Roadside Vegetation Management Research – 2022 Report

ANNUAL REPORT

June 30, 2022

By Jeffrey C. Jodon, Elizabeth Egan and James C. Sellmer

THE PENNSYLVANIA STATE UNIVERSITY

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION

Purchase Order No: 4300710617
Purchase Order Description:
Master Agreement # 4400023298

Technical Report Documentation Page

1. Report No. PA-2022-017-PSU RVM 4300710617	**2. Government Accession No.**	**3. Recipient's Catalog No.**	
4. Title and Subtitle Roadside Vegetation Management Research – 2022 Report		**5. Report Date** June 30, 2022	
		6. Performing Organization Code	
7. Author(s) Jeffrey C. Jodon, Elizabeth Egan and James C. Sellmer.		**8. Performing Organization Report No.**	
9. Performing Organization Name and Address The Pennsylvania State University College of Agricultural Sciences University Park, PA 16802		**10. Work Unit No. (TRAIS)**	
		11. Contract or Grant No. Purchase Order No: 4300710617	
12. Sponsoring Agency Name and Address The Pennsylvania Department of Transportation Bureau of Planning and Research Commonwealth Keystone Building 400 North Street, 6th Floor Harrisburg, PA 17120-0064		**13. Type of Report and Period Covered** Annual Report: October 1, 2021 – June 30, 2022	
		14. Sponsoring Agency Code	
15. Supplementary Notes Project Management – Joseph S. Demko – Bureau of Maintenance and Operations, Office of Roadside Development			
16. Abstract This report details a cooperative research project performed for the Pennsylvania Department of Transportation's Bureau of Maintenance and Operations by Penn State. The report includes the following: Evaluation of Brush Herbicides and Mixes on Canopy Reduction of Autumn Olive *(Elaeagnus umbellata*) -3rd Year, Evaluation of TerraVue Applications to Amur Honeysuckle *(Lonicera maackii*) for Canopy Reduction- 2nd Year, Evaluation of Foliar Applications to Shrub Honeysuckle During Flowering for Canopy Reduction- 2nd Year, Evaluation of Foliar Applications to Invasive Callery Pear for Canopy Reduction, Evaluation of PennDOT Formula R, Evaluation of Native Grass and Pollinator Seed Mixes and Seeding Methods for Conversion and Establishment Along Roadsides- 2nd Year, Evaluation of Alternative Bareground Herbicide Mixes			
17. Key Words Roadside vegetation management, herbicides, brush canopy reduction, autumn olive, honeysuckle, TerraVue, Formula R, native grass, bareground		**18. Distribution Statement** No restrictions. This document is available from the National Technical Information Service, Springfield, VA 22161	
19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 55	**22. Price**

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

ACKNOWLEDGMENTS

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

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

We are grateful for the assistance of the representatives of the various manufacturers providing products for the vegetation management industry, who have lent their time, expertise, and material support on many occasions. The following manufacturers assisted this research project during the 2021 season: Bayer Environmental Science, NuFarm, and Corteva Agrisciences.

This work and project are partially supported by the USDA National Institute of Food and Agriculture and Hatch Appropriations under Project #PEN04675 and Accession #1017790.

This work was sponsored by the Pennsylvania Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration. The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration, U.S. Department of Transportation, or the Commonwealth of Pennsylvania at the time of publication. This report does not constitute a standard, specification, or regulation.

TABLE OF CONTENTS

INTRODUCTION

In October 1985, personnel at Penn State began a cooperative research project with the Pennsylvania Department of Transportation (PennDOT) to investigate several aspects of roadside vegetation management. An annual report has been submitted each year that describes the research activities and presents the data. The previous reports are listed below:

Report # PA86-018 + 85-08 - Roadside Vegetation Management Research Report

Report # PA87-021 + 85-08 - Roadside Vegetation Management Research Report - Second Year Report

Report # PA89-005 + 85-08 - Roadside Vegetation Management Research Report - Third Year Report

Report # PA90-4620 + 85-08 - Roadside Vegetation Management Research Report - Fourth Year Report

Report # PA91-4620 + 85-08 - Roadside Vegetation Management Research Report - Fifth Year Report

Report # PA92-4620 + 85-08 - Roadside Vegetation Management Research Report - Sixth Year Report

Report # PA93-4620 + 85-08 - Roadside Vegetation Management Research Report - Seventh Year Report

Report # PA94-4620 + 85-08 - Roadside Vegetation Management Research Report - Eighth Year Report

Report # PA95-4620 + 85-08 - Roadside Vegetation Management Research Report - Ninth Year Report

Report # PA96-4620 + 85-08 - Roadside Vegetation Management Research Report - Tenth Year Report

Report # PA97-4620 + 85-08 - Roadside Vegetation Management Research Report - Eleventh Year Report

Report # PA98-4620 + 85-08 - Roadside Vegetation Management Research Report - Twelfth Year Report

Report # PA99-4620 + 85-08 - Roadside Vegetation Management Research Report - Thirteenth Year Report

Report # PA00-4620 + 85-08 - Roadside Vegetation Management Research Report - Fourteenth Year Report

Report # PA01-4620 + 85-08 - Roadside Vegetation Management Research Report - Fifteenth Year Report

Report # PA02-4620 + 85-08 - Roadside Vegetation Management Research Report - Sixteenth Year Report

Report # PA03-4620 + 85-08 - Roadside Vegetation Management Research Report
-Seventeenth Year Report

Report # PA04-4620 + 85-08 - Roadside Vegetation Management Research Report
-Eighteenth Year Report

Report # PA05-4620 + 85-08 - Roadside Vegetation Management Research Report
-Nineteenth Year Report

Report # PA-2008-003-PSU 005 Roadside Vegetation Management Research Report
-Twenty-second Year Report

Report # PA-4620-08-01 / LTI 2009-23 Roadside Vegetation Management Research Report

-Twenty-third Year Report

Report # PA-2010-005-PSU-016 Roadside Vegetation Management Research Report
-Twenty-fourth Year Report

Report # PA-2011-006-PSU RVM Roadside Vegetation Management Research

– 2011 Report

Report # PA-2012-007-PSU RVM Roadside Vegetation Management Research

– 2012 Report

Report # PA-2013-008-PSU RVM Roadside Vegetation Management Research

– 2013 Report

Report # PA-2014-009-PSU RVM Roadside Vegetation Management Research

– 2014 Report

Report # PA-2015-010-PSU RVM Roadside Vegetation Management Research

– 2015 Report

Report # PA-2016-011-PSU RVM Roadside Vegetation Management Research

– 2016 Report

Report # PA-2017-012-PSU RVM Roadside Vegetation Management Research

– 2017 Report

Report # PA-2018-013-PSU RVM Roadside Vegetation Management Research

– 2018 Report

Report # PA-2019-014-PSU RVM Roadside Vegetation Management Research

– 2019 Report

Report # PA-2020-015-PSU RVM Roadside Vegetation Management Research – 2020 Report

Report # PA-2021-016-PSU RVM Roadside Vegetation Management Research – 2021 Report

These reports are available by request from the authors and are available online in portable document format (PDF) at https://plantscience.psu.edu/research/projects/vegetation-management/annual-reports.

Use of Statistics in This Report

Many of the individual reports in this document make use of statistical analysis, particularly techniques involved in the analysis of variance. The use of these techniques allows for the establishment of criteria for significance. Numbers are said to be significantly different when the differences between them are most likely due to the different treatments, rather than chance. We have relied almost exclusively on the commonly used probability level of 0.05. When a treatment effect is significant at the 0.05 level, this indicates that there is only a five percent chance that the differences are due to chance alone. Once this level of certainty is reached with the analysis of variance, Tukey's HSD separation test is employed to separate the treatments into groups that are significantly different from each other. In many of our results tables, there is/are a letter or series of letters following each number and a notation which states, 'within each column, numbers followed by the same letter are not significantly different at the 0.05 level'. In addition, absence of letters within a column or the notation 'n.s.' indicates that the numbers in that column are not significantly different from each other at the 0.05 level.

This report includes information from studies relating to roadside brush control, herbaceous weed control, plant growth regulators, native species establishment, low maintenance groundcovers, and total vegetation control. Herbicides are referred to as product names for ease of reading. The herbicides used are listed on the following page by product name, active ingredients, formulation, and manufacturer.

Product Information Referenced in This Report

The following details additional information for products referred to in this report. DF = dry flowable, DG = dispersible granules, L = Liquid, EC = emulsifiable concentrate, ME = microencapsulated, RTU = ready to use, S = water soluble, SC = soluble concentrate, SG = soluble granule, SL = soluble liquid, WDG=water-dispersible granules, WE= water emulsion, XP= Extruded Paste.

Trade Name	Active Ingredients	Formulation	Manufacturer
Accord XRT II	glyphosate	5 S	Corteva Agriscience
Arsenal Powerline	imazapyr	2 S	BASF Corp.
Esplanade 200 SC	indaziflam	1.67 SC	Bayer Environmental Science
Esplanade Sure	indazflam + rimsulfuron	24.3 + 16.7 WDG	Bayer Environmental Science
Freelexx	2,4-D choline	3.8 S	Corteva Agriscience
Garlon 3A	triclopyr amine	3 S	Corteva Agriscience
Hyvar X-L	bromacil	2 SL	Bayer Environmental Science
MSM 60	metsulfuron methyl	60 DF	Alligare LLC
Method 240SL	aminocyclopyrachlor	2 SL	Bayer Environmental Science
Milestone VM	aminopyralid	2 S	Corteva Agriscience
Pendulum Aquacap	pendimethalin	3.8 ME	BASF Corp.
Piper	flumioxazin + pyroxasulfone	33.5+42.5 WDG	NuFarm Inc.
Plateau	imazapic	2 S	BASF Corp.
ProClipse	prodiamine	65 WDG	NuFarm Inc.
RoundUp Pro Concentrate	glyphosate	5 S	Monsanto Company
Spyder Extra	sulfometuron + metsulfuron	56.25 + 15 WDG	NuFarm Inc.
SFM Extra	sulfometuron + metsulfuron	56.25 + 15 WDG	Alligare LLC
TerraVue	aminopyralid+florpyrauxifen-benzyl	71 + 6 WDG	Corteva Agriscience
Triplet LO	2,4-D+mecoprop-p+dicamba	2.38+0.63+0.22 S	NuFarm Inc.
Vastlan	triclopyr choline	4 S	Corteva Agriscience
Vanquish	dicamba	4 S	NuFarm Inc.

EVALUATION OF BRUSH HERBICIDES AND MIXES FOR CANOPY REDUCTION OF AUTUMN OLIVE *(ELAEAGNUS UMBELLATA)*-3rd YEAR

Herbicide trade and common names: Freelexx (2,4-D choline); Method 240SL (*aminocyclopyrachlor*); MSM 60 (*metsulfuron methyl*); Garlon 3A (*triclopyr amine*); Vanquish (*dicamba*)

Plant common and scientific name: autumn olive (*Elaeagnus umbellata*)

ABSTRACT

Autumn olive is an invasive plant in Pennsylvania and has proven to be difficult to control through mowing and cutting activities without the use of herbicides. An experiment was conducted at the Penn State Russell E. Larson Agricultural Research Center, Agronomy Farm near Rock Springs, PA to compare commonly used brush herbicides for canopy reduction of autumn olive. In a continuing effort to develop effective brush herbicide mixes, this experiment evaluated ten herbicide treatments including Freelexx at rates of 96 oz/ac and 128 oz/ac, Freelexx at 96 oz/ac tank mixed with Method 240SL at 16 oz/ac and MSM 60 at 0.5 oz/ac, Freelexx at 96 oz/ac tank mixed with Garlon 3A at 64 oz/ac and MSM 60 at 0.5 oz/ac, Method 240SL at 16 oz/ac, MSM 60 at 0.5 oz/ac, Garlon 3A at rates of 64 oz/ac, 128 oz/ac, and 384 oz/ac, and Vanquish at 64 oz/ac. By 14 days after treatment (DAT), Freelexx at 96 oz/ac, Freelexx at 96 oz/ac tank mixed with Method 240SL at 16 oz/ac and MSM 60 at 0.5 oz/ac, and Garlon 3A at 64 oz/ac provided a minimum of 99% injury of autumn olive. At 229 DAT, treatments of MSM 60 at 0.5 oz/ac resulted in the highest canopy reduction of autumn olive at 100% while Vanquish at 64 oz/ac resulted in 99.7% canopy reduction, Freelexx at 96 oz/ac + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac resulted in 97.22% canopy reduction, Method 240SL at 16 oz/ac resulted in 96.9% canopy reduction, Freelexx at 96 oz/ac resulted in 91.7% canopy reduction, and Garlon 3A at 384 oz/ac resulted in 91.3% canopy reduction. However, by 370 DAT, MSM 60 at 0.5 oz/ac reduced canopy size by 100% while Method 240SL at 16 oz/ac did by 97.5%. The last rating occurred on September 15, 2021, 728 DAT. MSM 60 at 0.5 oz/ac reduced canopy size by 100% while Method 240SL at 16 oz/ac reduced canopy size by 95.71%. All other herbicide treatments showed lower percent canopy reduction of autumn olive when compared to data collected 229 DAT and 370 DAT indicating regrowth of autumn olive.

