	10	9	9	9
Milestone VM Overdrive	7 8	10	9	10	10
Transline Overdrive	8 8	10	9	9	9
Fisher's protected LSD (p=0.05)		1	n.s.	n.s.	1

Table 2. Percent vegetation cover ratings for herbicide treatments applied to a Canada thistle (CIRAR) infested crownvetch (CZRVA) stand near University Park, PA on October 5, 2007 and near St. Clairsville, PA on October 11, 2007. A broadcast seeding of Formula L (TURF) was made October 10, 2007 at the University Park site and October 11, 2007 at the St. Clairsville site. Visual ratings of percent CZRVA and TURF cover were taken June 24, 2008 and November 18, 2008 (University Park) and June 25, 2008 (St. Clairsville), 263, 372 and 258 days after treatment, DAT. Each value is the mean of three replications.

		University Park, PA				St. Clairsville, PA	
	Product	CZRVA		TURF		CZRVA	TURF
Product	Rate	6/08	11/08	6/08	11/08	6/08	6/08
	oz/ac	-----------------------------% Cover-----------------------------					
Untreated	---	52	70	1	2	42	0
RoundUp Pro Conc.	96	0	0	5	10	1	0
Milestone VM	7	0	0	3	3	0	0
Transline	8	0	0	12	11	0	0
Tordon K	24	0	0	2	2	0	0
Vanquish Overdrive	32 8	1	2	1	10	1	0
Milestone VM Overdrive	7 8	0	0	0	1	0	0
Transline Overdrive	8 8	1	0	1	3	0	0
Fisher's protected LSD (p=0.05)		18	9	n.s.	n.s.	20	n.s.

Table 3. Canada thistle (CIRAR) stem counts for herbicide treatments applied to a Canada thistle infested crownvetch (CZRVA) stand near University Park, PA on October 5, 2007 and near St. Clairsville, PA on October 11, 2007. Original CIRAR stem numbers were counted October 10, 2007 (University Park) and October 15, 2007 (St. Clairsville). CIRAR stem numbers were again counted June 24, 2008 (University Park) and June 25, 2008 (St. Clairsville), 263 and 258 days after treatment, DAT. Each value is the mean of three replications.

		University Park, PA		St. Clairsville, PA	
Product	Product Rate	CIRAR 2007	CIRAR 2008	CIRAR 2007	CIRAR 2008
	oz/ac	--------------------Stem Number--------------------			
Untreated	---	31	19	37	45
RoundUp Pro Conc.	96	31	5	31	58
Milestone VM	7	25	6	36	48
Transline	8	30	14	35	75
Tordon K	24	20	4	31	98
Vanquish Overdrive	32 8	26	17	31	51
Milestone VM Overdrive	7 8	22	1	32	14
Transline Overdrive	8 8	36	8	28	85
Fisher's protected LSD (p=0.05)		---	n.s.	---	n.s.

RESPONSE OF FINELEAF FESCUES TO HERBICIDES APPLIED DURING ESTABLISHMENT

Herbicide trade and common chemical names: Accord Concentrate (*glyphosate*), Garlon 3A (*triclopyr*), Milestone VM (*aminopyralid*), Tordon K (*picloram*), Transline (*clopyralid*), Vanquish (*dicamba*), Weedestroy (*2,4-D*)
Plant common and scientific names: Canada thistle (*Cirsium arvense*), creeping red fescue (*Festuca rubra* ssp. *rubra*), crownvetch (*Coronilla varia*), hard fescue (*Festuca trachyphylla*), perennial ryegrass (*Lolium perenne*), quackgrass (*Elymus repens*)

ABSTRACT

Planting a mixture of hard fescue and creeping red fescue ('Formula L', Publication 408) as a replacement groundcover for crownvetch is a weed management approach employed to manage Canada thistle in highway rights-of-way. Garlon 3A, Milestone VM, Tordon K, Transline, Vanquish, or Weedestroy were applied either 30, 15, or 0 days before seeding (DBS), or 15 or 30 days after emergence (DAE) of September fineleaf fescue seedings in State College or Manheim, PA to determine if they would inhibit fescue establishment. At State College, there were no significant interactions between application timing and herbicide, and no significant treatment effects on fescue cover in November 2007. When evaluated in May 2008, Vanquish- and Milestone VM-treated plots at State College had lower fescue cover ratings than the other treatments. There was a significant interaction between application timing and herbicide at Manheim. In November 2007, Vanquish-treated plots had lower fescue cover than the other treatments at the 0 DBS and 15 DAE application timings, and in May 2008 Vanquish-treated plots had lower fescue cover when treated 0 DBS.

INTRODUCTION

Crownvetch stands are often infested with dicot (broadleaf) weeds, with Canada thistle as a prominent example. Selective removal of broadleaf weeds from a broadleaf groundcover is difficult. One approach to the problem is to remove both the weeds and crownvetch with herbicides and revegetate the site with grasses. Conversion to grass provides the advantage of a competitive groundcover and easier management of broadleaf weeds. Broadleaf weed management options after conversion include the use of selective herbicides for removal of broadleaf weeds from the turf and mowing in areas where the terrain allows.

Glyphosate is used for non-selective weed control prior to reseeding because it has no soil activity and will not inhibit germination and establishment of the seeding. In settings where desirable grasses are already present or where Canada thistle is the primary target, having alternative herbicides to glyphosate would be useful. Glyphosate will kill grasses that are present. The broadleaf herbicides aminopyralid, clopyralid, dicamba, and picloram have demonstrated utility against Canada thistle and would be safe to existing grasses. Previous research at Penn State demonstrated that Garlon 3A, Transline, Vanquish, and Tordon K did not inhibit fineleaf fescue seedings when applied the day of seeding[1].

Previous trials evaluated only pre-plant applications of broadleaf herbicides. For the current research a trial was developed to add Milestone VM and a 2,4-D product and the effect of these herbicides on newly emerged turf seedlings was evaluated. The objective was to determine which application timings are available during the establishment period of a crownvetch-to-grass renovation.

MATERIALS AND METHODS

The study sites were located at the Landscape Management Research Center in State College, PA and the Southeastern Agricultural Research and Extension Center near Manheim, PA. Accord Concentrate at 3 qt/ac plus Activator 90 surfactant at 0.25 percent, v/v, was applied to kill existing weeds on July 18 and 19, 2007 at State College and Manheim, respectively. Vegetation at State College was herbaceous perennials, featuring quackgrass. The Manheim site was fallow after a pumpkin crop in 2006 and featured annual weeds.

The experimental design at both sites was a randomized complete block with four replications. Plots sizes were 3 by 12 ft at State College and 4 by 11 ft at Manheim. Herbicide treatments included Garlon 3A at 64 oz/ac, Vanquish at 64 oz/ac, Transline at 8 oz/ac, Milestone VM at 7 oz/ac, Tordon K at 32 oz/ac, Weedestroy at 64 oz/ac, and an untreated check. All herbicide treatments included Activator 90 at 0.25 percent, v/v. Plots were treated with a CO_2-powered hand-held sprayer with a single TeeJet 9506E VS tip. Treatments were applied 30, 15, or 0 days before seeding (DBS), or 15 or 30 days after emergence (DAE). Seeding dates were September 7, 2007 for State College and September 12 for Manheim. Accord Concentrate was applied at 96 oz/ac plus surfactant to the entire study area at both sites the day of seeding. After the glyphosate application, a 55:35:10 mixture, w/w, of hard fescue: creeping red fescue: perennial ryegrass was seeded at 120 lb/ac with a drop seeder, then sliced with a seeder to incorporate the seed. Each plot was visually evaluated for percent total vegetative cover, weed cover, and fescue cover in late November 2007 and early May 2008. At State College, weed cover was categorized as either broadleaf or undesirable grass due to the prevalence of quackgrass, while all non-planted vegetation at Manheim was simply categorized as weed cover. The data were subjected to analysis of variance, and where treatment effects were significant ($p \leq 0.05$), means were compared using Fisher's least significant difference (LSD). Weed pressure, particularly from quackgrass, was higher at State College, and two plots were deleted from the analysis of variance as outliers due to low vegetative cover.

RESULTS AND DISCUSSION

Average ratings for total, weed, and fescue cover at State College were 75, 17, and 59 percent, respectively for November; and 77, 43, and 34 percent, respectively for May. Average ratings for total, weed, and fescue cover at Manheim were 81, 7, and 74 percent respectively for November; and 82, 2, and 81 percent respectively for May.

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[1] Gover, A.E., J.M. Johnson, and L.J. Kuhns. 2000. Effects of pre-plant herbicides on establishment of fine fescues during roadside renovation. Proceedings Northeastern Weed Science Society, 53:152. (http://www.newss.org)

At State College, the response variables with a significant treatment effect were fescue cover in May and broadleaf weed cover in November and May. May fescue cover ratings were lowest for dicamba- or aminopyralid-treated plots at 27 and 29 percent, while ratings for the other treatments averaged 35 to 37 percent (Table 1). Differences in broadleaf weed cover in November were significant for application timing (6 to 15 percent) and herbicide (5 to 16 percent) but did not contribute to significant differences in fescue cover or total cover (Table 1). Differences in broadleaf weed cover in May were relevant to fescue cover, as Vanquish-treated plots had the lowest ratings for fescue cover and the highest ratings for broadleaf weed cover. Herbicide treatment effect was not significant for total cover and weedy grass cover in May, and Vanquish-treated plots had more broadleaf cover than untreated plots, suggesting that reduced fescue establishment may have created opportunity for broadleaf infestation, rather than poor broadleaf suppression (i.e., untreated check) suppressing fescue establishment. Plots treated with Milestone VM were rated significantly lower for fescue cover in May than the best-rated treatments but were not significantly different from the untreated plots.