INTRODUCTION

Autumn olive (*Elaeagnus umbellata*) is a spreading and colonizing invasive shrub found along roadsides in Pennsylvania. Introduced to the United States from East Asia in 1830 autumn olive was planted extensively in Pennsylvania and other states to revegetate severely disturbed sites such as stripe mines[1]. *Elaeagnus umbellata* is a small tree or multi-stem shrub, capable of fixing nitrogen, which aids its establishment and growth in poor soil conditions found along the

[1] Ann F Rhoads and Timothy A Block. Morris Arboretum of the University of Pennsylvania 2011. Autumn Olive and Russian Olive. http://paflora.org/original/pdf/INV-Fact%20Sheets/Elaeagnus%20spp.pdf

roadside[2]. Plants can grow 20 feet in height and spread 30 feet wide[3]. Autumn olive matures quickly and can produce fruit in as little as three years. This shrub will fruit prolifically with birds dispersing the seeds[1]. After mowing or cutting autumn olive vigorously resprouts, crowding out desirable vegetation, and reducing visibility for motorists and impeding maintenance operations. In order to effectively manage autumn olive, the root system must be controlled. This experiment evaluated the effectiveness of Freelexx, Method 240SL, MSM 60, Garlon 3A, Vanquish, a mix of Freelexx plus Method 240SL and MSM 60, and a mix of Freelexx plus Garlon 3A and MSM 60 applied to the entire autumn olive shrub.

MATERIALS AND METHODS

The experiment was established at the Penn State Russell E. Larson Agricultural Research Center, Agronomy Farm in Rock Springs, PA. The herbicide treatments included Freelexx at 96 oz/ac and 128 oz/ac; Freelexx at 96 oz/ac + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac; Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac; Method 240SL at 16 oz/ac; MSM 60 at 0.5 oz/ac; Garlon 3A at 64 oz/ac, 128 oz/ac, and 384 oz/ac; Vanquish at 64 oz/ac; and an untreated check. Methylated seed oil at 1% v/v was added to all herbicide treatments. The experiment was established as a complete randomized design with ten plants per treatment. Individual shrubs were measured, the average width was multiplied by the height which was then multiplied by 2 to determine the entire canopy area of each plant. The dose of the herbicide application to individual plants was based on the calculated canopy area. By the last rating, several treatments had missing plants for various reasons, however, trees falling on autumn olive was the main reason. Final replication numbers per treatment ranged from 7 to 10. After each treatment the final number of replicates for that treatment are in parentheses: untreated (9); Freelexx at 96 oz/ac + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac (9); Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac (9); Method 240SL at 16 oz/ac (7); Garlon 3A at 64 oz/ac (9); Garlon 3A at 128 oz/ac (8); Garlon 3A at 384 oz/ac (9); Freelexx at 96 oz/ac (10); Freelexx at 128 oz/ac (8); Vanquish at 64 oz/ac (8); and MSM 60 at 0.5 oz/ac (10). A complete table can be found in the appendix at the end of this report (Appendix Table 1). At application, the sky was mostly sunny with some cloud coverage and air speed of 0-5 mph, temperature 70° F, with 50% relative humidity. Treatments were applied using a CO_2-powered backpack sprayer equipped with a handgun and one PPX 6 nozzle. The application was made at a carrier volume of 35 gallons per acre (GPA) and a pressure of 35 pounds per square inch (psi). The autumn olive was treated on September 19, 2019.

Treatments were visually rated for percent injury where 0 = no injury–100 = complete injury on October 3, 2019, 14 days after treatment (DAT) and for percent canopy reduction where 0 = no canopy reduction–100 = complete canopy reduction on May 5, 2020, 229 DAT; September 22, 2020, 370 DAT and September 15, 2021, 728 DAT. All data were subject to analysis of variance and when treatment F-tests were significant ($p \leq 0.05$), treatment means were compared using Tukey's HSD separation test.

[2] Jeffrey C Jodon et al 2018. Comparison of Aminocyclopyrachlor, Aminopyralid, and Two Formulations of Triclopyr for Control of Autumn Olive *(Elaeagnus umbellata)* Using Low Volume Foliar Treatments. Roadside Vegetation Management Research – 2018 Report. pp 1-5.
[3] Autumn Olive. https://extension.psu.edu/autumn-olive

RESULTS AND DISCUSSION

Percent injury was rated on October 3, 2019, 14 DAT. Usually, injury ratings are conducted 1 month after treatment. However, to avoid rating after a killing frost, injury ratings were conducted 14 DAT, before the frost event. By 14 DAT, MSM 60 at 0.5 oz/ac showed less injury (4%) than untreated plants (6.5%) and were not statistically different (Table 1). Freelexx at 128 oz/ac, Method 240SL at 16 oz/ac and Garlon 3A at 128 oz/ac resulted in injury ratings of 80.6%, 81.4%, and 89.2%, respectively. Vanquish at 64 oz/ac, Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac, and Garlon 3A at 384 oz/ac showed injury ratings of 96.4%, 96.8%, and 97.3%, respectively. Freelexx at 96 oz/ac, Freelexx at 96 + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac, and Garlon 3A at 64 oz/ac resulted in 99.2%, 99.6%, and 99.7% injury, respectively.

By 229 DAT, MSM 60 at 0.5 oz/ac resulted in 100% canopy reduction followed by Vanquish at 64 oz/ac resulted in 99.7% canopy reduction and Method 240SL at 16 oz/ac resulted in 96.9% canopy reduction. Freelexx at 96 oz/ac showed greater canopy reduction (91.7%) than Freelexx at 128 oz/ac (71.11%). The treatment effects of two commonly used brush mixes of Freelexx at 96 oz/ac tank + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac showed 97.22% canopy reduction and Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac showed 82.8% canopy reduction. Garlon 3A at increasing rates of 64 oz/ac, 128 oz/ac, and 384 oz/ac, ranged from 82.89%-91.3% and showed mixed results. Canopy reduction only slightly increased as rates of Garlon 3A increased from 64 oz/ac to 384 oz/ac. However, results showed that Garlon 3A at 128 oz/ac had less canopy reduction than Garlon 3A at 64 oz/ac.

On September 22, 2020, 370 DAT, MSM 60 at 0.5 oz/ac continued to show the highest autumn olive canopy reduction at 100%. When compared to the May rating, Method 240SL at 16 oz/ac increased percent canopy reduction from 96.9 to 97.22. All other treatments showed less canopy reduction than the rating in May indicating the ability of autumn olive to grow despite the herbicide treatments. Commonly used brush tank mixes of Freelexx at 96 oz/ac + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac showed 83.33% canopy reduction and Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac showed 46.5% canopy reduction. One observation while evaluating percent canopy reduction was herbicide mixes typically showed less canopy reduction compared to the individual herbicide applied alone. For example, herbicides applied alone such as MSM 60 at 0.5 oz/ac resulted in 100% canopy reduction, Method 240SL at 16 oz/ac resulted in 97.22% canopy reduction, Freelexx at 96 oz/ac resulted in 59.5% canopy reduction and Garlon 3A at 64 oz/ac resulted in 70.5% canopy reduction. In comparing the mix Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac (46.5% canopy reduction) to the same herbicides and rates applied individually, those applied alone had greater canopy reduction. However, one exception to the trend of individual herbicides outperforming mixes was Freelexx at 96 oz/ac (59.5% reduction) was less than the mix Freelexx at 96 oz/ac + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac (83.33%).

The experiment concluded on September 15, 2021, with the 728 DAT rating. MSM 60 at 0.5 oz/ac resulted in 100% canopy reduction which was the same at 370 DAT and the only treatment in the experiment to show complete control of autumn olive. Canopy reduction of the untreated

control plants increased to 15.22%. This may be due to several reasons including pests, pathogens or other factors influencing autumn olive growth, though no pattern was observed. In comparing the remaining treatments at the 370 DAT rating, all treatments showed a decrease in canopy reduction. In other words, the canopy increased indicating growth from dormant buds, basal resprouts or other parts of the plant unaffected by the treatments. Based on canopy reduction, the following treatments were statistically similar to MSM 60 at 5 oz/ac: Method 240SL at 16 oz/ac (95.71%), Vanquish at 64 oz/ac (83.13%), Freelexx at 96 oz/ac + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac (66.67%), and Garlon 3A AT 384 oz/ac (62.22%). The following treatments were statistically similar to the untreated control include: Freelexx at 128 oz/ac (33.13%), Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac (37.78%), Freelexx at 96 oz/ac (39.50%), Garlon 3A at 128 oz/ac (45.75%), and Garlon 3A at 64 oz/ac (50%). Interestingly, 2,4-D, aminocyclopyrachlor, triclopyr, and dicamba are Weed Science Society of America (WSSA) group 4 herbicides, whereas metsulfuron methyl is a WSSA group 2 herbicide.

CONCLUSIONS

By October 3, 2019, 14 DAT, percent injury of the herbicide treatments ranged from 4% to 99.7%. All of the herbicide treatments, except for MSM 60 (4% injury), had similar levels of injury as a result of herbicide treatments. While Garlon 3A at 64 oz/ac (99.7%) resulted in the highest rate of injury, by 229 days after treatment, MSM 60 at 0.5 oz/ac had the highest canopy reduction of autumn olive at 100% followed by Vanquish at 99.7%. The least effective treatment was Freelexx at 128 oz/ac with 71.11% canopy reduction. With the exception of MSM 60, all remaining treatments showed signs of resprouting from dormant buds or roots at 229 days after treatment. This trend continued while rating one and two years after treatment. MSM 60 at 0.5 oz/ac showed the highest percent canopy reduction at 100% and Method 240SL at 16 oz/ac showed 95.71 percent canopy reduction. Increasing the rate of Garlon 3A from 64 oz/ac to 128 oz/ac did not increase canopy reduction, however, increasing the rate of Garlon 3A to 384 oz/ac did increase canopy reduction. Similarly, increasing the rate of Freelexx from 96 oz/ac to 128 oz/ac did not increase canopy reduction. Herbicide mixes containing MSM 60 resulted in less canopy reduction of autumn olive than MSM 60 applied alone. Future research should continue to evaluate metsulfuron-methyl products efficacy at reduced rates. Additionally, alternative brush mixes should be evaluated to determine effectiveness on multiple problematic roadside species.

MANAGEMENT IMPLICATIONS

By 229 DAT and continuing two years after treatment MSM 60 showed 100% canopy reduction, while the other herbicide treatments showed resprouts from dormant buds. Method 240SL at 16 oz/ac reduced canopy by 95% requiring retreatment. This experiment demonstrated that herbicide mixes containing metsulfuron-methyl was not as effective as metsulfuron-methyl applied alone. If autumn olive is the target, consider applications of metsulfuron-methyl at 0.5 oz/ac. MSM 60 or products containing metsulfuron-methyl and Method 240SL or products containing aminocyclopyrachlor should be used with caution. Previous work by the roadside project recommended rates of metsulfuron-methyl not to exceed 0.5 oz/ac to minimize damage to

understory grass[4]. The Method 240SL label cautions that exceeding rates of 8 oz/ac may result in unacceptable injury to desirable turfgrasses, the addition of MSO adjuvant may increase the potential for turfgrass injury, and potential to injure desirable trees and plants when their root system extend into treated areas[5]. Since PennDOT relies on brush mixes to treat roadsides, consideration should be given to individual species and effective treatments where feasible.

Table 1. Percent injury and canopy reduction of autumn olive (*Elaeagnus umbellata*). The experiment was visually rated for percent injury where 0 = no injury –100 = complete injury on October 3, 2019, 14 days after treatment (DAT), and percent canopy reduction where 0 = no canopy reduction –100 = complete canopy reduction on May 5, September 22, 2020, and September 15, 2021, 229, 370 and 728 DAT, respectively. Treatments were applied September 19, 2019. All treatments included methylated seed oil at 1% v/v. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/ac	% Injury 10/03/19 14 DAT	% Canopy Reduction 05/05/20 229 DAT	% Canopy Reduction 09/22/20 370 DAT	% Canopy Reduction 09/15/21 728 DAT
Untreated	--	6.5 a	11 a	9.67 a	15.22 a
Freelexx Method 240 SL MSM 60	96 16 0.5	99.6 b	97.22 b	83.33 cd	66.67 bcd
Freelexx Garlon 3A MSM 60	96 64 0.5	96.8 b	82.8 b	46.5 b	37.78 ab
Method 240 SL	16	81.4 b	96.9 b	97.22 d	95.71 d
Garlon 3A	64	99.7 b	87.4 b	70.5 bcd	50 abc
Garlon 3A	128	89.2 b	82.89 b	61.67 bc	45.75 abc
Garlon 3A	384	97.3 b	91.3 b	71 bcd	62.22 bcd
Freelexx	96	99.2 b	91.7 b	59.5 bc	39.50 ab
Freelexx	128	80.6 b	71.11 b	47.78 b	33.13 ab
Vanquish	64	96.4 b	99.7 b	85.5 cd	83.13 cd
MSM 60	0.5	4 a	100 b	100 d	100 d

[4] Jon M Johnson et al 2014. Examining Potential Turf Phytotoxicity Caused by Escort XP, Krenite S and MAT 28. Roadside Vegetation Management Research – 2014 Report. pp 23-26.
[5] Bayer CropScience LP. Method 240SL label. http://www.cdms.net/ldat/ldCFU015.pdf Internet November 23, 2020

EVALUATION OF TERRAVUE APPLICATIONS TO AMUR HONEYSUCKLE (*Lonicera maackii*) FOR CANOPY REDUCTION- 2nd YEAR

Herbicide trade and common names: TerraVue (*aminopyralid + florpyrauxifen*), Freelexx (*2,4-D choline*), MSM 60 (*metsulfuron-methyl*), Vastlan (*triclopyr choline*)

Plant common and scientific names: Amur honeysuckle (*Lonicera maackii)*

ABSTRACT

Amur honeysuckle is an invasive plant along the roadsides of Pennsylvania that has proven difficult to control. An experiment was conducted at the Penn State Russell E. Larson Agricultural Research Center, Agronomy Farm near Rock Springs, PA to evaluate the efficacy of TerraVue alone and tank mixes containing TerraVue. The herbicide treatments included TerraVue at 2.85 oz/ac, TerraVue at 2.85 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac, TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac, and an untreated check. By 23 days after treatment, TerraVue at 2.85 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac resulted in 99.6% injury and TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac resulted in 95.6% injury. TerraVue at 2.85 oz/ac produced 67% injury while the untreated check had 1% injury to honeysuckle. By one year after treatment, TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac resulted 85.5% canopy reduction, TerraVue at 2.85 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac resulted in 79% canopy reduction, and TerraVue at 2.85 oz/ac resulted in 35.5% canopy reduction. No herbicide treatment showed 100% canopy reduction of amur honeysuckle.

INTRODUCTION

Invasive shrub honeysuckle species continue to spread along Pennsylvania roadsides and remain difficult to control. Native to Europe, Asia, and Japan, exotic honeysuckle species were introduced in the 1800's as ornamentals and planted as a food and cover crop for wildlife even though native plants are higher in nutritional value than the exotic honeysuckle[6]. Amur honeysuckle can reach heights of 15 feet tall and has a white to yellow flower with a shorter peduncle. A competitive advantage of honeysuckle is its ability to leaf out early in the spring before other plants and hold onto leaves until later in the fall. TerraVue is a relatively new product on the market. TerraVue is a combination product containing aminopyralid and florpyrauxifen. This experiment was designed to determine the efficacy of TerraVue applied alone and in combination with two standard brush herbicide mixes for canopy reduction of amur honeysuckle.

MATERIALS AND METHODS

The experiment was established at the Penn State Russell E. Larson Agricultural Research Center, Agronomy Farm in Rock Springs, PA. The herbicide treatments included TerraVue at 2.85 oz/ac, TerraVue at 2.85 oz/ac + Freelexx at 64 oz/ac + MSM 60 at 0.5 oz/ac,

[6] http://elibrary.dcnr.pa.gov/GetDocument?docId=1738689&DocName=shrub_honeysuckles.pdf. Shrub Honeysuckles. Viewed November 5, 2021.

TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac, and an untreated check. Induce, a non-ionic surfactant, at 0.25% v/v was added to all herbicide treatments. The experiment was established as a complete randomized design with ten plants per treatment. Each shrub was identified on September 4, 2020. Individual shrubs were measured, the average width was multiplied by the height which was then multiplied by 2 to determine the entire canopy area of each plant. The dose of the herbicide application to individual plants was based on the calculated canopy area (Appendix Table 2). At application the sky was clear and sunny with wind speeds of 5-10 mph, air temperature of 75° and 75% relative humidity. Treatments were applied using a CO_2-powered backpack sprayer equipped with a 30 GunJet spray gun and one PPX 6 adjustable nozzle at 35 pounds per square inch (PSI). The application was made at a carrier volume of 35 gallons per acre (GPA). Treatments were applied on September 9, 2020.

Treatments were visually rated for percent injury 0 = no injury–100 = complete injury on October 2, 2020, 23 days after treatment (DAT) and for percent canopy reduction where 0 = no canopy reduction–100 = complete canopy reduction on September 8, 2021, 364 DAT. All data were subjected to analysis of variance, and when treatment effect F-tests were significant ($p \leq 0.05$), treatment means were compared using Tukey's HSD separation test.

RESULTS AND DISCUSSION

By 23 DAT, TerraVue at 2.85 oz/ac tank mixed with Freelexx at 64 oz/ac and MSM 60 at 0.5 oz/ac resulted with the highest injury rating of 99.6%. Similar results occurred with TerraVue at 2.85 oz/ac tank mixed with Freelexx at 64 oz/ac and Vastlan at 64 oz/ac resulting in an injury rate of 95.6%. Single treatment of TerraVue at 2.8 oz/ac produced a significantly lower injury rating of 67.4%. On September 8, 2021, 364 DAT, percent canopy reduction ranged from 3.7% for the untreated check to 85.5 % for TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac treatment. TerraVue at 2.85 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac resulted in 79% canopy reduction and Terra Vue at 2.85 oz/ac showed only 35.5% canopy reduction.

CONCLUSIONS

All herbicide treatments resulted in various rates of injury to the amur honeysuckle. TerraVue at 2.85 oz/ac should not be considered as a treatment on amur honeysuckle. Further data collection, 2 years after treatment, will determine if tank mixes of TerraVue 2.85 oz/ac + Vastlan 64 oz/ac + Freelexx 64 oz/ac or TerraVue 2.85 oz/ac + Freelexx 96 oz/ac + MSM 60 0.5 oz/ac can provide 100% canopy reduction of amur honeysuckle or if the honeysuckle continues to grow. No treatment resulted in 100% canopy reduction.

MANAGEMENT IMPLICATIONS

The mixes of TerraVue 2.85 oz/ac + Vastlan 64 oz/ac + Freelexx 64 oz/ac and TerraVue 2.85 oz/ac + Freelexx 96 oz/ac + MSM 60 0.5 oz/ac should be monitored to determine if 100% canopy reduction is achieved 2 years after treatment or if the honeysuckle continues to grow, ultimately requiring a follow up treatment. At that time, future recommendations will be made regarding the treatments evaluated in this experiment.

Table 1. Percent injury and canopy reduction of amur honeysuckle (*Lonicera maackii)*. The experiment was visually rated for percent injury where 0 = no injury - 100 = complete injury on October 2, 2020, 32 days after treatment (DAT) and canopy reduction where 0 = no canopy reduction – 100 = complete canopy reduction on September 8, 2021, 364 DAT. Herbicides were applied on September 9, 2020. All treatments included Induce, a non-ionic surfactant at 0.25% v/v. Each value is the mean of ten replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Product	Rate oz/ac	% Injury 10/2/20 23 DAT	% Canopy Reduction 9/8/21 364 DAT
untreated	--	1 a	3.7 a
TerraVue	2.85	67.4 b	35.5 b
TerraVue Freelexx MSM 60	2.85 96 0.5	99.6 c	79 c
TerraVue Vastlan Freelexx	2.85 64 64	95.6 c	85.5 c

EVALUATION OF FOLIAR APPLICATIONS TO SHRUB HONEYSUCKLE DURING FLOWERING FOR CANOPY REDUCTION-2nd YEAR

Herbicide trade and common names: Freelexx (*2, 4-D choline*), Method 240SL (*aminocyclopyrachlor*), MSM 60 (*metsulfuron-methyl*), Garlon 3A (*triclopyr amine*), Vanquish (*dicamba*), RoundUp Pro Concentrate (g*lysophate*), TerraVue (*aminopyralid + florpyrauxifen*), Vastlan (*triclopyr choline*)

Plant common and scientific names: Morrow's honeysuckle *(Lonicera morrowii*), Amur honeysuckle (*Lonicera maackii),* and Tatarian honeysuckle *(Lonicera tatarica)*

ABSTRACT

Shrub honeysuckle continues to be a problematic plant to control along roadsides of Pennsylvania. An experiment was established at the Penn State Russell E. Larson Agricultural Research Center, Horticulture Farm near Rock Springs, PA to evaluate the efficacy of brush herbicide applications during the flowering stage of exotic shrub honeysuckle. The herbicide treatments included Freelexx at 96 oz/ac + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac; Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac; Freelexx at 96 oz/ac + TerraVue at 2.85 oz/ac + MSM 60 at 0.5 oz/ac; Garlon 3A at 64 oz/ac + Freelexx at 128 oz/ac; Garlon 3A at 128 oz/ac; Vanquish at 64 oz/ac; RoundUp Pro Concentrate at 104 oz/ac; TerraVue at 2.85 oz/ac, Freelexx at 128 oz/ac; MSM 60 at 0.5 oz/ac; Initial and Post Rain TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac; and an untreated check. Treatments 2-10 were applied on June 4, 2020. A heavy rainstorm developed about 20-30 minutes after treatment 10 was sprayed, so no further treatments were applied. The following day, June 5, 2020, treatments 11 and 12 were applied. Since a rainstorm developed on June 4 shortly after the application of treatment 10, potentially compromising the treatment due to the herbicide being washed off the leaf surface by the rainstorm this treatment (Initial, TerraVue at 2.85 oz/ac + Freelexx 64 oz/ac + Vastlan 64 oz/ac), was re-applied to additional honeysuckle plants on June 8, 2020. Treatment 13 (Post Rain, TerraVue 2.85 oz/ac + Freelexx 64 oz/ac + Vastlan 64 oz/ac) identifies this as an alternative to treatment 10. By 63 days after treatment (DAT), Freelexx at 128 oz/ac, TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac, and Freelexx at 96 oz/ac + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac provided a minimum of 99% injury to shrub honeysuckle. At 377 DAT, Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac resulted in 97% canopy reduction while Alternate TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac provided 96.4% canopy reduction. Additional treatments with at least 91% canopy reduction were Freelexx at 96 oz/ac + TerraVue at 2.85 oz/ac + MSM at 0.5 oz/ac and Garlon 3A at 64 oz/ac + Freelexx at 128 oz/ac. No treatment resulted in 100% canopy reduction.

INTRODUCTION

The introduction and use of shrub honeysuckle as an ornamental planting and the continuous spread of the plant's seed has made non-native honeysuckles extremely difficult to control in Pennsylvania. Native and non-native honeysuckle can be easily differentiated by the

stem pith, native species have a solid pith and non-native species have a hollow pith. Like the native species, the exotic shrub honeysuckle species produces seeds which are viable for years. The seeds are readily distributed by foraging birds which has created an ongoing need for control of exotic shrub honeysuckle[7].

Each shrub was identified on May 26, 2020. Two characteristics that were used to identify the different species of shrub honeysuckle are the length of the flower peduncles compared to the leaf petioles and the flower color. The three most common non-native honeysuckle species include morrow's honeysuckle, amur honeysuckle, and tatarian honeysuckle[8]. Amur honeysuckle has a white to yellow flower with a shorter peduncle, morrow's honeysuckle has a creamy-white to yellow flower with a longer peduncle, and tatarian honeysuckle has a pink to white flower with a longer peduncle[9]. Within the experimental area, only two shrubs of morrow's honeysuckle were identified, with the remaining identified as amur honeysuckle.

This experiment was designed to determine the efficacy of several herbicide treatments applied during the flowering period. A Missouri field crop study focusing on control of perennial broadleaf weeds showed that effective control can be achieved before and during flower bud initiation when food supplies are being transported down to the root system along with any penetrating herbicide[10]. Another study examining the effect of application timing on morrow's honeysuckle showed that control can be successful when the application coincides with a plant's flowering stage. The levels of total nonstructural carbohydrates (TNC) that are stored in the roots, fluctuate during different phenological stages of a plant, lowering the levels and nearly exhausting the plant during flowering[11]. This experiment was designed to utilize the low levels of TNC during flowering to allow for maximum efficacy of the herbicides.