There was a significant interaction between herbicide and application date for fescue cover at Manheim for the November and May ratings. When herbicide effects were analyzed by application date, there were no significant herbicide effects 30 or 15 days before seeding or 30 days after emergence. The most dramatic herbicide effects were seen at the 0 days before seeding application (Table 2). Plots treated with Vanquish averaged 34 percent fescue cover in November, while the other treatments had average ratings between 66 and 80 percent. In May, Vanquish-treated plots averaged 66 percent fescue cover 0 DBS, while the other treatment ratings averaged 77 to 84 percent. For the applications made 15 DAE, there were significant herbicide effects at the November rating, but not in May. In November, plots treated with Vanquish or Garlon 3A averaged 67 and 61 percent fescue cover, while the remaining treatments averaged 74 to 84 percent.

When the sites were observed in late 2008, there were no visible "plot effects" remaining. The treatment effects observed at 2 and 8 months after seeding were no longer apparent at either site.

CONCLUSIONS

Vanquish at 64 oz/ac caused inhibition of establishment at both sites. At Manheim this was apparent 8 months after seeding only in the 0 DBS plots. At State College, Vanquish-treated plots averaged the least amount of fescue cover in May and were rated significantly lower than untreated plots. Garlon 3A-treated plots had low fescue cover ratings in November at Manheim when applied 0 DBS and 15 DAE. Fescue cover increased in these plots by the May rating, and they were not different from the untreated plots.

All treatment effects on fescue were transient and no longer apparent by one year after seeding.

MANAGEMENT IMPLICATIONS

All the broadleaf herbicides evaluated in this trial demonstrated enough safety to be considered for broadleaf weed suppression in a crownvetch-to-grass conversion sequence. Vanquish was inhibitory at 64 oz/ac, but previous studies at 32 oz/ac showed no inhibition.

Ongoing research to identify the most efficacious herbicides and application timings for suppression of crownvetch and Canada thistle will likely narrow the list of herbicide options. However, each of the materials tested could be considered for suppression treatments immediately preceding or following a grass seeding to replace weed-infested crownvetch.

Table 1. Herbicide treatments were applied 30, 15, or 0 days before seeding (DBS), or 15 or 30 days after emergence (DAE) to a mixture of hard fescue, creeping red fescue, and perennial ryegrass seeded September 7, 2007, in State College, PA. Visual ratings of total, broadleaf weed, grass weed, and seeded grass cover were taken November 29, 2007 and May 9, 2008. Application timing treatments are the mean of 28 observations (7 herbicides by 4 replications), and herbicide treatments are the mean of 20 observations (5 application timings by 4 replications). Where treatment effect was significant, means were compared using Fisher's LSD (p=0.05). A single LSD value is not reported because of unequal replications due to deletion of two outlier values.

	Nov 29, 2007				May 9, 2008			
Application Timing	Total	Broadleaf Weed	Grass Weed	Seeded Grass	Total	Broadleaf Weed	Grass Weed	Seeded Grass
	% cover							
30 DBS	80	15 a	8	58	78	24 ab	20	34
15 DBS	76	11 ab	8	57	77	25 a	23	30
0 DBS	74	13 a	5	56	79	25 a	19	35
15 DAE	66	6 c	3	60	75	17 c	22	35
30 DAE	75	8 bc	5	63	76	20 bc	20	36
LSD (p=0.05)	n.s.		n.s.	n.s.	n.s.		n.s.	n.s.
Herbicide (oz/ac)								
	% cover							
Untreated	75	16 ab	6	54	78	26 a	17	35 ab
Weedestroy (64)	72	9 cd	6	57	76	19 bc	23	36 a
Garlon 3A (64)	74	9 cd	4	61	76	15 c	24	37 a
Tordon K (32)	76	5 d	6	65	75	17 bc	22	37 a
Milestone VM (7)	73	7 d	9	58	75	21 b	26	29 bc
Transline (8)	79	17 a	5	57	81	26 a	18	37 a
Vanquish (64)	71	12 bc	5	54	75	30 a	18	27 c
LSD (p=0.05)	n.s.		n.s.	n.s.	n.s.		n.s.	

Table 2. Herbicide treatments were applied 30, 15, or 0 days before seeding (DBS), or 15 or 30 days after emergence (DAE) to a mixture of hard fescue, creeping red fescue, and perennial ryegrass seeded September 12, 2007, in Manheim, PA. Visual ratings of total, weed, and seeded grass cover were taken November 29, 2007 and May 13, 2008. Values are the mean of four observations. Where treatment effect was significant, means were compared using Fisher's LSD (p=0.05).

		------ November 29, 2007 ------			-------- May 13, 2008 -------		
Herbicide (oz/ac)	Application Timing	Total	Weed	Seeded Grass	Total	Weed	Seeded Grass
		% cover					
Untreated	30 DBS	86	9	78	85	3	82
Weedestroy (64)	30 DBS	89	13	75	88	2	86
Garlon 3A (64)	30 DBS	90	12	78	86	2	84
Tordon K (32)	30 DBS	85	6	79	83	2	80
Milestone VM (7)	30 DBS	91	10	81	84	2	82
Transline (8)	30 DBS	86	11	76	85	2	83
Vanquish (64)	30 DBS	89	19	70	88	2	86
LSD (p=0.05)		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Untreated	15 DBS	81	9	72	80	2	78
Weedestroy (64)	15 DBS	88	11	77	86	1	85
Garlon 3A (64)	15 DBS	81	9	73	84	1	82
Tordon K (32)	15 DBS	85	3	82	85	1	84
Milestone VM (7)	15 DBS	81	5	76	83	1	81
Transline (8)	15 DBS	88	7	81	88	2	86
Vanquish (64)	15 DBS	71	7	65	81	1	80
LSD (p=0.05)		10	n.s.	n.s.	n.s.	n.s.	n.s.
Untreated	0 DBS	88	8	80	85	1	84
Weedestroy (64)	0 DBS	80	8	72	83	2	81
Garlon 3A (64)	0 DBS	74	8	66	80	3	77
Tordon K (32)	0 DBS	78	3	74	83	1	82
Milestone VM (7)	0 DBS	75	5	70	81	1	80
Transline (8)	0 DBS	80	8	72	81	2	79
Vanquish (64)	0 DBS	40	6	34	69	2	66
LSD (p=0.05)		7	n.s.	7	7	n.s.	8
Untreated	15 DAE	88	9	79	85	2	83
Weedestroy (64)	15 DAE	75	1	74	79	1	78
Garlon 3A (64)	15 DAE	61	0	61	76	1	76
Tordon K (32)	15 DAE	85	1	84	83	1	82
Milestone VM (7)	15 DAE	76	2	74	81	1	80
Transline (8)	15 DAE	84	5	79	83	1	81
Vanquish (64)	15 DAE	68	0	67	76	1	75
LSD (p=0.05)		9	2	8	n.s.	n.s.	n.s.
Untreated	30 DAE	83	7	75	83	1	81
Weedestroy (64)	30 DAE	86	7	79	80	1	79
Garlon 3A (64)	30 DAE	80	5	75	81	2	80
Tordon K (32)	30 DAE	86	3	82	84	1	83
Milestone VM (7)	30 DAE	86	4	81	81	1	80
Transline (8)	30 DAE	89	9	80	85	2	84
Vanquish (64)	30 DAE	86	5	80	84	1	82
LSD (p=0.05)	30 DAE	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

IMPLEMENTING JAPANESE KNOTWEED REMOVAL AND CONVERSION TO GRASSES

Herbicide trade and common chemical names: Accord Concentrate (*glyphosate*), Banvel (*dicamba*), Credit Extra (*glyphosate*), Vanquish (*dicamba*), Edict IVM (*pyraflufen-ethyl*), Milestone VM (*aminopyralid*).

Plant common and scientific names: Canada thistle (*Cirsium arvense*), common teasel (*Dipsacus fullonum*), garlic mustard (*Alliaria petiolata*), giant knotweed (*Polygonum sachalinense*), Japanese knotweed (*Polygonum cuspidatum*), mile-a-minute (*Polygonum perfoliatum*).

ABSTRACT

Locations of Japanese knotweed (Watsontown, PA) or giant knotweed (Summerhill, PA) were treated in the summer and fall of 2007 with foliar herbicide applications and seeded to a mixture of cool- and warm-season grasses the following spring. The dual herbicide treatments resulted in 97 percent or greater reduction of knotweed by the fall of 2007. By September 2008 knotweed cover at both sites ranged from 3 to 10 percent. Unfortunately, the desirable grasses were sparse and accounted for less than 1 percent cover at Watsontown and 15 percent cover at Summerhill.

INTRODUCTION

Japanese knotweed and giant knotweed (hereafter, knotweed) are rhizomatous, herbaceous perennials native to East Asia. The plant forms dense monotypic stands reaching 6 to 10 feet in height. The plant can develop from seed, but the movement of rhizome fragments is the primary means of migration. Events such as flooding, construction, and maintenance activities contribute to the spread of knotweed rhizome fragments.

Past efforts to control knotweed have demonstrated that a long-term, programmed approach is required to manage existing stands. Glyphosate-based mixtures applied later in the growing season have shown success, substantially decreasing the stand. Once the knotweed has been suppressed, then follow-up treatments and reseeding of the area to a competitive groundcover (e.g., grasses) may be possible, if the terrain allows.

This demonstration examined the efficacy of a multiple-step herbicide approach to eradicating a knotweed stand while establishing a desirable grass groundcover. The warm and cool season grass mixture seeded on these sites was selected for its tolerance to a wide range of site conditions. The spring seeding allowed for a dual herbicide treatment the prior season targeting the knotweed plus over-winter degradation of the knotweed residue. Past efforts to seed before allowing sufficient time for control and deterioration of the knotweed residue have resulted in poor grass establishment.[1/]

[1/] Comparison of Rehabilitation Sequences for Japanese and Giant Knotweed Infestations. 1999. Roadside Vegetation Management Research Report – Fourteenth Year Report. http://vm.cas.psu.edu/1999/final1999.pdf

MATERIALS AND METHODS

Implementation sites were located along SR 405 S near Watsontown, PA and at the SR 219 S/SR 53 interchange near Summerhill, PA. At the time of application, a mixed stand of vegetative stage Japanese and giant knotweed were found at both sites and ranged from 5 to 10 ft tall. On June 21 and 25, 2007, the Watsontown and Summerhill sites, respectively, received an application of Vanquish at 64 oz/ac plus Edict at 2.7 oz/ac with Activator 90, surfactant, at 0.25% v/v. Treatments were applied using a John Bean truck-mounted hydraulic sprayer equipped with a No. 46 Spraying Systems GunJet and AYHSS120 tip, targeting 100 gal/ac. After the initial application, the sites were treated with glyphosate at 3 lb ae/ac on August 30 and September 15, 2007, respectively. The glyphosate products used were Credit Extra at 1.0% v/v, plus defoamer at the Watsontown site and Accord Concentrate at 0.75% v/v, plus Activator 90 nonionic surfactant at 0.25% v/v, at the Summerhill location.

The Summerhill and Watsontown sites received seed and soil supplements on April 17 and 21, 2008, respectively, plus a late season selective herbicide treatment. The seed was a customized Formula L mix containing 32% creeping red fescue, 51% hard fescue, 9% perennial ryegrass, 4% switchgrass, and 4% Canada wild rye by weight. Seed was broadcast at a rate of 116 lb/acre. Granular fertilizers with analysis of 20-10-10 and 8-32-16 were also applied according to soil test results. The Watsontown site was 2.25 acres in size and required 490 lb 20-10-10; 1,377 lb 8-32-16; and 261 lb seed. The Summerhill site was 0.42 acres and required 92 lb 20-10-10; 257 lb 8-32-16; and 50 lb seed. The Watsontown site was treated on September 5, 2008 using 2 qt/ac Banvel plus methylated seed oil surfactant at 0.25% v/v. A total of 175 gallons of solution was applied. The Summerhill site was treated on September 8, 2008 using 2 qt/ac Vanquish plus 7 oz/ac Milestone VM plus 0.25% v/v methylated seed oil. A total of 75 gallons of solution was applied.

Percent control of knotweed was evaluated at the Watsontown site on October 6, 2007, 37 days after the second treatment. The Summerhill site was evaluated during the September 15, 2007 application. Both cover by knotweed and desirable grasses were evaluated during the spray visit in September 2008.

RESULTS AND DISCUSSION

Knotweed at the Watsontown site was heavily impacted by the June 21, 2007 herbicide treatment, but considerable foliage and resprouts were still present throughout the treatment area during the return visit on August 30, 2007. By October 6, 2007, prior to the onset of any frost, the control of knotweed exceeded 97 percent. By September 5, 2008, knotweed cover had increased to approximately 10 percent. Most of the surviving knotweed in the previously treated area was diminished in size to a few feet. Mature, flowering knotweed at the back edge of the previously treated area was also targeted along with other species, including mile-a-minute and garlic mustard. The desirable grass cover was sparse and estimated at only 1 percent. It is uncertain whether allelochemicals may have inhibited the establishment of grasses to date.

The knotweed stand at Summerhill was nearly eliminated by the initial, June 25, 2007 application. Few targets, other than Canada thistle and teasel, were present for the follow-up treatment on September 15, 2007. A later evaluation was not necessary given the success of the initial treatment, with only isolated knotweed stems remaining. The September 8, 2008 herbicide treatment included Milestone VM. This was added to target crownvetch within the study area. Knotweed cover was estimated at 3 percent, and desirable grass cover was 15 percent. Knotweed control and the establishment of desirable cover were better for this location compared to Watsontown. A selective herbicide treatment targeting knotweed sprouts and other unwanted plant species is planned for 2009 at both locations.

CONCLUSIONS

Sequential treatments during the first season are a viable approach to managing a knotweed stand. Past experience has shown that a mowing or herbicide treatment in June followed by a late-season glyphosate treatment greatly reduces the knotweed infestation. Seeded grasses have been slow to establish at these sites, especially Watsontown. Allelochemicals from knotweed and garlic mustard are known to inhibit plant growth[2/]. Therefore, where extensive knotweed stands and other inhibitive pioneer species exist, a second season of chemical control may allow for further elimination of undesirable plants and degradation of residues prior to seeding. A cool-season grass mixture would then best be seeded in the fall of the second season, allowing two full growing seasons to control the knotweed stand. However, Watsontown and Summerhill were seeded in spring to accommodate the warm season grasses in the seed mixture.

Further work and investigation on these two sites will determine if the warm and cool season grass mix offers a viable alternative to the cool season grass mix, Formula L, which has been used successfully in the past. The quality of many sites is too poor to sustain a Formula L seeding over time. Once established, the warm season grasses will tolerate these low-quality sites.

MANAGEMENT IMPLICATIONS

Roadside Japanese knotweed stands are manageable. Target this species with a spring "knock-down" herbicide treatment or cutting, followed by a late-season glyphosate treatment. Follow-up in the second year with additional glyphosate treatment and then grass seeding to promote a competitive groundcover. The grass groundcover will require initial maintenance through periodic application of selective herbicides to target knotweed sprouts.

[2/] Weston, L.A. 2005. History and Current Trends in the Use of Allelopathy for Weed Management.
http://www.regional.org.au/au/allelopathy/2005/molisch/2533_weston1.htm?print=1.

EFFICACY OF KIXOR™ FOR SELECTIVE POSTEMERGENCE APPLICATION

Herbicide trade and common chemical names: BAS800H/Kixor™ (*saflufenacil*), BAS 80200H (*saflufenacil plus imazapic*)
Plant common and scientific names: Canada thistle (*Cirsium arvense*), kochia (*Kochia scoparia*), quackgrass (*Agropyron repens*)

ABSTRACT

A new PPO-inhibiting herbicide with trade name Kixor™ and active ingredient *saflufenacil* was evaluated at a roadside location for use alone, in three different formulations and at several rates, ranging from 100 to 400 g ai/ha, as well as in combination with *imazapic*, for selective postemergence weed control. Results showed no apparent differences in BAS800H performance against kochia or Canada thistle among the emulsifiable concentrate, soluble concentrate, or water-dispersible granule formulations at rates of either 100 or 200 g ai/ha; however, the emulsifiable concentrate tended to provide the best control at 200 g ai/ha among formulations. The emulsifiable concentrate, targeted for release to noncrop markets in 2010 and which was the only formulation tested at rates up to 400 g ai/ha, failed to provide significantly better control of either kochia or Canada thistle at rates above 200 g ai/ha. By the end of the season, the emulsifiable concentrate at a rate of 400 g ai/ha tended to have lower total, kochia, and Canada thistle cover than lower use rates; however, it is possible that *saflufenacil* may have had an antagonistic effect on the perennial grasses present at higher rates. Future trials conducted in turf would be necessary to determine the potential for rate-dependent injury to desirable grasses and efficacy of BAS8020H (*imazapic* premix) for use in seedhead suppression. *Saflufenacil*, the active ingredient in Kixor™, has the potential for use as a selective, postemergence treatment at rates of 100 to 400 g ai/ha, especially against ALS and glyphosate-resistant broadleaf species, such as kochia and marestail. Combination with *glyphosate* would provide broad-spectrum control.

INTRODUCTION

BAS800H (trade name Kixor™) is a new herbicide that has been introduced to the agricultural market by the BASF Corporation but is awaiting release to the noncrop market. Kixor™ is intended for contact and residual control of dicot weeds. *Saflufenacil*, the active ingredient in Kixor™, is a protoporphyrinogen-IX-oxidase (PPO) inhibitor belonging to the pyrimidinedione class of chemistry. *Saflufenacil* is absorbed by plant roots, shoots, and leaves and translocated primarily through the xylem. 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 other ALS-resistant biotypes. In bareground settings, residual weed control may be improved along with an increased control spectrum by combining Kixor™ with *imazapic*. For selective application, research results have shown that most perennial grass species, including natives, are tolerant of Kixor™[2]. BASF plans to market products with Kixor™ for burndown and residual control of dicot weeds in non-crop settings with registration anticipated for the 2010 use season in North America.

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

This trial evaluated BAS800H alone, in three different formulations (emulsifiable concentrate, soluble concentrate, and water-dispersible granule) and at several rates, ranging from 100 to 400 g ai/ha, as well as in combination with *imazapic* (BAS 80200H), for selective postemergence and residual weed control.

MATERIALS AND METHODS

The trial was located in the center median of SR 322 at the Route 26 overpass in State College, PA. The study treatments were applied to 6 by 15 ft plots, arranged in a randomized complete block design, on June 16, 2008. Treatments were applied using one of two adjuvants, either methylated seed oil (MSO) at 1% v/v or Induce 90 nonionic surfactant at 0.25% v/v. Treatments applied with MSO were as follows: BAS80003H (emulsifiable concentrate) at 11.4, 22.8, 34.3, and 45.7 oz/ac, equivalent to 100, 200, 300, and 400 g ai/ha, respectively; BAS80004H (soluble concentrate) at 4 and 8 oz/ac, equivalent to 100 and 200 g ai/ha, respectively; and BAS80001H (water-dispersible granule) at 2.04 and 4.08 oz/ac, equivalent to 100 and 200 g ai/ha, respectively. Alternatively, BAS80200H (*imazapic* premix, water-dispersible granule) at 2.09 oz/ac or 102 g ai/ha and BAS80003H at 5.7 oz/ac or 50 g ai/ha were applied with Induce 90 at 0.25% v/v. All treatments were applied at 30 gal/ac using a CO_2-powered backpack sprayer equipped with a 6-ft boom and four 8002 VS tips. At the time of treatment, kochia was up to 8 inches tall but averaged about 1.5 inches. The kochia stand was very dense with apparent intraspecific competition; therefore, only solitary kochia plants tended toward the maximum height of 8 inches. Canada thistle plants were in bud stage, averaging 18 inches in height with the tallest stems 36 inches. Total vegetative, kochia, and Canada thistle cover, as well as kochia and Canada thistle control were visually rated. Control was evaluated on a scale of 0 to 100, where 0 = no control and 100 = plant death. Data were collected on June 16, July 1, July 16, September 15, and October 14, 2008, which corresponded to 0, 15, 30, 91, and 120 days after treatment (DAT), respectively. Data were subjected to analysis of variance, and means were compared using Fisher's Protected LSD. Results were considered significant when $P < 0.05$.