MATERIALS AND METHODS

The experiment was established at the Penn State Russell E. Larson Agricultural Research Center, Horticulture Farm in Rock Springs, PA. The herbicide treatments included Freelexx at 96 oz/ac + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac; Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac; Freelexx at 96 oz/ac + TerraVue at 2.85 oz/ac + MSM 60 at 0.5 oz/ac; Garlon 3A at 64 oz/ac + Freelexx at 128 oz/ac; Garlon 3A at 128 oz/ac; Vanquish at 64 oz/ac; RoundUp Pro Concentrate at 104 oz/ac; TerraVue at 2.85 oz/ac; Freelexx

---

[7] Jeffrey C Jodon et. al. 2021. Evaluation of brush control herbicides on control of exotic shrub honeysuckle-3rd year. Roadside Vegetation Management Research 2021 Report. pp 1-4.

[8] Gover, Art, Johnson, Jon, and Kuhns, Larry. Noxious and Troublesome Roadside Weeds. Herbicide Applicator Training Module 4. Penn State Vegetation Management

[9] Olson, Cassandra and Cholewa, Anita F. Table comparing nonnative shrubby Lonicera spp. A guide to Non-native Invasive Plants Inventoried in the North by Forest Inventory and Analysis. NRS Publications and Data. Viewed June 2020. https://www.nrs.fs.fed.us/pubs/34183

[10] DeFelica, Michael S. and Sims, Barry D. Control of perennial broadleaf weeds in Missouri field crops. Agricultural Guide. Published by the University Missouri-Columbia Extension Division. Department of Agronomy College of Agriculture. Viewed April 29, 2021

[11] Love, Jason P. and Anderson, James T. Seasonal Effects of Four Control Methods on the Invasive Morrow's Honeysuckle (Lonicera morrowii) and Initial Responses of Understory Plants in a Southwestern Pennsylvania Old Field. Restoration Ecology Research Article. The Journal of the Society of Ecological Restoration International. Viewed April 29, 2021

at 128 oz/ac; MSM 60 at 0.5 oz/ac; TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac; and an untreated check. Methylated seed oil at 1% v/v was added to all herbicide treatments. The experiment was established as a complete randomized design with ten plants per treatment. Individual shrubs were measured, the average width was multiplied by the height, then multiplied by 2 to determine entire canopy area. The dose of herbicide application to individual plants was based on the calculated canopy area. A complete table can be found in the appendix at the end of this report (Appendix Table 3). The application was made at a carrier volume of 35 gallons per acre (GPA). All treatments were applied using a CO_2-powered backpack sprayer equipped with a 30 GunJet spray gun and one PPX 6 adjustable nozzle at 32 pounds per square inch (PSI).

Treatments 2-10 were applied on June 4, 2020. The weather at the time of application was sunny to partly cloudy skies, air temperature of 76°F, 65% relative humidity with wind speeds of 5-10 mph. Due to a heavy rainstorm that developed in the area approximately 20-30 minutes after treatment 10 was sprayed, no further treatments were applied that day. The following day, June 5, 2020, treatments 11 and 12 were applied. The weather at the time of application consisted of sunny skies, wind speeds of 5-10 mph, air temperature of 72° F, and 71% relative humidity. Since a rainstorm developed shortly after the application of treatment 10, potentially compromising the treatment due to the herbicide being washed off the leaf surface by the rainstorm this treatment (Initial TerraVue at 2.85 oz/ac + Freelexx 64 oz/ac + Vastlan 64 oz/ac), was re-applied to additional honeysuckle plants on June 8, 2020. Treatment 13 (Post Rain, TerraVue 2.85 oz/ac + Freelexx 64 oz/ac + Vastlan 64 oz/ac) identifies this as an alternative to treatment 10. In Appendix Table 2, plant A1 through A10 represents the honeysuckle treated. The weather at the time of the application on June 8, 2020, consisted of sunny skies, wind speeds of 5-10 mph, air temperature of 72° F, and 43% relative humidity.

Treatments were visually rated for percent injury 0 = no injury – 100 = complete injury on July 6, & August 6, 2020, 32 days after treatment (DAT) and 63 DAT, respectively, and canopy reduction on June 14, 2021, 377 DAT. To simplify the presentation of Table 1, the application date of June 4 will be used for all treatments to calculate days after treatment (DAT). All data were subjected to analysis of variance, and when treatment effect F-tests were significant ($p \leq 0.05$), treatment means were compared using Tukey's HSD separation test.

RESULTS AND DISCUSSION

Initial injury of the herbicide treatments ranged from 26 to 98.2% on July 6, 2020, 32 DAT, while the untreated check showed 1.1% (Table 1). By 63 DAT, percent injury increased for all herbicide treatments, except MSM 60 at 0.5 oz/ac. Freelexx at 128 oz/ac, Post Rain TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac, and Freelexx at 96 oz/ac + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac showed 99% injury. The following treatments resulted in over 90% injury: Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac (97.5%), Garlon 3A at 64 oz/ac + Freelexx at 128 oz/ac (95.5%), Freelexx at 96 oz/ac + TerraVue at 2.85 oz/ac + MSM 60 at 0.5 oz/ac (95%), and Garlon 3A at 128 oz/ac (92.5%). Vanquish at 64 oz/ac (72%), MSM 60 at 0.5 oz/ac (56.9%), TerraVue at 2.85 oz/ac (48%), and RoundUp Pro Concentrate at 104 oz/ac (40%), produced less percent injury. The untreated check showed 1 percent injury.

By 377 DAT, canopy reduction ranged from 0.6% for the untreated check to 97% for the Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac treatment. Other treatments with at least 90% canopy reduction included Post Rain TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac (96.4%), Freelexx at 96 oz/ac +TerraVue at 2.85 oz/ac + MSM 60 at 0.5 oz/ac (91.5%) and Garlon 3A at 64 oz/ac + Freelexx at 128 oz/ac (91%). The percent canopy reduction for the remaining treatments were Garlon 3A at 128 oz/ac (89.5%), Freelexx at 128 oz/ac (87.9%), RoundUp Pro Concentrate at 104 oz/ac (71.7%), Initial TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac (69.5%), Vanquish at 64 oz/ac (62%), MSM 60 at 0.5 oz/ac (44.5%), and TerraVue at 2.85 oz/ac (38%).

All treatments that resulted in over 90% canopy reduction, were herbicide mixes and all contained Freelexx at various rates ranging from 64 oz/ac to 128 oz/ac. Interestingly, the individual components of the mixes, when applied alone, showed less canopy reduction compared to the herbicide mixes: Freelexx at 128 oz/ac (87.9%), Garlon 3A at 128 oz/ac (89.5%), MSM 60 at 0.5 oz/ac (44.5%) and TerraVue at 2.85 oz/ac (38%).

On June 4th the treatments were applied in order 2 through 10 (Table 1). Possibly three treatments may have been impacted by the rainstorm: Initial TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx 64 oz/ac (treatment 10), TerraVue at 2.85 oz/ac (treatment 9) and RoundUp Pro Concentrate at104 oz/ac (treatment 8).

In comparing the Initial and Post Rain TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx 64 oz/ac treatments, it appears the rainstorm impacted the Initial TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx 64 oz/ac treatment. Percent injury of honeysuckle was 30% lower for the Initial TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx 64 oz/ac treatment compared to the Post Rain TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx 64 oz/ac treatment. This trend continued one year after treatment. Percent canopy reduction of the Post Rain TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx 64 oz/ac treatment was 96.4% where the Initial TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx 64 oz/ac treatment was 69.5%. It appears from the data presented that the Initial TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx 64 oz/ac treatment was not rain-safe 30 minutes after application.

TerraVue at 2.85 oz/ac showed similar percent canopy reductions when comparing this experiment to work done concurrently by the project[12]. In comparing, canopy reduction one year after treatment for the current experiment TerraVue at 2.85 oz/ac resulted in 38% canopy reduction whereas the experiment evaluating TerraVue and mixes on Amur honeysuckle showed TerraVue at 2.85 oz/ac resulted in 35.5% canopy reduction. TerraVue at 2.85 oz/ac (treatment 9) based on field notes was applied about 1-1.5 hours before the rainstorm.

Previous work by the roadside project (Jodon et.al. 2021) showed higher percent injury and percent canopy reduction of honeysuckle with RoundUp Pro at 128 oz/ac, which was an equivalent rate to the amount of glyphosate used in the current experiment. Uncertainty remains if the rainstorm impacted the RoundUp Concentrate at 104 oz/ac treatment or if this is the effect of difference in the seasonal timing of application between the two experiments. Based on field

[12] Jeffrey C Jodon et. al. 2022. Evaluation of TerraVue Applications to Amur Honeysuckle for Canopy Reduction 2nd year. Roadside Vegetation Management Research 2022 Report. pp 6-8.

notes, the RoundUp Pro Concentrate treatment was completed approximately 2-2.5 hours before the rainstorm.

CONCLUSIONS

At 377 DAT, Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac was most effective at 97% canopy reduction while Post Rain TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac was similar in overall canopy reduction at 96.4%. Additional treatments that were statistically similar but on average less effective in percentage canopy reduction included Freelexx at 96 oz/ac + TerraVue at 2.85 oz/ac + MSM at 0.5 oz/ac and Garlon 3A at 64 oz/ac + Freelexx at 128 oz/ac. It appears that TerraVue at 2.85 oz/ac and MSM 60 at 0.5 oz/ac are both treatments that should not be consider for use due to poor performance to date. We have noticed in comparing these results to other woody invasive species canopy reduction experiments (e.g., autumn olive) that here the herbicide mixes proved more effective, whereas with other species the components alone were more effective in long-term canopy reduction[13,14]. We have not determined where or why an antagonism is occurring in other species with mixes, but not with non-native honeysuckle experiments. Further data collection and analysis, two years after treatment, will determine canopy reduction and future recommendations.

MANAGEMENT IMPLICATIONS

One year after treatment, no herbicide treatments resulted in 100% canopy reduction. All herbicide treatments showed resprouts from dormant buds. Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac and Post Rain TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac are two treatments to monitor to determine if the plants are completely controlled 2 years after treatment. If applications during flowering prove successful, this technique may be an option to expand the application timing currently employed by roadside specialist to control honeysuckle.

[13] Jeffrey C Jodon et. al. 2022. Evaluation of Brush Herbicides and Mixes for Canopy Reduction of Autumn Olive (*Elaeagnus umbellata*), 3rd year. Roadside Vegetation Management Research 2022 Report. pp 1-5.
[14] Jeffrey C Jodon et. al. 2021. Evaluation of brush control herbicides on control of exotic shrub honeysuckle- 3rd year. Roadside Vegetation Management Research 2021 Report. pp 1-4.

Table 1. Percent injury and canopy reduction of shrub honeysuckle (*Lonicera morrowii* and *Lonicera maackii)*. The experiment was visually rated for percent injury where 0 = no injury - 100 = complete injury on July 6, 2020, 32 days after treatment (DAT) & August 6, 2020, 63 DAT, and percent canopy reduction where 0 = no canopy reduction – 100 = complete canopy reduction. Herbicides were applied on June 4 (treatments 1-10), June 5 (treatment 11 & 12) & June 8 (treatment 13), 2020. June 4 was the application date used to calculated DAT. All treatments included methylated seed oil at 1% v/v. Each value is the mean of ten replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Treatment	Product	Rate oz/ac	% Injury 7/6/20 32 DAT	% Injury 8/6/20 63 DAT	% Canopy Reduction 6/14/21 377 DAT
1	untreated	--	1.1 a	1 a	0.6 a
2	Freelexx Method 240 SL MSM 60	96 16 0.5	94.9 def	99 d	89.5 cd
3	Freelexx Garlon 3A MSM 60	96 64 0.5	96 ef	97.5 d	97 d
4	Freelexx TerraVue MSM 60	96 2.85 0.5	90.9 def	95 d	91.5 cd
5	Garlon 3A Freelexx	64 128	94 def	95.5 d	91 cd
6	Garlon 3A	128	83.5 def	92.5 d	89.5 cd
7	Vanquish	64	67 cde	72 cd	62 bc
8	RoundUp Pro Concentrate	104	26 ab	40 b	71.7 bcd
9	TerraVue	2.85	35.5 b	48 bc	38 b
10	TerraVue-Initial Vastlan Freelexx	2.85 64 64	43.5 bc	62 bc	69.5 bcd
11	Freelexx	128	97.5 f	99.3 d	87.9 cd
12	MSM 60	0.5	66 cd	56.9 bc	44.5 b
13	TerraVue-Post Rain Vastlan Freelexx	2.85 64 64	98.2 f	99 d	96.4 d

EVALUATION OF FOLIAR APPLICATIONS TO INVASIVE CALLERY PEAR FOR CANOPY REDUCTION

Herbicide trade and common names: TerraVue (*aminopyralid + florpyrauxifen*), Accord XRT II (*glyphosate*), Freelexx (*2, 4-D choline*), Method 240SL (*aminocyclopyrachlor*), MSM 60 (*metsulfuron-methyl*), Vastlan (*triclopyr choline*)
Plant common and scientific name: Callery pear (*Pyrus calleryana*)

ABSTRACT

Callery pear has become a widespread weed along Pennsylvania roadsides. As a complement to the recent ban of the tree's propagation, sale, and planting as a class B noxious weed in Pennsylvania, an effective herbicide program will be necessary to prevent further spread and any potential hazard to the environment and to the motoring public in the roadside corridor. An experiment was conducted at the North Atherton Street/I-99 interchange in State College, PA to evaluate the efficacy of herbicide applications to Callery pear trees. The herbicide treatments included TerraVue at 2.85 oz/ac, Accord XRT II at 96 oz/ac tank mixed with Vastlan at 48 oz/ac, Freelexx at 128 oz/ac, Freelexx at 96 oz/ac tank mixed with Method 240SL at 16 oz/ac, and MSM 60 at 0.5 oz/ac, Freelexx at 96 oz/ac tank mixed with Vastlan at 48 oz/ac, and MSM 60 at 0.5 oz/ac, MSM 60 at 1 oz/ac, Method 240SL at 16 oz/ac tank mixed with MSM 60 at 2 oz/ac, and an untreated check. By 62 days after treatment, all treatments except for Terra Vue at 2.85 oz/ac provided a minimum of 99% injury of Callery pear tree.

INTRODUCTION

Callery pear is a small tree reaching 40 feet in height preferring full sun and found naturalizing along the edges of fields, forests, and roadsides. Callery pear was originally introduced into the landscape industry in the 1950's and has since become one of the most popular ornamental flowering trees in street, residential, and commercial settings. Native to Asia, Callery pear was originally introduced in the early 1900's as a potential fire blight resistant root stock for common pear; however, its form, early flowering, disease, and insect resistance, and fall leaf color made it attractive as a landscape tree for small urban spaces[15]. Originally introduced as a single selection from one region in China and given the cultivar name Bradford the pear did not have a mating partner and was considered sterile. This changed with introductions of other cultivars from other regions of China. The continued introduction and use of Callery pear has made this non-native tree difficult to control and more widespread as offsite seedlings across the United States. Callery pear's natural root suckering habit, heavy fruiting, and wildlife food source potential contribute to its further spread and dispersal of seedlings outside of the managed landscape. Fruits are consumed by foraging birds and are then dispersed through their droppings. In addition, Callery pear's shallow root system and wide environmental tolerances aid in the quick spread of both new seedlings and clonal plants into new disturbed

[15] https://extension.psu.edu/callery-pear . Invasive Plant Fact Sheet, Callery Pear *(Pyrus calleryana)* pp.1.Viewed on December 8, 2021.

sites[16,17]. As a weed in roadside settings, Callery pear detrimentally effects the establishment of late to middle stage successional native species due to its high demand for light and clonal suckering habit. In addition, Callery pear volunteer seedlings create dense impenetrable thickets of thorny stems which prevent human movement and may be hazardous to traffic where brittle trees breakdown in ice storms and high winds[18].

Control of Callery pear is possible by physical removal through hand-pulling or wrenching out of the ground of small plants; however, care must be taken to ensure all root fragments have been removed to eliminate resprouting. Mowing and cutting methods are also effective when followed by a cut stump herbicide application or through allowing rapid regrowth of foliage followed by a foliar herbicide application later in the growing season. Cut stump followed by either glyphosate or triclopyr solution applied directly to the cut surface can be effective but the process is time consuming and labor intensive. Mowing and allowing rapid succulent resprouting followed by foliar applications of a combination of glyphosate and triclopyr can also be effective but requires a delay in treatment and a second visit to the site for the herbicide treatment. To manage and control Callery pear along the roadside corridor where it has spread requires an efficient and effective approach using a targeted application without the time and labor consuming requirements of mowing, cut surface and individual stem applications and preferably without second visits to the site. For this reason, the experiment reported here was applied as a foliar application to individual trees similar to previous experiments with invasive exotic shrub honeysuckle and autumn olive[19]. The experiment compared the efficacy of seven herbicide treatments including: TerraVue, Accord XRT II plus Vastlan, Freelexx, Freelexx plus Method 240SL plus MSM 60, Freelexx plus Vastlan plus MSM 60, MSM 60, and Method 240SL plus MSM 60.

MATERIALS AND METHODS

The experiment was established in the median between the north and south lanes of North Atherton Street (also known as US 322 Business) and the interchange with I-99 in State College, Pennsylvania with ten trees per treatment. Each tree was measured to determine the canopy area of each plant, the average width was multiplied by its height then multiplied by 2 to capture the whole plant as a three-dimensional object (Appendix Table 4). The herbicide application amounts were based on the calculated canopy area. Treatments included: TerraVue at 2.85 oz/ac; Accord XRT II at 96 oz/ac + Vastlan at 48 oz/ac; Freelexx at 128 oz/ac; Freelexx at 96

[16]https://www.researchgate.net/publication/232682928_The_Beginning_of_a_New_Invasive_Plant_A_History_of_the_Ornamental_Callery_Pear_in_the_United_States, pp. 6 The Beginning of a New Invasive Plant: A History of the Ornamental Callery Pear in the United States, Viewed on December 8, 2021.

[17]https://extension.psu.edu/callery-pear . Invasive Plant Fact Sheet, Callery Pear *(Pyrus calleryana)* pp.1.Viewed on December 8, 2021.

[18]https://www.researchgate.net/publication/232682928_The_Beginning_of_a_New_Invasive_Plant_A_History_of_the_Ornamental_Callery_Pear_in_the_United_States, pp. 6 The Beginning of a New Invasive Plant: A History of the Ornamental Callery Pear in the United States, Viewed on December 8, 2021.

[19] Jodon et. al. 2021 Evaluation of Brush Herbicides on Canopy Reduction of Exotic Honeysuckle (Lonicera spp.)-Third Year and Evaluation of Brush Herbicides and Mixes on Canopy Reduction on Autumn Olive (Elaeagnus umbellate)-Second Year. Roadside Vegetation Management-2021 Report. pp 1-9.

oz/ac + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac; Freelexx at 96 oz/ac + Vastlan at 48 oz/ac + MSM 60 at 0.5 oz/ac; MSM 60 at 1 oz/ac; Method 240SL at 16 oz/ac + MSM 60 at 2 oz/ac; and an untreated check. Methylated seed oil at 1% v/v was added to all herbicide mixes. The application was made at a carrier volume of 35 gallons per acre (GPA). All treatments were applied using a CO_2-powered backpack sprayer equipped with a 30 GunJet spray gun and one PPX 6 adjustable nozzle at 32 pounds per square inch (PSI). The weather at the time of application was sunny to partly cloudy with wind speeds of 5-10 mph, 60% relative humidity, and air temperatures of 85° F. Soil temperatures at the surface, 1-inch, 3-inch, and 6-inch depths were 78°F, 77° F, 74° F and 72°F, respectively. Trees were treated on July 7, 2021.

Treatments were visually rated for percent injury 0 = no injury – 100 = complete injury on August 5, 2021, 29 days after treatment (DAT) and on September 7, 2021, 62 DAT, respectively. All data were subjected to analysis of variance, and when treatment effect F-tests were significant ($p \leq 0.05$), treatment means were compared using Tukey's HSD separation test.

RESULTS AND DISCUSSION

Percent injury of the herbicide treatments ranged from 74.6% to 100% on August 5, 2021, 29 DAT, while the untreated check showed a percent injury of 9.5% (Table 1). A similar percent injury range (71% to 100%) was observed at 62 DAT.

By 62 DAT, treatments with the greatest injury included MSM 60 alone or mixes containing MSM 60 and Method 240SL. The treatments resulting in 100% injury were Freelexx at 96 oz/ac plus Vastlan at 48 oz/ac plus MSM 60 at 0.5 oz/ac: Method 240SL at 16 oz/ac plus MSM 60 at 2 oz/ac: Freelexx at 96 oz/ac plus Method 240SL at 16 oz/ac plus MSM 60 at 0.5 oz/ac: MSM 60 alone at 1 oz/ac: and Method 240SL at 16 oz/ac plus MSM 60 at 2oz/ac. Freelexx alone at 128 oz/ac resulted in 99.8% injury, while Accord XRT II at 96 oz/ac plus Vastlan at 48 oz/ac resulted 99.7% injury. TerraVue at 2.85 oz/ac resulted in the lowest injury with 71%. The percent injury of the untreated check was 8.1.

CONCLUSIONS

By September 7, 2021, 62 DAT, all herbicide treatments resulted in injury of more than 99%. TerraVue at 2.85 oz/ac showed a lower injury of 71%. Further data collection and analysis, one and two years after treatment, will determine canopy reduction and future recommendations.

Table 1. Percent injury of Callery pear tree *(Pyrus calleryana)*. The experiment was visually rated for percent injury on August 5, 2021, 29 DAT and September 7, 2021, 62 DAT. Herbicides were applied on July 7, 2021. All treatments included Methylated seed oil at 1% v/v. Each value is the mean of ten replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Treatment	Rate oz/ac	% Injury 08/05/2021 29 DAT	% Injury 09/07/2021 62 DAT
untreated	--	9.5a	8.1a
TerraVue	2.85	74.6b	71b
Accord XRT II Vastlan	96 48	99.6c	99.7c
Freelexx	128	99.4c	99.8c
Freelexx Method 240SL MSM 60	96 16 0.5	99.8c	100c
Freelexx Vastlan MSM 60	96 48 0.5	100c	100c
MSM 60	1	99.7c	100c
Method 240SL MSM 60	16 2	100c	100c

EVALAUTION OF PENNDOT FORMULA R

Plant common and scientific names: creeping bentgrass (*Agrostis stolonifera*); redtop (*Agrostis alba*); cosmos sedge (*Carex comosa*); fox sedge (*Carex vulpinoides*); alkaligrass (*Puccinellia distans*); riverbank wildrye (*Elymus riparius*)

INTRODUCTION

PennDOT recently created a seed mix committee to review and recommend new seed mix formulas for PennDOT. Formula R is designed for use in seasonally flooded areas or basin bottoms and consists of creeping bentgrass (*Agrostis stolonifera*), redtop (*Agrostis alba*), cosmos sedge (*Carex comosa*), fox sedge (*Carex vulpinoides*), alkaligrass (*Puccinellia distans*), and riverbank wildrye (*Elymus riparius*). Formula R was seeded at a committee recommended rate of 5.2 lbs per 1000 square yards into an established retention basin located along the I-99 Shiloh Road exit near State College, PA. On May 14, 2021, the site was rototilled multiple times to eliminate existing vegetation with a Troy built walk behind rototiller. The site was hand broadcast seeded with Formula R at 25.17 lbs./acre (creeping bentgrass 5.03 lbs./ac + redtop 5.03 lbs./ac + cosmos sedge 2.52 lbs./ac + fox sedge 2.52 lbs./ac + alkaligrass 5.03 lbs./ac + riverbank wild + 5.03 lbs./ac), while oats were hand seeded at 30 lbs./ac as a cover crop. The site was fertilized with 24-6-10 at a rate of 1lb. N/1000 square feet followed by the installation of East Coast ECS-1erosion control straw blankets. Future plant counts will determine the success of the seeding formula R in a basin

MATERIAL AND METHODS

Formula R was seeded into an established retention basin located along the I-99 Shiloh Road exit near State College, PA. The area to be seeded was 100 feet by 25 feet or approximately one quarter of the entire basin. No herbicide applications were applied to control existing vegetation due to the potential for herbicide movement in the water in and beyond the basin. On May 14, 2021, the site was rototilled multiple times to eliminate existing vegetation with a Troy built walk behind rototiller. The site was hand broadcast seeded with Formula R at 25.17 lbs./acre (creeping bentgrass 5.03 lbs./ac + redtop 5.03 lbs./ac + cosmos sedge 2.52 lbs./ac + fox sedge 2.52 lbs./ac + alkaligrass 5.03 lbs./ac + riverbank wild + 5.03 lbs./ac), while oats were hand seeded at 30 lbs./ac as a cover crop. The site was fertilized with 24-6-10 at a rate of 1lb. N/1000 square feet followed by the installation of East Coast ECS-1erosion control straw blankets. Weather at the time of seeding was sunny skies and air temperature of 68°F. The soil temperatures at the surface, 1-inch, 3-inch, and 6-inch depths were 68°F, 68°F, 65°F, and 60°F, respectively. Eight subplots were established with the basin to conduct plant counts of the seeded species. Each subplot is a square meter. Plant counts were conducted on November 9, 2021.

RESULTS AND DISCUSSION

The basin seeded with formula R showed very little germination by the seeded species. Of the eight subplots evaluated (Table 2), two subplots contained plants of creeping bentgrass,

two subplots contained redtop plants, and possibly one seedling of riverbank wildrye was identified in one subplot. One possible reason for the low germination and emergence of the seeded species maybe due to not doing standard seed bed prep of eliminating any competitive ground cover with a non-selective herbicide treatment before seeding. It was observed that a portion of the basin was reinfested with soft rush which was present before seeding formula R.