RESULTS AND DISCUSSION

At time of treatment, there were no significant differences in total vegetative (17 to 28 percent), kochia (5 to 23 percent), or Canada thistle (3 to 12 percent) cover (data not shown). At 15 DAT, all treatments applied with MSO provided significantly greater kochia control (35 to 85 percent) than no treatment (Table 1); however, BAS80003H and BAS8020H applied with nonionic surfactant produced unacceptable control levels (8-10 percent). Treatments containing BAS80003H at rates equal to or higher than 200 g ai/ha provided the greatest kochia control at 75 to 85 percent. There were no significant differences among the three BAS800 formulations with MSO at a rate of either 100 or 200 g ai/ha. Results for Canada thistle control were similar to kochia at 15 DAT, but control varied more widely within treatments than for kochia, with one treatment ranging between 35 and 95 percent control (data not shown). The reason for this variation is unclear, but for some treatments, plots having lower Canada thistle cover had greater control values.

Total cover at 30 DAT ranged from 8 to 38 percent and tended to decrease with higher rates of BAS800H. However, total cover does not provide a useful indication of product efficacy since BAS800H is a selective broadleaf herbicide and perennial grasses, mainly quackgrass, comprised a large portion of the cover in many plots. There were no significant differences among treatments in kochia cover at 30 DAT, which ranged from 2 to 11 percent; BAS80003H at 400 g ai/ha produced the lowest kochia cover (2 percent), while the untreated check (8 percent) was intermediate among treatments. In this case, kochia growth on untreated plots was likely limited by increased competition with other plants, as indicated by higher total cover. Canada thistle cover at 30 DAT was significantly lower for all herbicide treatments than the untreated check. Control tended to increase with increasing herbicide rate. There were no significant differences among the three formulations at a given rate.

At 91 and 120 DAT, there were no significant differences among herbicide treatments for total, kochia, or Canada thistle cover; furthermore, while all herbicide treatments had significantly lower Canada thistle cover than the untreated check at 91 DAT, no significant differences existed between the herbicide treatments and the untreated check on or after 91 DAT for total, kochia, or Canada thistle cover. Total cover at 91 DAT ranged from 13 to 32 percent, kochia cover from 3 to 12 percent, and Canada thistle cover from 3 to 21 percent. Untreated plots continued to have moderate kochia cover among treatments, likely due to the continued negative effect of competition on kochia growth. This trend continued to 120 DAT. At 120 DAT, total, kochia, and Canada thistle covers ranged from 27 to 53 percent, 2 to 13 percent, and 5 to 37 percent, respectively.

Throughout the course of the trial, there were no significant differences in control or cover among the BAS8020H, an *imazapic* premix, and BAS80003H treatments applied with Induce 90 nonionic surfactant. Therefore, it seems that *imazapic* did not increase the efficacy of BAS800H as a broadleaf herbicide. These two products may have application for seedhead suppression at the rates tested and in combination with a nonionic surfactant, since MSO is not recommended for use on cool-season grasses. However, the effects of the treatments on cool-season grasses were not evaluated since the dominant grass, quackgrass, is a weedy species.

CONCLUSIONS

Overall, the postemergence treatments were expected to have little or no effect on kochia seedlings that were shielded from the herbicide spray by larger vegetation. Both qualitatively and based on ratings from the untreated plots, it was apparent that existing kochia was released when the herbicide treatments eliminated competing vegetation. In the untreated plots, competing vegetation did limit kochia growth, with kochia cover values lower than many of the herbicide treatments at 120 DAT.

There were no apparent differences in BAS800H performance against kochia or Canada thistle among the emulsifiable concentrate, soluble concentrate, or water-dispersible granule formulations at rates of either 100 or 200 g ai/ha; however, BAS80003H, the emulsifiable concentrate, tended to provide the best control at 200 g ai/ha among formulations. The emulsifiable concentrate, targeted for release to noncrop markets and which was the only formulation tested at rates up to 400 g ai/ha, failed to provide significantly better control of either kochia or Canada thistle at rates above 200 g ai/ha. By the end of the season, the emulsifiable concentrate at a rate of 400 g ai/ha tended to have lower total, kochia, and Canada thistle cover than lower-use rates. Future trials conducted in turf would be necessary to determine the potential for rate-dependent injury to desirable grasses and efficacy of BAS8020H (*imazapic* premix) for use in seedhead suppression.

MANAGEMENT IMPLICATIONS

Saflufenacil, the active ingredient in Kixor™, has the potential for use as a selective, postemergence treatment at rates of 100 to 400 g ai/ha, especially against ALS and glyphosate-resistant broadleaf species, such as kochia and marestail. Combination with *glyphosate* would provide broad-spectrum control. The *saflufenacil*/*imazapic* premix (BAS80200H) may have utility in PennDOT's grass growth regulation program (7711-03) if future research can demonstrate good seedhead suppression and safety to turf. Current Kixor™-based products evaluated in this trial that have been released to the agricultural market include Sharpen™ (BAS 80004H) for field and row crops and Treevix™ (BAS 80001H) for tree, fruit, and nut crops.

Table 1. Visual ratings of total vegetative, kochia, and Canada thistle cover, as well as kochia and Canada thistle control according to treatment. All treatments except those listed with "Induce 90" were applied with methylated seed oil at 1% v/v. "Form" = formulation, where EC = emulsifiable concentrate, SC = soluble concentrate, WG = water-disperable granule; "AI" = active ingredient. Postemergence herbicide treatments were applied to a roadside guiderail location on June 16, 2008. Ratings were collected on June 16 (0 days after treatment, DAT), July 1 (15 DAT), July 16 (30 DAT), September 15 (91 DAT), and October 14, 2008 (120 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, ns = not significant.

Product	Form	AI Rate (g/ha)	15 DAT Kochia	CIRAR	30 DAT Total	Kochia	CIRAR	91 DAT Total	Kochia	CIRAR	120 DAT Total	Kochia	CIRAR
			-- % Control --		--------------------------------- % Cover -------------------------------------								
Untreated	---	---	0	0	38	8	26	32	7	21	47	5	37
BAS80003H	EC	100	53	45	23	9	10	28	12	7	30	11	8
BAS80004H	SC	100	35	32	27	10	6	22	11	7	52	12	17
BAS80001H	WG	100	40	40	33	11	9	28	12	10	40	12	12
BAS80003H	EC	200	75	85	22	9	4	25	12	3	35	13	5
BAS80004H	SC	200	55	50	22	4	8	18	4	7	35	6	13
BAS80001H	WG	200	60	50	18	3	8	18	3	10	37	2	18
BAS80003H	EC	300	78	50	13	5	4	23	5	8	35	9	12
BAS80003H	EC	400	85	67	8	2	1	13	4	5	27	3	8
BAS80200H Induce 90	WG	102	8	10	25	4	12	20	6	7	40	5	17
BAS80003H Induce 90	EC	50	10	15	28	4	12	23	6	8	40	2	22
Protected LSD (p=0.05)			25	36	10	ns	7	ns	ns	8	ns	ns	ns

OPTIONS FOR POSTEMERGENCE KOCHIA CONTROL

Herbicide trade and common chemical names: Arsenal (*imazapyr*), BAS80001H (*saflufenacil*), Escort XP (*metsulfuron methyl*), Garlon 3A (triclopyr), *glyphosate* - 3.8 lb ae/gal, KJM 44 (*aminocylopyrachlor*), Milestone VM (*aminopyralid*), Oust Extra (*sulfometuron methyl* plus *metsulfuron methyl*), Overdrive (*dicamba* plus *diflufenzopyr*) Plateau (*imazapic*), Transline (*clopyralid*), Vanquish (*dicamba*), Velpar DF (*hexazinone*), Vista (*fluroxypyr*), Weedestroy (*2,4-D)*

Plant common and scientific names: kochia (*Kochia scoparia*), marestail (*Conyza canadensis*)

ABSTRACT

Kochia that escapes early-season treatments in bareground settings can grow up to 7 ft tall, posing line-of-sight issues and leading to prolific seed production. Once kochia has passed the seedling stage, control becomes increasingly difficult. Postemergence kochia control was compared at two roadside locations among 15 non-crop herbicides, including two new chemistries, BAS 80001, a PPO inhibitor, and KJM44, a synthetic auxin. Results showed that *glyphosate*, Vanquish, and Vista provided the best control. Overdrive also provided good control but appeared to produce greater injury to vigorously growing kochia than to stressed plants. Further work will be required to determine whether KJM44 produces satisfactory kochia control at rates above 1 oz/ac. BAS80001 caused severe initial injury to kochia followed by recovery; this product may prove more effective when combined with *glyphosate* to prevent regrowth but will also require further testing.

INTRODUCTION

Kochia presents a season-long threat to bareground programs. When shielded from early-season treatment, seedlings are released from competition and grow rapidly. In addition, kochia seeds may continue to germinate after the initial spring flush. Once beyond the seedlings stage, kochia plants are substantially more difficult to control. Since kochia has known resistance to herbicides acting as ALS inhibitors, synthetic auxins, and photosynthesis inhibitors[3], which include many of the herbicides currently used in roadside programs, effective postemergence rotation options for kochia are needed. The new chemistries of *saflufenacil*, a PPO-inhibitor, and *aminocycolpyrachlor*, a synthetic auxin, add to a long list of herbicides to be screened for use on kochia.

Saflufenacil (BAS800H) has been introduced to the market by BASF, under the trade name Kixor™, as a pre- and postemergence herbicide, available in an emulsifiable concentrate, soluble concentrate, and wettable granules. *Saflufenacil* is readily absorbed by foliage, roots, and shoots and is predominantly translocated through the xylem, with limited movement in the phloem. *Saflufenacil* is recommended as a mix with glyphosate to control problematic weeds such as marestail (*Conyza canadensis*) and prickly lettuce (*Lactuca serriola*).

Aminocylopyrachlor (KJM44) is currently under development by DuPont for use in noncrop markets including rights-of-way, bareground, roadsides, and invasive weed management. This systemic herbicide is absorbed by both leaves and roots and is targeted for uses similar to Milestone VM (*aminopyralid*). *Aminocyclpyrachlor* is reputed to provide postemergent and soil

[3] Heap, I. The International Survey of Herbicide Resistant Weeds. Online. Internet. November 09, 2008. Available www.weedscience.com.

residual activity against many annual and perennial broadleaf weeds and brush species. The product also has the potential to control ALS- and glyphosate-resistant weeds such as kochia and marestail.

The objective of this experiment was to compare postemergence kochia control among 15 noncrop herbicides.

MATERIALS AND METHODS

Trials were located at two roadside sites, the median of SR 220 at the SR 26 overpass, near Bellefonte, PA, and on the shoulder of SR 220 North before the Thomas St. exit, near Jersey Shore, PA. Plots were established at the Bellefonte site inside of and adjacent to the guiderail in a mix of bareground and turf. At Jersey Shore, plots were laid out in gravel at the edge of the pavement. Plots at both sites were 4 by 12 ft in size and arranged in a randomized complete block design with three replications. The treatments included an untreated check and the following herbicides (in oz/ac): 2.4-D at 64, *glyphosate* (3.8 lb ae/gal) at 52, Vista at 16, Vanquish at 24, Overdrive at 4, Garlon 3A at 32, Milestone VM at 4, Transline at 4, Escort XP at 1, Oust Extra at 4, Arsenal at 16, Velpar DF at 20, Plateau at 12, BAS80001H (*saflufenacil*, wettable granule, 70% active) at 2, and KJM44 (*aminocyclopyrachlor*, wettable granule, 80% active) at 1. Activator 90 nonionic surfactant at 0.25% (v/v) was included in all treatments. Treatments were applied at the Bellefonte and Jersey Shore sites on July 18 and 29, 2008, respectively, using a CO_2-powered sprayer with an ultra-low volume wand and a single TeeJet OC-12, off-center flat spray tip, delivering 40 gal/ac at 28 psi.

The trials were visually rated for total and kochia cover at time of treatment. Percent injury to kochia was rated on August 4 and 12 (17 and 14 DAT), and percent kochia control was rated August 19 and 28 (32 and 30 DAT) at the Bellefonte and Jersey Shore sites, respectively. Control was evaluated on a scale of 0 to 100, where 0 = no control and 100 = plant death. The Bellefonte site received an additional control rating on September 15, 2008 (59 DAT), which is not reported. A final rating of total and kochia cover was taken September 24 and 30, 2008 (57 and 74 DAT) for the Jersey Shore and Bellefonte sites, respectively. All data were subjected to ANOVA and means were compared using Fisher's Protected LSD. Results were considered significant at the $p < 0.05$ level.

RESULTS AND DISCUSSION

Postemergence kochia control appeared to vary with plant size and vigor. At 0 days after treatment (DAT), total and kochia cover at Jersey Shore were 5 and 4 percent, respectively, with no significant differences among treatments (Table 1). By 14 DAT, percent kochia injury ranged from 10 to 97 percent among treatments with *glyphosate* (97 percent), BAS80001H (95 percent), Vanquish (83 percent), and *2,4-D* (75 percent) appeared most effective. Interestingly, Overdrive (*dicamba* plus *diflufenzopyr*) at 4 oz/ac provided significantly less control than Vanquish (*dicamba*) at 24 oz/ac. At 30 DAT, kochia control ranged from 3 to 99 percent with *glyphosate* (99 percent), Vanquish (95 percent), *2,4-D* (81 percent), and Vista (72 percent) performing best. Between 14 and 30 DAT, BAS80001H control dropped to 50%, and new growth was visible from the apical meristems of treated plants. By 57 DAT, there were no significant differences in either total cover or kochia cover, which ranged from 1 to 5 and 0 to 5 percent, respectively. For the low-vigor kochia at this site, *diflufenzopyr* did not appear to increase the efficacy of *dicamba*. Overall, significant differences in injury and control ratings at the poor-quality, low-vigor Jersey

Shore site did not translate into differences in percent kochia cover, which remained low at season's end.

Kochia was more vigorous at the Bellefonte site, with some plants as tall as 4 ft at the time of treatment. At 0 DAT, total and kochia cover at Bellefonte was 34 and 29 percent, respectively, with no significant differences among treatments (Table 2). Kochia injury at 17 DAT ranged from 2 to 94 percent, with *glyphosate* (94 percent), BAS80001H, (85 percent), and Vanquish (84 percent) causing the most injury. At 32 DAT, percent control ranged from 2 to 91 percent, with Vanquish (91 percent), Overdrive (77 percent), Vista (75 percent), and *glyphosate* (72 percent) most effective. Similar to the response at Jersey Shore, BAS80001H dropped to 35 percent control, and new growth was again apparent on treated plants. At 74 DAT, Vanquish (4 percent), *glyphosate* (10 percent), Overdrive (12 percent), Vista (19 percent), and *2,4-D* (20 percent) provided significant reduction in kochia cover compared to the untreated plots (45 percent).

Herbicide mixtures were not tested in this study, but *glyphosate* provided good control when applied alone at 52 oz/ac. Our results show that *2,4-D* does not provide satisfactory control of vigorous kochia at a rate of up to 64 oz/ac. Although Vanquish, Overdrive, and Vista provided significantly better control than the untreated check, Vanquish tended to outperform Vista at the rates chosen. Environmental conditions may affect the efficacy of Vista, which provides inconsistent control under dry soil conditions and drought stress[4,5]. When *diflufenzopyr* was combined with a reduced rate of *dicamba*, post control of kochia tended to decrease; therefore, it appears that *diflufenzopyr* did not increase the efficacy of *dicamba* against kochia in these trials. Kochia resistance to *dicamba* has been reported in Montana, North Dakota, and Idaho[1]. However, development of *dicamba* resistance appears to spread more slowly than observed with other herbicides, probably because the mechanism is controlled by multiple genes[6]. The new chemistries tested may require additional screening against kochia. KJM44 provided unacceptable control at a rate of 1 oz/ac. Other work has shown that KJM44 produces excellent control against marestail at rates of 3.7 oz/ac or greater[7]; therefore, the rates used in this study may have been too low to cause injury. Although BAS80001H at 2 oz/ac caused severe injury, kochia recovered from treatment by producing new growth at apical meristems. Marestail injury of 97% or greater at 14 DAT has been reported at a lower rate than used in our study (1 oz/ac)[8]. Similar to our observations with kochia, marestail tends to regrow at low application rates and when portions of taller plants are missed[9].

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[7] Montgomery, D. et al. 2009. Control of Kochia with DPX-KJM44 along Oklahoma Highway Rights-of-way. WSSA Proceedings, p. 493.

[8] Mellendorf, T.G. et al. 2008. Influence of horseweed height on the foliar efficacy of saflufenacil. North Central Weed Science Society Proceedings.

[9] Mellendorf, T.G. Personal communication. February 19, 2009.

CONCLUSIONS

Among the herbicides screened for postemergence activity on kochia, *glyphosate*, Vanquish, and Vista provided the best control. Overdrive also provided good control but appeared to produce greater injury to vigorously growing kochia than stressed plants. Further work will be required to determine whether KJM44 produces satisfactory kochia control at rates above 1 oz/ac. BAS80001 may prove more effective in the long-term when combined with *glyphosate* to prevent regrowth. While *aminocylopyrachlor* acts as a synthetic auxin like both *dicamba* and *fluroxypyr*, *saflufenacil*, a PPO-inhibitor, provides a different mode of action against kochia and would be worth evaluating further.

MANAGEMENT IMPLICATIONS

Current rotation options for postemergence kochia control include *glyphosate*, Vanquish, Overdrive, and Vista.

Table 1. Visual ratings of total vegetative cover and kochia cover as well as kochia injury and control after treatment with fifteen different herbicides. Postemergence herbicide treatments were applied to a roadside kochia infestation near Jersey Shore, PA, on July 29, 2008. Ratings were collected on July 29 (0 days after treatment, "DAT"), August 12 (14 DAT), August 28 (30 DAT), and September 24 (57 DAT). Injury and control were evaluated on a scale of 0 to 100, where 0 = no injury or control and 100 = plant death. Each value is the mean of three replications, ns = not significant.

Product	Product Rate (oz/ac)	--- 0 DAT --- Total	Kochia	14 DAT Kochia	30 DAT Kochia	--- 57 DAT --- Total	Kochia
		-- % Cover --		% Injury	% Control	-- % Cover --	
Untreated	---	5	4	0	0	5	4
Glyphosate (3.7 lb ae)	52	5	4	97	99	1	0
2,4-D (3.8 lb ae)	64	5	4	75	81	3	2
Vista	16	4	3	75	72	3	1
Vanquish	24	6	5	83	95	3	1
Overdrive	4	6	5	63	68	4	3
Garlon 3A	32	5	4	73	62	5	3
Milestone VM	4	6	4	10	7	5	4
Transline	4	5	4	13	3	4	3
Escort XP	1	6	5	17	18	4	4
Oust Extra	4	6	5	10	17	5	4
Arsenal	16	5	4	32	15	4	3
Velpar DF	20	6	6	27	7	5	5
BAS80001H	2	4	4	95	50	4	3
Plateau	12	4	3	23	17	3	3
KJM 44	1	5	3	62	60	4	2
Protected LSD (p=0.05)		ns	ns	13	16	ns	ns

Table 2. Visual ratings of total vegetative cover and kochia cover as well as kochia injury and control after treatment with fifteen different herbicides. Postemergence herbicide treatments were applied to a roadside kochia infestation near Bellefonte, PA, on July 18, 2008. Ratings were collected on July 18 (0 days after treatment, "DAT"), August 4 (17 DAT), August 19 (32 DAT), and September 30 (74 DAT). Injury and control were evaluated on a scale of 0 to 100, where 0 = no injury or control and 100 = plant death. Each value is the mean of three replications, ns = not significant.