CONCLUSIONS

Establishment of formula R species, in the basin bottom, appears slow. Future plant counts will determine the success of seeding formula R in a basin without the use of a non-selective herbicide before seeding.

Table 1. Formula R seed mix components, lb./1000 square yards, number of seeds/lb., % of mix based on weight, and lbs./acre

Common Name	Species	lb./1000 Square Yards	seeds/lb.	% mix based on weight	lbs./acre
creeping bentgrass	*Agrostis stolonifera*	1.04	6130000	20.0	5.03
redtop	*Agrostis alba*	1.04	4851000	20.0	5.03
cosmos sedge	*Carex comosa*	0.52	480000	10.0	2.52
fox sedge	*Carex vulpinoides*	0.52	1297000	10.0	2.52
alkaligrass	*Puccinellia distans*	1.04	1200000	20.0	5.03
riverbank wildrye	*Elymus riparius*	1.04	125000	20.0	5.03
Total		5.2		100	25.17

Table 2. Plant counts per square meter. Eight subplots were established to conduct plant counts within the basin for the species seeded with formula R. Formula R was seeded May 14, 2021, and plant counts were conducted November 9, 2021.

	SPECIES					
subplot	creeping bentgrass	redtop	cosmos sedge	fox sedge	alkaligrass	riverbank wildrye
1	2	0	0	0	0	0
2	0	0	0	0	0	0
3	3	0	0	0	0	1
4	0	1	0	0	0	0
5	0	1	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0

EVALUATION OF NATIVE GRASS AND POLLINATOR SEED MIXES AND SEEDING METHODS FOR CONVERSION AND ESTABLISHMENT ALONG ROADSIDES -2nd YEAR

Herbicide trade and common names: Accord XRT II (*glyphosate*)
Plant common and scientific names: hard fescue mixture (*Festuca longifolia*), creeping red fescue (*Fescue rubra*), little bluestem (*Andropogon scoparius*), Canada wildrye (*Elymus canadensis*), Virginia wildrye (*Elymus virginicus*), Indiangrass (*Sorghastrum nutans*), spring oats spp., winter wheat spp., annual ryegrass spp., black-eyed Susans (*Rudbeckia hirta*), New England aster (*Symphyotrichum novae-angeliae*), ox-eye sunflower (*Heliopsis helianthoides*), big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), sheep fescue (*Festuca ovina L.*), creeping red fescue (*Festuca rubra*), chewing's fescue (*Festuca rubra subsp. commutata*)

ABSTRACT

Utilizing native grass species for sites along the roadsides of Pennsylvania has gained momentum and is being promoted as a viable option for future revegetation programs. Soil stability, germination rate and speed of cover, vehicular safe site distance conditions, and ease of maintenance are all very important factors roadside managers consider when selecting seed mixes. A demonstration area was established where two native seed mixes, Formula N and modified Formula N, were seeded at a pure live seed (PLS) rate and at PennDOT's standard bulk rate. Once established, half of the site was subjected to standard maintenance practices while the other half was not in order to determine whether the seed mixes can tolerate and thrive under present roadside maintenance practices. By 474 DAS (days after seeding), at the two different seeding rates, the bulk seeded Formula N with no maintenance plots resulted in the highest average number of seedlings including fine fescue, little bluestem, and black-eyed Susan compared to the bulk rate maintenance and both PLS seeded plots. The bulk seeded Formula N with maintenance next highest in seedling count with fine fescue and little bluestem represented; however, it also had the highest weed counts. Among the modified Formula N plots, switchgrass was most prominent in the in the bulk seed rate-maintenance plots along with the presence of Indiangrass and little bluestem. No difference was found among the maintenance and non-maintenance plots for weed seedling emergence. Broadleaf and grass weeds showed an increase from year one to year two within all plots. The sites will be evaluated throughout the coming years to assess the progress of establishment among the seeding formulas and their associated seeding rates. In addition, this long-term experiment will help to determine whether establishing early maintenance will assist the native seed establishment process.

INTRODUCTION

PennDOT traditionally selects seed mixes based on adaptability to site conditions and to assure ease of future maintenance[20]. With a growing call to employ native species along the PennDOT right-of-way while continuing to maintain soil stability during establishment and

[20] Johnson et. Al. 2009. Native Seed Mix Establishment Implementation. Roadside Vegetation Management Research-2009 Report. pp. 50.

traveler safety, we evaluated alternative grass species within a previously created PennDOT native seed mix (PennDOT Formula N). Formula N created in 2009 included native warm-season grasses (WSG) and was designed as an alternative to the PennDOT Formula C seed mix containing crownvetch and used for rocky, shallow soil, difficult to mow areas near road cuts and embankments. Crownvetch has been classified as a "situational invasive" by the PA DCNR[21] due to its potential to spread away from the roadside right-of-way.

The established Formula N (Table 1) seed mix consists of little bluestem and Indiangrass, which once established adapt well to poor soil conditions, provide sufficient groundcover, and prevent erosion. These two grasses are tall bunch type grass species with a very deep root system[22]. The hard and creeping red fescue components (CSG) of the mix germinate within 2-3 weeks of seeding and provide early cover thus reducing weed pressure and erosion caused by heavy spring precipitation. The oats and wildrye also provide early cover and erosion protection. To support native wildlife food resources, the black-eyed Susan, oxeye sunflower and New England aster are nectar sources to foraging bees, butterflies, and insects, and seeds for birds. However, slow establishment was the main drawback with Formula N due to the WSG component, which generally requires three to four seasons to provide satisfactory groundcover and thus increased opportunities for erosion and weed pressure[23]. This slow establishment may be partially due to seed dormancy constraints which may require natural cold stratification to germinate, and the variation dormancy levels within seed lots[24].

The creation of a modified Formula N (Table 2) was intended to enhance the WSG component of the seed mix to better adapt to heat, drought, variable pH levels, low fertility, and salt buildup (Johnson et al., 2014) while assuring a better stand of WSG. To do this the Canada and Virginia wildrye, black-eyed Susan, oxeye sunflower, and New England aster were replaced with big bluestem, and switchgrass. In addition, the CSG component was enhanced with addition of sheep and chewing's red fescue to provide better gap coverage for several seasons allowing the WSG time to establish while reducing weed pressure and possible soil erosion. The modified Formula N seed mix components were chosen based on grass type, site conditions, and concerns around standard broadleaf weed management procedures applied during seedling establishment and in future maintenance. Seeds were selected based on availability and applicability to the site.

A secondary goal of this experiment was to compare the effectiveness and potential cost saving of seeding the plots based on label bulk weight seed rates to pure live seed rates (PLS). Traditionally, PennDOT has seeded new and revegetated sites using bulk weight seed rates. The present view by forage, field production, and natural area seed industry professionals is that PLS seeding rates are more effective, assures better quality stand development, and seedling

---

[21] Johnson et. Al. 2014. Evaluation of Native Seed Mixes For Roadside Application – Year Three. Roadside Vegetation Management Research-2014 Report. pp. 27-28.
[22] Delong, C. and M. Brittingham. 2007. Warm-Season Grasses and Wildlife. Penn State Extension. https://extension.psu.edu/warm-season-grasses-and-wildlife. Viewed April 15, 2020.
[23] Johnson et. Al. 2009. Native Seed Mix Establishment Implementation. Roadside Vegetation Management Research-2009 Report. pp. 50.
[24] Establishing Native Grasses, Conservation Reserve Program Job Sheet CP2, March 2011. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_017880.pdf Viewed May 5, 2021

survival[25]. The decision to compare these two seeding rates were the result of discussions within PennDOT on the economics and potential overall success of plant establishment on newly seeded sites with native seed mixes. For this reason, Formula N and modified Formula N were seeded at PennDOT's standard bulk rate versus a standardized pure live seed (PLS) rate.

The final goal of this experiment was to determine how the implementation of maintenance practices early in the establishment process would impact seedling success of plot establishment. To achieve this the seed plots were subdivided after seeding into standard maintenance implemented one year after seeding and no maintenance to determine the effect on establishment. This paper represents second year observations of the seeding process

MATERIALS AND METHODS

A demonstration site was established along Park Avenue on the back slope under the interchange of I-99 and SR 322. The site had a slight slope with poor soil conditions. There were several cool-season grass species onsite including fine fescue, tall fescue, Kentucky bluegrass, and reed canary grass, along with several broadleaf weed species. Four replicate plots of 60' x 160' were created and arranged in a randomized block design. Each replicate plot was split into four treatment plots of 30' x 40' and arranged in a complete randomized block design. Each treatment plot was then split into subplots that were 30' x 20' to compare maintenance vs. non-maintenance. To measure the performance, plants were counted within four sub plots that were 2' x 2' in size and were arranged on a diagonal line running along the center of each treatment replication. On June 1, 2020, all plots were sprayed with Accord XRT II at 64 oz/ac in a carrier volume of 50 gallons per acre (GPA) with a pressure of 35 pounds per square inch (PSI) using a CO_2 powered backpack sprayer with a six-foot boom equipped with four 8004VS nozzles to eliminate vegetation. A surfactant, CWC 90, was added to all treatments at 0.25% v/v. The weather at the time of application consisted of sunny skies, wind speeds of 5-10 mph, air temperature of 74° F, and 20% relative humidity. Soil temperatures at the surface, 1-inch, and 3-inch depths, were 71° F, 71°F and 71° F, respectively. Following this application, on June 22 and 23, 2020, the soil was cultivated with a disc harrow, pulled by a Kubota L2500 tractor. Seeds were purchased from native seed nurseries and stored until planting. Seeds were weighed and bagged for each plot separately. To assure accuracy in seeding rates and seed purity, the seeding rates were calculated for each species using pure live seed (PLS), standardizing the overall seeding rate among the mix at 430 PLS seeds per square meter based on a recent research report on seeding native forb and grasses to assure accuracy and acceptable cover[26]. Eight plots were broadcast seeded, four with a PennDOT standard rate per acre and four with a rate based on PLS per acre. Specifically, Formula N was seeded at PennDOT's bulk rate of 105.1 lbs./acre and at the PLS rate of 4.91 lbs./acre. Modified Formula N was seeded at a bulk rate of 40 lbs./acre

[25] Bogge s, Moriah and Brooke, Jarred. YEAR. Pure Live Seed: Calculations and Considerations For Wildlife Food Plots. Purdue University Extension. https://www.purdue.edu/fnr/extension/pure-live-seed/ https://www.purdue.edu/fnr/extension/pure-live-seed/ Viewed June 7, 2022

[26] Meissen, Justin; Williams, Dave; and Jackson, Laura (2017) "Cost-Effective Native Seed Mix Design and First-Year Management," Farm Progress Reports: Vol. 2016 : Iss. 1 , Article 62. DOI: https://doi.org/10.31274/farmprogressreports-180814-1632 Available at: https://lib.dr.iastate.edu/farmprogressreports/vol2016/iss1/62. Viewed May 5, 2021

and at the PLS rate of 50.4lbs./acre. A quick cover of oats was seeded over the top at 30 lbs./acre to protect the seed and prevent erosion. Plots were fertilized with 10-6-4 at 1 lb. N per 1000 sq. ft. and covered with erosion control straw blankets on June 25, 2020. Local rain events occurred on June 27, July 1, and 3, 2020, measuring 0.52", 0.01", and 0.09", respectively, according to http://newa.cornell.edu. The nearest weather station was located at Rock Springs, PA[27].

During the second growing season, on June 25th, 2021, the plots included in the maintenance program were sprayed with Triplet LO at 64 oz/ac in a carrier volume of 35 gallons per acre (GPA) with a pressure of 33 pounds per square inch (PSI) using a CO_2 powered backpack sprayer with a six-foot boom equipped with four 8004VS nozzles to eliminate broadleaf weeds. A surfactant, Induce, was added to all treatments at 0.25% v/v. At the time of application, weed pressure was significantly high. The weather at the time of application consisted of clear skies, wind speeds of 0-5 mph, air temperature of 72° F, and 52% relative humidity. Soil temperatures at the surface, 1-inch, 3-inch, and 6-inch depths, were 78° F, 80° F, 74°, and 69° F, respectively. On August 3rd, 2021, all plots receiving maintenance were mowed using a Kubota with a mower attachment at a height of 6 inches to prevent further infestation of weeds including thistle and several grass weeds. All data were subjected to analysis of variance, and when treatment effect F-tests were significant ($p \leq 0.05$), treatment means were compared using Tukey's HSD separation test.

RESULTS AND DISCUSSION

The experimental site was seeded after the typical spring seeding window and the growing season did not include a significant amount of precipitation immediately after seeding. The 2020 growing season was generally categorized as a drought season with little precipitation. The dry conditions likely inhibited seed germination and represents what may happen in roadside plantings where supplemental irrigation is not available or financially justified. All treatments (Table 3 & 5) showed germination of broadleaf weeds, grass weeds, and oats at the end of the first growing season.