Product	Product Rate (oz/ac)	--- 0 DAT --- Total	Kochia	17 DAT Kochia	32 DAT Kochia	--- 74 DAT --- Total	Kochia
		-- % Cover --		% Injury	% Control	-- % Cover --	
Untreated	---	28	23	0	0	50	45
Glyphosate (3.7 lb ae)	52	30	26	94	72	10	10
2,4-D (3.8 lb ae)	64	33	29	55	55	29	20
Vista	16	32	30	55	75	21	19
Vanquish	24	35	31	84	91	8	4
Overdrive	4	32	26	63	77	18	12
Garlon 3A	32	37	31	43	58	42	38
Milestone VM	4	33	30	2	5	42	41
Transline	4	35	31	3	2	62	62
Escort XP	1	35	29	13	8	48	36
Oust Extra	4	33	26	7	7	50	50
Arsenal	16	28	26	33	50	33	28
Velpar DF	20	37	29	48	25	40	40
BAS80001H	2	43	40	85	35	55	41
Plateau	12	28	25	20	18	43	37
KJM 44	1	37	26	53	62	39	31
Protected LSD (p=0.05)		ns	ns	23	22	23	23

SELECTIVE CONTROL OF DICOTS USING DPX-KJM44

Herbicide trade and common chemical names: DPX-KJM44 (aminocyclopyrachlor), Escort XP (metsulfuron), Milestone VM (aminopyralid), Plateau (imazapic), Roundup (glyphosate), Telar (chlorsulfuron).

Plant common and scientific names: bull thistle (*Cirsium vulgare*), crownvetch (*Coronilla varia*), musk thistle (*Carduus nutans*), plumeless thistle (*Carduus acanthoides*), tall fescue (*Festuca arundinacea*).

ABSTRACT

DPX-KJM44 is an experimental herbicide that was investigated for use in foliar treatments to control plumeless thistle in a crownvetch stand. Control was evaluated using multiple rates of DPX-KJM44 alone and in combination with other broadleaf chemistry. The herbicide treatments were also evaluated for their safety to grasses. DPX-KJM44 at 2 oz/ac alone or Milestone VM at 1.25 oz/ac alone provided excellent control of both plumeless thistle and crownvetch without noticeable injury to tall fescue.

INTRODUCTION

DPX-KJM44 (proposed common name, *aminocyclopyrachlor*) is an experimental herbicide that was investigated for use in foliar treatments to control plumeless thistle in a crownvetch stand. Biennial thistles, like plumeless thistle, plague the roadside environment where they often become established in crownvetch areas. Two closely associated thistles, musk and bull thistle, are listed as Pennsylvania noxious weeds. The seeds from these plants often move from the roadside to agricultural areas where they develop and interfere with crop production. Selectively treating crownvetch stands infested with biennial thistles is challenging. Both are broadleaf plants and are therefore usually injured simultaneously by herbicide treatment. The elimination of weed infested crownvetch stands and replacement with grasses has been demonstrated as a viable approach to combating these ongoing weed problems. Herbicides or combinations that effectively control future broadleaf weed problems within the grass stand are needed. This investigation tested *saflufenacil* control of plumeless thistle and persistent crownvetch, as well as its safety to grasses.

MATERIALS AND METHODS

Two sites were established near State College, PA along the shoulder of SR 322 East before the Oak Hall exit and in the infield off of SR 322 adjacent to Park Avenue. The efficacy of DPX-KJM44 treatments on plumeless thistle and crownvetch were evaluated at the Oak Hall exit. Treatments were applied at prescribed dosages to 6-by-15-ft plots on May 23, 2008. Treatments were applied at 20 gal/ac using a CO_2-powered backpack sprayer equipped with a 6-ft boom and four 8002 VS tips at 28 psi. Percent total vegetative cover, percent cover by plumeless thistle, and percent cover by crownvetch were evaluated May 23 and September 18, 2008, 0 and 118 days after treatment, DAT. Percent injury to plumeless thistle and crownvetch were rated June 9, June 26, and July 22, 2008, 17, 34, and 60 DAT.

Potential DPX-KJM44 toxicity to turf was evaluated at the SR 322 infield adjacent to Park Avenue. Identical treatment, plot sizes, and equipment were used in this application. Treatments were applied May 28, 2008 to a mixed stand comprised primarily of tall fescue, fine fescue, and crownvetch. Percent injury to tall fescue, fine fescue, and crownvetch was evaluated June 12, June 30, July 28, and September 26, 2008, 15, 33, 61, and 121 DAT.

RESULTS AND DISCUSSION

The Oak Hall site had original total vegetative cover ranging from 73 to 90 percent. Initial cover by plumeless thistle ranged from 17 to 29 percent, while cover by crownvetch ranged from 47 to 69 percent. The untreated check and Milestone VM plus Plateau treatment had only 1 percent cover by plumeless thistle remaining on September 18, 2008, the highest levels observed. Significant loss of crownvetch occurred with all treatments compared to the untreated check, except for 0.5 oz/ac DPX-KJM44, which maintained a substantial crownvetch stand. DPX-KJM44 at rates of 1 and 1.5 oz/ac and Milestone VM plus Plateau had from 10 to 20 percent crownvetch cover at September 18, 2008. All other treatments completely eliminated the plumeless thistle stand and reduced the crownvetch cover to between 0 and 6 percent.

Injury observed among nearly all treatments between the May 23, 2008 application and evaluations made September 18, 2008 explained the significant losses to both plumeless thistle and crownvetch. At 17 DAT, all treatments produced injury ratings from 53 to 96 percent for plumeless thistle and 50 to 98 percent for crownvetch. The least injury to plumeless thistle and crownvetch came from 0.5 oz/ac DPX-KJM44 alone or combined with 0.19 oz/ac Telar. By 60 DAT, all treatments except the lowest rate of DPX-KJM44 caused from 99 to 100 percent injury to plumeless thistle. Even 0.5 oz/ac DPX-KJM44 substantially injured the thistle (95 percent) by this date. Dramatic injury also occurred to crownvetch by 60 DAT. All treatments produced from 93 to 100 percent injury, except 0.5 oz/ac DPX-KJM44 (73 percent injury), by this date.

Tall fescue showed injury symptoms from treatments containing Telar, Escort, Plateau, or Roundup beginning at 15 DAT. These treatments continued to express significant symptoms at 33 DAT with the greatest injury occurring from Roundup. By 61 DAT, only treatments containing Roundup had elevated levels of injury (38 to 50 percent). Injury symptoms had diminished by 121 DAT, and no treatments were significantly different.

CONCLUSIONS

DPX-KJM44 alone at 2 oz/ac or Milestone VM alone at 1.25 oz/ac provided excellent control of both plumeless thistle and crownvetch without noticeable injury to tall fescue. The materials used at these rates would provide viable options to control unwanted broadleaf plants within stands of industrial turf on the roadside.

MANAGEMENT IMPLICATIONS

DPX-KJM44, or *aminocyclopyrachlor*, will provide a viable alternative to many of the broadleaf herbicides used on the roadside. It appears safe to turf and provides substantial control of some of the more troublesome dicot weeds common to roadside turf areas.

Table 1. Visual ratings of percent total vegetative cover, plumeless thistle (CRUAC) cover, and crownvetch (CZRVA) cover were evaluated May 23 and September 18, 2008, 0 and 118 days after treatment, DAT. Herbicide treatments were applied to a plumeless thistle infested crownvetch stand near State College, PA on May 23, 2008. Each value is the mean of three replications.

		Total Cover		CRUAC Cover		CZRVA Cover	
Treatment	Rate	May 23	Sep 18	May 23	Sep 18	May 23	Sep 18
	(oz/ac)	----------------------------------	----------------------------------	----------------%	-----------------	----------------------------------	----------------------------------
Untreated	---	82	40	21	1	61	38
DPX-KJM44	0.5	82	43	18	0	64	42
DPX-KJM44	1	83	20	26	0	58	20
DPX-KJM44	1.5	77	11	22	0	54	11
DPX-KJM44	2	73	4	27	0	47	3
DPX-KJM44 Telar	0.5 0.19	82	4	19	0	63	0
DPX-KJM44 Telar	1 0.38	90	1	21	0	69	0
DPX-KJM44 Escort XP	1 0.3	88	1	19	0	69	1
DPX-KJM44 Escort XP	1.5 0.45	78	0	17	0	62	0
Milestone VM Plateau	1 0.71	82	12	29	1	52	10
Milestone VM	1.25	83	16	21	0	63	6
DPX-KJM44 Telar	1.5 0.56	78	0	22	0	57	0
DPX-KJM44 Telar	2 0.75	85	0	28	0	57	0
DPX-KJM44 Escort XP Roundup	2 0.45 8	82	1	24	0	58	0
DPX-KJM44 Telar Roundup	2 0.75 8	87	0	25	0	62	0
LSD (p=0.05)		n.s.	12	n.s.	0.4	n.s.	12

Table 2. Percent injury to plumeless thistle (CRUAC) and crownvetch (CZRVA) was evaluated June 9, June 26, and July 22, 2008, 17, 34, and 60 days after treatment, DAT. Herbicide treatments were applied to a plumeless thistle infested crownvetch stand near State College, PA on May 23, 2008. Untreated checks were given a "0" rating and were not included in the ANOVA. Each value is the mean of three replications.

		CRUAC Injury			CZRVA Injury		
Treatment	Rate	Jun 9	Jun 26	Jul 22	Jun 9	Jun 26	Jul 22
	(oz/ac)	-----------------------------------%-----------------------------------					
Untreated	---	0	0	0	0	0	0
DPX-KJM44	0.5	53	80	95	50	80	73
DPX-KJM44	1	82	94	100	85	96	93
DPX-KJM44	1.5	82	97	100	93	98	96
DPX-KJM44	2	83	99	100	92	98	97
DPX-KJM44 Telar	0.5 0.19	73	90	100	77	96	99
DPX-KJM44 Telar	1 0.38	82	97	100	87	98	99
DPX-KJM44 Escort XP	1 0.3	82	97	100	87	97	99
DPX-KJM44 Escort XP	1.5 0.45	87	98	100	94	99	99
Milestone VM Plateau	1 0.71	85	97	99	92	99	96
Milestone VM	1.25	90	99	100	93	98	98
DPX-KJM44 Telar	1.5 0.56	85	98	100	95	98	99
DPX-KJM44 Telar	2 0.75	90	99	100	97	99	100
DPX-KJM44 Escort XP Roundup	2 0.45 8	96	100	100	98	99	100
DPX-KJM44 Telar Roundup	2 0.75 8	96	100	100	97	99	99
LSD (p=0.05)		6	3	1	6	1	2

Table 3. Visual ratings of percent injury to tall fescue were taken June 12, June 30, July 28, and September 26, 2008, 15, 33, 61, 121 days after treatment, DAT. Herbicide treatments were applied to mixed stand of turf near State College, PA on May 28, 2008. Untreated checks were given a "0" rating and were not included in the ANOVA. Each value is the mean of three replications.

		Tall Fescue Injury			
Treatment	Rate	Jun 12	Jun 30	Jul 28	Sep 26
	(oz/ac)	%			
untreated	---	0	0	0	0
DPX-KJM44	0.5	0	0	0	0
DPX-KJM44	1	7	3	0	0
DPX-KJM44	1.5	0	0	0	0
DPX-KJM44	2	0	0	0	0
DPX-KJM44 Telar	0.5 0.19	20	23	7	0
DPX-KJM44 Telar	1 0.38	20	20	10	0
DPX-KJM44 Escort XP	1 0.3	27	27	10	0
DPX-KJM44 Escort XP	1.5 0.45	30	33	10	0
Milestone VM Plateau	1 0.71	17	23	10	3
Milestone VM	1.25	0	0	3	0
DPX-KJM44 Telar	1.5 0.56	27	33	10	0
DPX-KJM44 Telar	2 0.75	27	27	7	3
DPX-KJM44 Escort XP Roundup	2 0.45 8	63	63	38	10
DPX-KJM44 Telar Roundup	2 0.75 8	53	57	50	35
LSD (p=0.05)		15	13	23	n.s.

FURTHER EVALUATION OF ALTERNATIVES TO DIURON FOR KOCHIA CONTROL

Herbicide trade and common chemical names: Aquaneat (*glyphosate*), Arsenal (*imazapyr*), Endurance (*prodiamine*), GlyPro Plus (*glyphosate*), Karmex XP (*diuron*), Krovar I (*bromacil plus diuron*), Landmark XP (*sulfometuron plus chlorsulfuron*), Oust Extra (*sulfometuron plus chlorsulfuron*), Payload (*flumioxazin*), Pendulum AquaCap (*pendimethalin*), Throttle XP (*sulfometuron, chlorsulfuron, and sulfentrazone*).
Plant common and scientific names: kochia (*Kochia scoparia*)

ABSTRACT

The advent of *diuron*-resistant kochia will require significant changes to the herbicide mixtures used to maintain bareground along guiderails. Several *diuron* alternatives were evaluated for efficacy on kochia at State College and Enola, PA in 2007, and the trial was repeated in 2008 in State College. Results from the 2008 trial are reported here and discussed in the context of conclusions drawn from the 2007 trials. The trials tested kochia control by Landmark XP alone as well as in combination with *diuron* and *diuron* alternatives. Experimental results were variable. Within-treatment variations in kochia control among the trials were most likely a result of differences in kochia size and vigor at time of treatment. In 2007, the product Throttle XP, which is the commercially available pre-mix of Landmark XP and *sulfentrazone*, provided effective kochia control at both State College and Enola, where kochia was more and less vigorous, respectively. Treatments containing Karmex XP, Payload, Pendulum AquaCap, and Endurance were not effective against the vigorous kochia at the State College guiderail site. In 2007, it was uncertain whether the glyphosate component of the treatment eliminated existing kochia as intended. However, in the 2008 State College trial, all herbicide treatments had eliminated existing kochia plants at 14 days after application, allowing comparison of residual control among treatments. By the end of the season, Krovar I, Throttle XP, and Landmark XP combined with either Karmex, Payload, Pendulum AquaCap, or Endurance were rated significantly lower for kochia cover (2 to 23 percent) compared to Landmark XP alone (48 percent). Collectively, the three pre trials tested diuron alternatives under different kochia growth conditions. Throttle XP appeared to have the most activity against vigorously growing kochia. However, all *diuron* alternatives in combination with Landmark XP performed better than Landmark XP alone against kochia emerging from seed.

INTRODUCTION

Kochia has developed widespread resistance to ALS-inhibiting herbicides, including sulfonylureas such as *metsulfuron* and *sulfometuron*, and is beginning to show resistance to photosystem II inhibitors, such as *diuron*[10]. Roadside and railroad trials conducted by the Penn State Vegetation Management Team have produced evidence of *sulfometuron*-resistant kochia in Pennsylvania. Among the herbicides currently employed by PennDOT, *diuron* has provided the

[10] Heap, I. The International Survey of Herbicide Resistant Weeds. Online. Internet. November 09, 2008. Available www.weedscience.com.

best control against kochia[11]. However, several Midwest and Western states have reported *diuron*-resistant kochia[12]. Alternatives to *diuron* are needed to provide rotation options for PennDOT's guiderail bareground program and to help prevent the development of *diuron*-resistant kochia.

Current candidate herbicides for kochia control in bareground settings are *flumioxazin* and *sulfentrazone*, both of which are PPO-inhibitors. *Pendimethalin* and *prodiamine*, which inhibit cell division, are also potential options for the program.

The objective of this experiment was to provide additional data comparing herbicide mixtures containing *diuron* and *diuron* alternatives, including *flumioxazin*, *sulfentrazone*, *pendimethalin*, and *prodiamine*. *Sulfentrazone* is most readily available as a component of the product Throttle XP. Throttle XP is a pre-mix of Landmark XP (*sulfometuron* plus *chlorsulfuron*) plus *sulfentrazone*. The recommended application rate of 12.5 oz/ac is equivalent to Landmark XP at 4.5 oz/ac plus 8 oz/ac of a 75 percent-active *sulfentrazone* product. Consequently, all treatments except Krovar I (*bromacil* plus *diuron*) included Landmark XP at 4.5 oz/ac as the broad spectrum residual component. This provided a rigorous test of the added herbicides against kochia because Landmark XP has not shown efficacy against kochia in previous work[13].

MATERIALS AND METHODS

The study was located behind the guiderail in the median of SR 322 W in State College, PA. Treatments included an untreated check; GlyPro Plus alone at 64 oz/ac; Landmark XP at 4.5 oz/ac plus GlyPro Plus at 64 oz/ac alone, or in combination with Karmex XP at 128 oz/ac, Payload at 8 oz/ac, Pendulum AquaCap at 134 oz/ac, or Endurance at 24 oz/ac; Throttle XP at 12.5 oz/ac plus GlyPro Plus at 64 oz/ac; and Krovar I at 128 oz/ac plus GlyPro Plus at 64 oz/ac. *Glyphosate* (GlyPro Plus) was added to all herbicide treatments with the intention to eliminate existing kochia plants and allow for comparison of residual kochia control among treatments. Plots measuring 6 by 15 ft in size were established on May 14, 2008 and arranged in a randomized complete block with three replications. Treatments were applied using a CO_2-powered, hand-held spray boom equipped with TeeJet XR8002VS tips, delivering 20 gal/ac at 30 psi.

The plots were visually rated for total vegetative cover and cover by kochia on May 14, May 28, June 12, July 12, and August 11, 2008. 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

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[12] Mengistu, LW et al. 2005. A psbA mutation in Kochia scoparia (L) Schrad from railroad rights-of-way with resistance to diuron, tebuthiuron and metribuzin. Pest Mngmt Science 61(11): 1035-1042.

[13] Are there alternative to diuron for kochia control? 2008. Roadside Vegetation Management Research Report – Twenty-third Year Report.

There were no significant differences in pre-treatment total and kochia cover ratings. Average total cover ranged from 23 to 37 percent, and kochia cover from 7 to 26 percent (Table 1), with plant size ranging from 1 to 6 inches tall. On May 28, 14 days after treatment (DAT), the treatments significantly reduced total cover (1 to 6 percent) compared to the untreated check (38 percent) and eliminated kochia, which accounted for 10 percent cover in untreated plots. By 29 DAT, total cover had increased to 53 percent in the untreated check and was significantly lower among the treated plots (0 to 4 percent); kochia cover remained low in treated plots (0 to 3 percent) but was not significantly different than the check (20 percent). At 59 DAT, total cover had increased significantly in the untreated plots (82 percent) as well as in the *glyphosate* (63 percent) and Landmark XP (40 percent) treatments as compared to Landmark XP with additives and Krovar I (1 to 9 percent). However, kochia cover increased much more dramatically in the Landmark XP treated plots (40 percent) compared to the the untreated (28 percent) and *glyphosate* treated (31 percent) plots. By 89 DAT, treatments containing Landmark XP combined with Karmex, Payload, Pendulum AQ, Endurance, or *sulfentrazone* (Throttle XP), as well as the Krovar I treatment, were rated significantly lower for kochia cover (2 to 23 percent) than Landmark XP alone (48 percent). The Landmark XP alone treatment also had significantly greater kochia cover than both the untreated (11 percent) and glyphosate-only treatment (28 percent). Therefore, it appears that competition from other weeds suppressed kochia growth in addition to the kochia control provided by the additives to Landmark XP. Among the additives tested, *diuron* and alternatives performed similarly against the kochia seedbank, providing several options for herbicide rotations, to help prevent the development of widespread resistance to *diuron*.

Previous trials conducted by Penn State Vegetation Management Research suggest that control varies with site quality, and thus kochia vigor, as well as application timing[14]. For example, in one of two replicated trials conducted in 2007, larger kochia plants, approximately 6 inches tall on May 29, were not eliminated by the *glyphosate* component of the bareground treatments as intended and were instead released from competition. In that trial, the immediate effects of the treatments on kochia were not apparent since the first rating occurred at 40 DAT. By the end of the season, only Throttle XP provided adequate control against the vigorous kochia growth. At the same site, areas treated a few weeks earlier in the season with an operational application of 3.5 oz/ac Oust Extra, 8 lb/ac Karmex DF, 8 oz/ac Arsenal, 24 oz/ac Aquaneat, and 1 qt/100 gal Peptoil were relatively kochia free, despite having similar weed pressure as the trial area. Assuming the operationally treated area received the intended dosage, the difference in kochia control was due to kochia size at time of treatment; that is, the post component was successful against the smaller kochia plants present at the time of the operational treatment.