At the end of the first growing season, 97 DAS (days after seeding), Formula N produced the highest plant count with Black-eyed Susan being the most prominent species present among the PennDOT bulk seed rate plots across maintenance regimes ranging on average from 3.38 maintenance and 4.13 no maintenance based on four 4 square foot subsampling units (Table 3). In contrast, Black-eyed Susan among the PLS seeded Formula N plots averaged 0.06 and 0.19 in maintenance and no maintenance plots, respectively. Among the WSG seedlings counted, Indiangrass was highest at 0.19 seedlings per 4' square subplot at the bulk seed rate compared to 0.06 in the PLS plots under the maintenance regime with no Indiangrass in the no maintenance plots for either seeding rate. Fine fescue was the next prominent species with the bulk seeded plots producing on average more seedlings at 1.88 and 0.44 based on maintenance regimes compared to the PLS rates of 0.19 and 0.13. Little bluestem was only found in the bulk seed rate plots. All other WSG and flowers were absent. There was no significant difference among the Formula N plots at either seeding rate for broadleaf weeds and grass weeds.

[27] Jodon et al. 2021. Evaluation of Native Grass and Pollinator Seed Mixes and Seeding Methods for Conversion and Establishment Along Roadsides. Roadside Vegetation Management Research – 2021 Report. pp. 48

Within the modified Formula N seed mix the bulk seed rate species present included big bluestem, little bluestem, and switchgrass, while the PLS seed rate plots had fine fescue, and switchgrass all in small amounts ranging from 0.06 to 0.38 seedlings per subplots (Table 4). Little bluestem was most prominent at 0.31 and 0.38 plants per subplot followed by Switchgrass, and then big bluestem. Among the PLS plots fine fescue was the most prominent at 0.13 and 0.31. The broadleaf weeds in all seeded plots ranged from 5.94 to 16.88 plants per 4 sq. ft. with no significant difference between seeding rate or maintenance regime. In contrast, there was a significant difference between plots for grass weed presence with more overall weeds found in the PLS seeded plots. The importance of the differences in weed count between PLS and the bulk rate as well as the differences in counts between maintenance regimes will be helpful in determining the best maintenance program to utilize. At this moment, the maintenance remains muddled based on the first-year data.

At the end of the second growing season, 474 DAS (days after seeding), Formula N produced the highest plant count with Black-eyed Susan being the most prominent followed by fine fescue and little bluestem (Table 4). However, compared to the first-year data the total average presence of Black-eyed Susan was reduced and only found in the no maintenance plots with an average of 2.0 seedlings per subplot found in the bulk rate plots and 0.19 seedlings in the PLS plots. Reduced seedling numbers were also found with little bluestem in the second year among the bulk rate plots compared to the first year with 0.13 under the maintenance regime and 0.06 under no maintenance compared to 0.25 and 0.88, respectively the first year (Table 3). Fine fescue also showed a drop in average seedling numbers compared to first year data under the maintenance regime for both bulk and PLS seedings. Whereas the no maintenance regime plots averaged the same number of seedlings as the first year at 1.88 and 0.13, respectively for seeding rates. No other WSG or flowers were found in the plots. The reason for the number drops may be tied to the damage caused by the maintenance program for Black-eyed Susan; however, the no maintenance plots also saw a drop in plant count. Weather may have been a factor as well and may have affected little bluestem and fine fescue counts at least under the maintenance regime. The broadleaf weeds and grass weed counts greatly increased from year one to year two with nearly a three-fold total increase in broadleaf weeds across all counted subplots and nearly a four-fold increase in grass weeds. There was no significant difference among the Formula N plots at both seeding rates for both broadleaf weeds and grass weeds in the second year.

Within the modified Formula N seed mix the seedlings present changed with an increase in fine fescue across the treatment plots with all plots recording fine fescue seedlings compared to the first year where only the PLS seeding produced plants (Table 6). Big bluestem was not found in any of the subplots across seeding rates and maintenance regimes and the amount of little bluestem was reduced from on average from 0.38 plants to 0.19 in the bulk rate planting under maintenance and from 0.31 to 0.13 in the PLS seeding under no maintenance. Switchgrass increased between the bulk rate maintenance regime compared to the bulk rate no maintenance subplots and the PLS rate maintenance subplots. The no maintenance bulk rate plot saw a decrease in average number of plants (0.06) compared to the first-year data of 0.31 (Table 5). A small amount of Indiangrass was found among the bulk rate maintenance subplots for the first time. The broadleaf weeds and grass weeds increased across all seedings and maintenance regimes treatment compared to the first year similar to the Formula N subplots. No significant difference in broadleaf weed germination was found between with the PLS seeding rate and the

bulk weight plots in year two. However, at the end of the second growing season the PLS seeding rate under the maintenance regime showed a significant increase in grass weed count compared to the bulk rates and the PLS rate under no maintenance.

Overall, the percent cover across the whole experiment is low. We have found in past experiments with WSG seedings that time to establishment can take more than two years. One consideration for the low percent cover may be due to the time of year the plots were seeded, after the typical spring seeding window. Furthermore, the growing season did not include a significant amount of precipitation immediately after seeding creating dry conditions for seed germination. A 2009 study evaluating the ability of native WSG species to establish at four different seeding dates throughout the year showed significantly different results. Seeding occurred in February, April, July, and August. Three years later, results showed the plots seeded in February produced the highest percent cover (25%), followed by plots seeded in April (20%), and then by plots seeded in July and August (1%). The soil moisture conditions and temperatures of the late winter through early spring season seem to be most favorable when establish WSG cover. Results of the 2009 study are comparable to this experiment 2 years later in that the late seeding inhibited reasonable cover and showed a low percent cover[28].

The concern of the standard broadleaf weed management strategies having a negative effect on the pollinator friendly components within the Formula N seed mix proved to be true. Overall, the Formula N plots, those that received maintenance showed a decrease in plant count of 0 for black-eyed Susan's. However, all seeding rates and treatments showed a reduction in black-eyed susan coverage compared to the first growing season data except for the PLS rate with no maintenance, which showed a slight increase. The variability in the weather over the winter may have played some role in the reduction of plants in combination with maintenance.

CONCLUSIONS

Second year results for all species within both seed mixes showed 2 percent cover or less. Broadleaf weeds and grass weeds increased significantly from the first year to the second year. The late season establishment, low precipitation, and late broadleaf weed control treatment are all possible factors to the low germination and establishment results and increased weed pressure. Within the modified Formula N seed mix, the fescue grasses were the only species that provided more cover. We will continue to evaluate throughout the coming years to monitor the progression of these plantings and maintenance regimes.

[28] Johnson et. Al. 2012. Seasonal Timing Effects on Warm Season Grass Establishment Relative to Crownvetch and Annual Ryegrass-Year Three. Roadside Vegetation Management Research-2012 Report. pp. 6-8.

Table 1: Formula N**:** Species included in Formula N seed mix at PennDOT's rate of 105.1 lbs./acre and at a PLS rate of 4.91 lbs./acre.

Common name	Scientific name	PennDOT Rate lbs./ac	430 PLS/m^2 Rate lbs./ac
Hard fescue	*Festuca longifolia*	43.56	2.03
Creeping red fescue	*Festuca rubra*	21.78	1.02
Little bluestem	*Schizachyrium scoparius*	5.81	0.27
Indiangrass	*Sorghastrum nutans*	4.36	0.02
Canada wildrye	*Elymus canadensis*	8.71	0.41
Virginia wildrye	*Elymus virginicus*	2	0.09
Black-eyed susan	*Rudbeckia hirta*	7.26	0.34
New England Aster	*Symphyotrichum novae-angeliae*	4.36	0.2
Ox-eye Sunflower	*Heliopsis helianthoides*	7.26	0.34
Total		105.1	4.91

Table 2: Modified Formula N: Species included in Modified Formula N seed mix at Penn State Roadside Project recommended rate of 40 lbs./acre and at a PLS rate of 5.04 lbs./acre.

Common name	Scientific name	PSU Rate lbs./ac	430 PLS/m^2 Rate lbs./ac
Big bluestem	*Andropogon gerardii*	6	0.76
Little bluestem	*Schizachyrium scoparius*	6	0.76
Indiangrass	*Sorghastrum nutans*	6	0.76
Switchgrass	*Panicum virgatum*	2	0.25
Hard fescue	*Festuca longifolia*	5	0.63
Sheep fescue	*Festuca ovina L.*	5	0.63
Creeping red fescue	*Festuca rubra*	5	0.63
Chewing's fescue	*Festuca rubra subsp. commutata*	5	0.63
Total		40	5.04

Table 3: Formula N 1st Year: Plant counts were conducted using four permanent sub plot samples per plot that were 2 x 2' in size. All plots were sprayed with Accord XRT II at 64 oz/ac on June 1, 2020. The soil was cultivated with a disc harrow on June 22 and 23, 2020. All plots were broadcast seeded with the specified seed mix shown below and oats at a rate of 30 lbs./acre, fertilized with 10-6-4 at 1 lb. N per 1000 sq. ft., and covered with erosion control straw blankets on June 25, 2020. Four plots were seeded with Formula N at PennDOT's rate of 105.1 lbs./acre and at a PLS rate of 4.91 lbs./acre. Each value is a mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Seed Mix	Seed Rate lbs./ac	Fine fescue Count 9/20	Little Bluestem Count 9/20	Indiangrass Count 9/20	Canada Wildrye Count 9/20	Virginia wildrye Count 9/20	Black-eyed susans Count 9/20	New England aster Count 9/20	Ox-eye Sunflower Count 9/20	Broadleaf Weeds Count 9/20	Grass Weeds Count 9/20	Oats Count 9/20
Formula N- Maint.	105.10	0.44	.25ab	0.19	0	0	3.38	0	0	7.06	3.38	5.38
Formula N- Maint.	4.91	0.19	0a	0.06	0	0	0.19	0	0	12.00	3.50	5.88
Formula N- No maint.	105.10	1.88	.88b	0	0	0	4.13	0	0	14.16	3.81	2.94
Formula N- No maint.	4.91	0.13	0a	0	0	0	0.06	0	0	5.88	3.19	5.38
		n.s.		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Table 4: Formula N 2nd Year: Plant counts were conducted using four permanent sub plot samples per plot that were 2 x 2' in size. All plots receiving maintenance were sprayed with Triplet LO at 64 oz/ac on June 25, 2021. Four plots were seeded with Formula N at PennDOT's rate of 105.1 lbs./acre and at a PLS rate of 4.91 lbs./acre. Each value is a mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

Seed Mix	Seed Rate lbs./ac	Fine fescue Count 10/21	Little Bluestem Count 10/21	Indiangrass Count 10/21	Canada wildrye Count 10/21	Virginia wildrye Count 10/21	Black-eyed susans Count 10/21	New England aster Count 10/21	Ox-eye sunflower Count 10/21	Broadleaf Weeds Count 10/21	Grass Weeds Count 10/21	Oats Count 10/21
Formula N- Maint.	105.10	0.25	0.13	0	0	0	0.00	0	0	42.56	16.25	0
Formula N- Maint.	4.91	0.13	0.00	0	0	0	0.00	0	0	22.44	16.25	0
Formula N- No maint.	105.10	1.88	0.06	0	0	0	2.00	0	0	27.50	15.81	0
Formula N- No maint.	4.91	0.13	0.00	0	0	0	0.19	0	0	29.81	11.25	0
		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Table 5: Modified Formula N 1st Year: Plant counts were conducted using four permanent sub plot samples per plot that were 2 x 2' in size. All plots were sprayed with Accord XRT II at 64 oz/ac on June 1, 2020. The soil was cultivated with a disc harrow on June 22 and 23, 2020. All plots were broadcast seeded with the specified seed mix shown below and 30 lbs./acre, fertilized with 10-6-4 at 1 lb. N per 1000 sq. ft., and covered with erosion control straw blankets on June 25, 2020. Four plots were seeded with Modified Formula N at a rate of 40 lbs./acre and at a PLS rate of 5.04 lbs./acre.

Seed Mix	Seed Rate lbs./ac	Fine fescue Count 9/20	Big bluestem Count 9/20	Little bluestem Count 9/20	Indiangrass Count 9/20	Switchgrass Count 9/20	Broadleaf Weeds Count 9/20	Grass Weed Count 9/20	Oat Count 9/20
Modified Formula N- Maint.	40.00	0	0.19	0.38	0	0.19	5.94	1.81a	5.19
Modified Formula N- Maint.	5.04	0.13	0	0	0	0.06	7.25	5.81b	4.13
Modified Formula N- No maint.	40.00	0	0.25	0.31	0	0.31	14.81	2.81ab	3.88
Modified Formula N- No maint.	5.04	0.31	0	0	0	0	16.88	4.19ab	2.88
		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.		n.s.