In the second 2007 trial, which was conducted at a separate location, differences in kochia cover among treatments were not significant at the end of the season, despite a similarly late application date of May 25; however, kochia at this location was less vigorous with only 25 percent cover in untreated plots at season's end. Therefore, differences in kochia control among treatments were not apparent against less vigorous plants.

[14] Are there alternatives to diuron for kochia control? 2008. Roadside Vegetation Management Research Report – Twenty-Second Year Report.

CONCLUSIONS

Treatments containing *diuron* and *diuron* alternatives performed similarly against ALS-resistant kochia growing from seed but not against vigorously growing plants. The collective results of three similar trials, which evaluated *diuron* alternatives under different kochia growth conditions, show that Throttle XP, Payload, Pendulum AQ, and Endurance, in combination with Landmark XP, provided better preemergence kochia control than Landmark XP alone against kochia from seed. However, s*ulfentrazone*, a component of Throttle XP, appears to have the most activity against vigorously growing kochia when applied late in the bareground operational window.

MANAGEMENT IMPLICATIONS

Throttle XP appears to be a leading candidate to be integrated into the bareground program rotation, especially when applied later in the operational window. The manufacturer cautions Throttle XP is weak against some biotypes of marestail and recommends tank mixing with *bromacil* (eg, Hyvar X or Krovar I) when targeting marestail. For applications made earlier in the operational window to suppress kochia growing from seed and tiny seedlings, Payload, Pendulum AQ, and Endurance are also viable rotation options to help prevent *diuron*-resistant kochia.

Table 1. Visual ratings of total vegetative cover and kochia cover after treatment with diuron and diuron alternative bareground herbicide products. Herbicide treatments were applied to a roadside kochia infestation near State College, PA, on May 29, 2008. Cover ratings were collected on May 14 (0 days after treatment, "DAT"), May 28 (14 DAT), June 12 (29 DAT), July 11 (59 DAT), and August 11, 2008 (89 DAT). All treatments, except for the untreated check, contained *glyphosate* (3 lb ae/gal) at 64 oz/ac. Each value is the mean of three replications, ns = not significant.

Product	Product Rate (oz/ac)	0 DAT Total	0 DAT Kochia	14 DAT Total	14 DAT Kochia	29 DAT Total	29 DAT Kochia	59 DAT Total	59 DAT Kochia	89 DAT Total	89 DAT Kochia
		(% Cover)									
Untreated	---	35	12	38	10	53	20	82	28	75	11
Glyphosate	64	37	11	6	0	4	3	63	31	65	28
Landmark XP	4.5	23	8	3	0	2	2	40	40	48	48
Throttle XP	12.5	30	18	2	0	0	0	2	2	19	19
Landmark XP Karmex XP	4.5 128	27	7	5	0	0	0	9	0	3	2
Landmark XP Payload	4.5 8	33	15	2	0	0	0	1	1	11	11
Landmark XP Pendulum AquaCap	4.5 134	30	11	5	0	2	1	2	2	21	20
Landmark XP Endurance	4.5 24	35	18	1	0	1	0	8	8	24	23
Krovar I	128	37	26	2	0	0	0	7	2	12	4
Protected LSD (p=0.05)		ns	ns	4	ns	9	ns	16	24	44	16

NATIVE SEED MIX ESTABLISHMENT IMPLEMENTATION

Plant common and scientific names: annual ryegrass (*Lolium multiflorum*), autumn bentgrass (*Agrostis perennans*), big bluestem (*Andropogon gerardii*), black eyed susan (*Rudbeckia hirta*), Canada wildrye (*Elymus canadensis*), crownvetch (*Coronilla varia*), fine fescue (*Festuca rubra*), giant foxtail (*Setaria faberi*), Indiangrass (*Sorghastrum nutans*), little bluestem (*Schizachyrium scoparius*), ox eye sunflower (*Heliopsis helianthoides*), partridge pea (*Chamaecrista fasciculata*), spring oats (*Avena sativa*), switchgrass (*Panicum virgatum*)

INTRODUCTION

Section 804 - *Seeding and Soil Supplement,* within PennDOT Publication 408, *Specifications*, describes six different seeding formulas used by PennDOT. These seed mixes are selected to provide groundcover based on site conditions and intended future maintenance. Formula C, a crownvetch plus annual ryegrass seed mix, is suited for use on poor soils (e.g., post-construction) and requires little maintenance. This mix is conventionally used on newly-developed sites or to rehabilitate sloped, difficult-to-mow areas. Crownvetch has been established operationally along roadsides for over 50 years but has gained a reputation as a weedy and “invasive” plant. In 2000, the PA Department of Conservation and Natural Resources classified crownvetch as a “situational invasive” in the publication *Invasive Plants in Pennsylvania*. Therefore, alternatives to Formula C are needed; however, new seed mixes must be designed and tested using practical application methods.

Formula N (Table 1) is a proposed alternative to Formula C. Native warm-season grasses provide the permanent component of Formula N, while spring oats and Canada wildrye are the short- and intermediate-term components, respectively. As an annual, the spring oats rapidly establish, providing low-cost cover in the first season after seeding. Canada wildrye, the single cool-season grass species in the mix, typically establishes during the first year, reaches maximum growth during the second or third years, and then dies off. Native warm-season grasses, the permanent component of the mix, are adapted to the poor soils present on many roadsides. Slow establishment is the main drawback to planting these grasses; they generally require three to four seasons to provide satisfactory cover. However, once established, their deep, fibrous root system provides better erosion control than the coarse, sparsely-branched roots of crownvetch. In addition to the grass components, partridge pea is an annual legume which is expected to reseed and provide nitrogen to the groundcover. Finally, black-eyed susan and ox eye sunflower add color to the mix.

Two application methods, hydroseeding and broadcasting, were employed to demonstrate the versatility of Formula N as an alternative seed mix.

MATERIALS AND METHODS

The demonstration was established at two locations, along SR I-80W in Montour Co. and at a stockpile along SR 56 near Homer City, PA. Both sites had a steeply-graded slope with poor, erosion-prone soil. In Montour Co., half of the site was broadcast and the other half hydroseeded with Formula N. In addition to broadcast and hydroseeding application of Formula N, Formula C, at 19 lb/ac crown vetch and 24 lb/ac annual ryegrass, was also hydroseeded in Homer City. Plots were seeded on April 29 and 30, 2008, for the Montour Co. and Homer City sites, respectively. Amendments were applied according to PennDOT Pub 408, section 804 specifications (Table 2). Hydroseeding was performed as a one-step process, in which seed, mulch, and soil amendments were mixed and applied together as a slurry. FlocLoc (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 on September 5 and 8, 2008, respectively. The plots will be evaluated again in 2009.

RESULTS AND DISCUSSION

Both the hydroseeded and broadcast plots in Montour Co. had 20 to 25 percent cover by fine fescue at time of seeding. As of September 5, 2008, the soil amendments appeared to have increased the growth of the existing fine fescue within the plots, which was greener and taller than the grass outside the plot area. Warm-season grasses were very sporadic, with few desirable species noted in either plot. Little bluestem seedlings were present at 6 to 8 inches tall, but no other species were positively identified. Another species, possibly Canada wildrye, had germinated sporadically in the hyrdoseeded plot. Most seedlings were located either at the crest or upper portion of the embankment. A single partridge pea and black eyed susan seedling was present in the broadcast and hydroseeded plot, respectively. Much of the seed in the hydroseeded plot remained trapped in the dried-out mulch layer and had not come in contact with the soil.

Warm-season grasses and forbs had germinated in both the hydroseeded and broadcast plots at Homer City by September 8, 2008. However, the broadcast area had a greater density of desirable seedlings, with close to 1 plant per square foot. Little bluestem was the dominant species identified on the broadcast plot and had established relatively well even in shale. Partridge pea and black eyed susan were also observed. Establishment was generally better on the upper half of the slope, as the lower portion was steep, loose shale. The hydroseeded area, with fewer desirable targets, was relatively densely covered by giant foxtail. No crown vetch had germinated in the plot hydroseeded to Formula C.

CONCLUSIONS

Establishment of grasses and forbs was slow at both sites, despite the seeding method; however, two to three seasons are often necessary for warm-season grasses to establish. Future evaluation will determine the success of Formula N. Unfortunately, much of the seed applied via hydroseeding remained in the mulch layer, where it was more susceptible to drying out. Ideally, the seed should be in direct contact with the soil. The long-term results of this demonstration will help determine whether a two-step hyrdoseeding procedure is necessary for successful establishment of Formula N. In the two-step approach, seed is applied first to allow direct contact with the soil, followed by the mulch in a second application. Since more seedlings were located on the upper portion of the slopes at both sites, tracking may also be crucial for good establishment. Considering the foxtail infestation observed in the hydroseeded area at Homer City, weed control may be necessary, especially when nitrogen fertilizer is applied during seeding.

MANAGEMENT IMPLICATIONS

Longer-term evaluation is necessary before management recommendations can be made regarding the use of Formula N as an alternative seed mix. However, it is apparent that warm-season grasses will require more than one season to establish in typical roadside soils.

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

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

Table 2. Size of areas either hydroseeded on broadcast in square yards (S.Y.) at the Montour Co. and Homer City locations on April 29 and 20, 2008, respectively. Actual amendment rates applied are reported in lb/1000 S.Y. in comparison to recommendations from PennDOT Publication 408 *Specification*s and soil test recommendations for "Roadside Area – to plant, no tillage" from the Penn State Agriculture Analytical Laboratory. Amendments were applied at twice the intended rate in Montour Co.

	Hydroseed	Broadcast	Mulch	Seed	Lime	N	P_2O_5	K_2O
	--------- S.Y.---------		--------------------- lb/1000 S.Y. ------------------------					
Montour Co.	472	472	318	21	900	39	90	50
Homer City	674	674	260	21	450	19	45	25
Pub 408	---	---	320	---	800	33	28	28
Soil test	---	---	---	---	450/900[1]	9	45	18

[1]Soil testing recommendations were 450 and 900 lb lime/1000 S.Y. for the Homer City and Montour Co. sites, respectively.