Table 6: Modified Formula N 2nd Year: Plant counts were conducted using four permanent sub plot samples per plot that were 2 x 2' in size. All plots receiving maintenance were sprayed with Triplet LO at 64 oz/ac on June 25, 2021. Four plots were seeded with Modified Formula N at a rate of 40 lbs./acre and at a PLS rate of 5.04 lbs./acre.

Seed Mix	Seed Rate lbs./ac	Fine fescue Count 10/21	Big bluestem Count 10/21	Little bluestem Count 10/21	Indiangrass Count 10/21	Switchgrass Count 10/21	Broadleaf weed Count 10/21	Grass weed Count 10/21	Oat Count 10/21
Modified Formula N- Maint.	40.00	0.125	0	0.19	0.06	0.31b	28.75	12.38	0.00
Modified Formula N- Maint.	5.04	0.38	0	0	0	0.06ab	30.25	21.13b	0.06
Modified Formula N- No maint.	40.00	0.25	0	0.13	0	0.06ab	22.38	8.88	0.00
Modified Formula N- No maint.	5.04	0.44	0	0	0	0a	27.75	12.13	0.00
		n.s.	n.s.	n.s.	n.s.		n.s.		n.s.

EVALUATION OF ALTERNATIVE BAREGROUND HERBICIDE MIXES

Herbicide trade and common names: Method 240SL *(aminocyclopyrachlor)*; Milestone VM *(aminopyralid)*; TerraVue *(aminopyralid + florpyrauxifen-benzyl)*; Esplanade 200 SC *(indaziflam)*; Esplanade Sure *(indaziflam + rimsulfuron)*; Arsenal Powerline *(imazapyr)*; Plateau *(imazapic)*; Piper *(flumioxazin + pyroxasulfone)*; Spyder Extra *(sulfometuron-methyl + metsulfuron-methyl)*; SFM Extra *(sulfometuron-methyl + metsulfuron-methyl)*; Pendulum Aquacap *(pendimethalin)*; ProClipse *(prodiamine)*; Hyvar X-L *(bromacil)*; RoundUp Pro Concentrate *(glyphosate)*

Plant common and scientific names: poverty dropseed *(Sporobolus vaginiflorus)*; Kentucky bluegrass *(Poa pratensis)*; foxtail *(Setaria spp.)*; witchgrass *(Panicum capillare)*; switchgrass *(Panicum virgatum)*; little bluestem (*Andropogon scoparius)*; big bluestem *(Andropogon gerardii)*; orchardgrass *(Dactylis glomerate)*; tall fescue *(Schedonorus arundinaceus)*; barnyardgrass *(Echinochloa crus-galli)*; American burnweed *(Erechtites hierciifolius)*; mugwort *(Artemisia vulgaris)*; sowthistle *(Sonchus oleraceus)*; birdsfoot trefoil *(Lotus corniculatus)*; wild carrot *(Daucus carota)*; common ragweed *(Ambrosia artemisiifolia)*; white wood aster *(Eurybia divaricate)*; buckhorn plantain *(Plantago coronopus)*; chicory*(Cichorium intybus)*; red clover *(Trifolium pratense)*; Pennsylvania smartweed *(Polygonum pensylvanicum)*; rough fleabane *(Erigeron asper)*; prostrate spurge *(Euphorbia humistrata)*; marestail *(Conyza canadensis)*; spotted knapweed *(Centurea stoebe var. microanthus)*; broadleaf dock *(Rumex obtusifolius)*; and prostrate knotweed *(Polygonum aviculare)*

ABSTRACT

Bareground weed control programs are an essential roadside vegetation management tool utilized by roadside specialist around guiderails, signs, and other fixed structures. In developing bareground weed control program herbicide mixes, vegetation managers must also consider alternative mixes that can be rotated into use over time to reduce the potential for herbicide resistance by the target plant populations. This experiment evaluated alternative bareground herbicide mixes compared to two standard PennDOT bareground herbicide mixes which center around Method 240SL + Esplanade 200 SC + Arsenal Powerline + Plateau + RoundUp Pro Concentrate and Milestone VM + Esplanade 200 SC + Arsenal Powerline + RoundUp Pro Concentrate. Treatments in this experiment included: Method 240SL at 16 oz/ac + Esplanade Sure at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Plateau at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Milestone VM at 7 oz/ac + Esplanade 200 SC at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; TerraVue at 5 oz/ac + Esplanade 200 SC at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Piper at 10 oz/ac + Spyder Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Pendulum Aquacap at 128 oz/ac + SFM Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Pendulum Aquacap at 128 oz/ac + Hyvar X-L at 256 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Pendulum Aquacap at 128 oz/ac + Plateau at 12 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; ProClipse at 32 oz/ac + SFM Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; ProClipse at 32 oz/ac + Hyvar X-L at 256 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; ProClipse at 32 oz/ac + Arsenal Powerline at 24 oz/ac + RoundUp Pro

Concentrate at 64 oz/ac; Esplanade Sure at 5 oz/ac + SFM Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; and an untreated check. By 178 DAT, the untreated check produced a total cover rating of 60% which was significantly higher than the herbicide treated plots. The plots with the lowest total cover at 2.9%, were TerraVue at 5 oz/ac + Esplanade 200 SC at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac. The plots with the highest percent total cover at 28.9%, were treated with ProClipse at 32 oz/ac + Arsenal Powerline at 24 oz/ac + RoundUp Pro Concentrate at 64 oz/ac. Treatments resulting in between 10% and 6% total cover included: Milestone VM at 7 oz/ac + Esplanade 200 SC at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (10.8%); Pendulum Aquacap at 128 oz/ac + Hyvar X-L at 256 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (8.4%); Method 240SL at 16 oz/ac + Esplanade Sure at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (7%); Esplanade Sure at 5 oz/ac + SFM Extra at 4oz/ac + RoundUp Pro Concentrate at 64 oz/ac (6%); and Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Plateau at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (5.8%)

INTRODUCTION

Roadside areas that require season-long bareground weed control include signs, guiderails, concrete barriers, and traffic islands, as well as other fixed structures. Areas maintained free of vegetation allow for proper surface water movement from the roadway, ease of maintenance operations, increased sight distance, and an overall clean and safe aesthetic. Bareground or total vegetation control mixes are comprised of three components: a post emergence, broad-spectrum residual, and a pre-emergence herbicide. Post emergence herbicides are effective at controlling actively growing and established weeds. Broad-spectrum residual herbicides provide control of existing weeds and soil residual activity to prevent emergence of weeds prior to activation of the preemergent herbicide. Preemergence herbicides prevent the establishment of weeds from seed. Roadside specialists select herbicides for bareground applications based on costs, availability, function, and site of action. Site of action (SOA) of herbicides are very important to consider while developing a bareground program. Depending on the component of the bareground mix, it is necessary to rotate site of action to minimize herbicide resistant weeds. This process will allow for current technology to be utilized longer than compared to the repeated use of the same site of action.

Ten alternative bareground mixes were evaluated and compared to two standard bareground mixes (Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Plateau at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac and Milestone VM at 7 oz/ac + Esplanade 200 SC at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac). The two standard mixes include *glyphosate* as a post emergence herbicide, *indaziflam* as a pre-emergence herbicide, *aminopyralid* or *aminocyclopyrachlor* as post emergence plus soil residual, and *imazapyr* as a broad-spectrum residual. The standard mix containing *aminocyclopyrachlor* also included *imazapic* as another post emergence herbicide plus soil residual. The purpose of this experiment was to evaluate the efficacy of alternative bareground mixes. These mixes included either *pendimethalin, prodiamine, or flumioxazin* as a pre-emergence herbicide. *Bromacil* offers an alternative site of action to *imazapyr* or *sulfometuron-methyl* as a broad-spectrum residual herbicide.

MATERIALS AND METHODS

The experiment was established as a randomized complete design with four replications on a site beneath a guiderail along SR 0053 between the overpasses of I-80 eastbound and westbound lanes near Kylertown, PA. Treatments include Method 240SL at 16 oz/ac + Esplanade Sure at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Plateau at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Milestone VM at 7 oz/ac + Esplanade 200 SC at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; TerraVue at 5 oz/ac + Esplanade 200 SC at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Piper at 10 oz/ac + Spyder Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Pendulum Aquacap at 128 oz/ac + SFM Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Pendulum Aquacap at 128 oz/ac + Hyvar X-L at 256 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Pendulum Aquacap at 128 oz/ac + Plateau at 12 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; ProClipse at 32 oz/ac + SFM Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; ProClipse at 32 oz/ac + Hyvar X-L at 256 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; ProClipse at 32 oz/ac + Arsenal Powerline at 24 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Esplanade Sure at 5 oz/ac + SFM Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; and an untreated check. Induce, a nonionic surfactant, was added to all herbicide treatments at 0.25% v/v. Plots were 20 by 3 feet in size. Treatments were pre-measured, mixed, and applied on April 23, 2021, using a CO_2 powered backpack sprayer equipped with one OC-04 nozzle, at 32 PSI (pounds per square inch), and delivered at 50 gallons per acre. Weather at the time of application consisted of clear skies, winds at 5-10 mph, 23% relative humidity, air temperature of 55°F, and soil temperatures of 58°F, 62°F, 62°F, and 54°F, at 0-, 1-, 3- and 6-inch depths, respectively. Local rain events on April 23, 29, May 3, 4, and 5, 2021 with 0.10”, 0.67”, 0.21”, 0.43”, and 0.19” respectively, according to http://new.cornell.edu. The nearest weather station was in DuBois, PA approximately 35 miles from the experiment site.

The experiment was visually rated for percent total vegetative cover on April 19, May 24, June 23, July 23, August 23, September 20, and October 18, 2021, 0, 31, 61, 91, 122, 150 and 178 DAT (days after treatment). Additionally, percent grass cover and percent broadleaf weed cover was visually rated on June 23, July 23, August 23, September 20, and October 18, 2021, 61, 91, 122, 150 and 178 DAT. All data were subjected to analysis of variance and when treatment F-tests were significant ($p \leq 0.05$), treatment means were compared using Tukey’s HSD separation test.

RESULTS AND DISCUSSION

The guiderail site was evaluated prior to the application on April 19, 2021 and ranged between 14.5 and 25 percent total cover with no significant difference between treatments (Table 1). Total cover diminished and ranged from 0.3 to 2.1 percent for the herbicide treatments and 22.5 percent for the untreated check on May 24, 31 DAT. On July 23, 91 DAT, the untreated check had 53.8% total cover, while all the herbicide treatments showed less than 7% total cover except for the ProClipse at 32 oz/ac + Arsenal Powerline at 24 oz/ac + RoundUp Pro

Concentrate at 64 oz/ac treatment (13.6%). Through the August, 122 DAT, and September, 150 DAT, evaluations, percent total cover continued to increase for all treatments. While the herbicide treatments were statistically similar, these treatments were significantly different when compared to the untreated check. By 178 DAT, the untreated check showed 60% total cover and was significantly different from all herbicide treatments. Plant species identified within untreated check plots included poverty dropseed, Kentucky bluegrass, foxtail, witchgrass, switchgrass, little bluestem, big bluestem, orchardgrass, tall fescue, barnyardgrass, American burnweed, mugwort, sowthistle, birdsfoot trefoil, wild carrot, common ragweed, white wood aster, buckhorn plantain, chicory, red clover, Pennsylvania smartweed, rough fleabane, prostrate spurge, marestail, spotted knapweed, and prostrate knotweed. The treatment with the lowest percent cover, 2.9%, was TerraVue at 5 oz/ac + Esplanade 200 SC at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac. The treatment with the highest percent total cover, 28.9%, was ProClipse at 32 oz/ac + Arsenal Powerline at 24 oz/ac + RoundUp Pro Concentrate at 64 oz/ac. Treatments near 10% total cover or less included: Milestone VM at 7 oz/ac + Esplanade 200 SC at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (10.8%); Pendulum Aquacap at 128 oz/ac + Hyvar X-L at 256 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (8.4%); Method 240SL at 16 oz/ac + Esplanade Sure at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (7%); Esplanade Sure at 5 oz/ac + SFM Extra at 4oz/ac + RoundUp Pro Concentrate at 64 oz/ac (6%); Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Plateau at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (5.8%); and TerraVue at 5 oz/ac + Esplanade 200SC at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (2.9%).

Grass cover between the herbicide treatments ranged from 0.2% to 3.4%, and the untreated check had 19.5% on June 23, 61 DAT (Table 2). There was a significant difference between all herbicide treatments and the untreated check. This trend continued through the last rating on October 18, 178 DAT. At that time, ProClipse at 32 oz/ac + Hyvar X-L at 256 oz/ac + RoundUp Pro Concentrate at 64 oz/ac resulted in 0.4 % grass cover, the lowest percent grass cover. Interestingly, ProClipse at 32 oz/ac + SFM Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac resulted in 8.8% grass cover while ProClipse at 32 oz/ac + Arsenal Powerline at 24 oz/ac + RoundUp Pro Concentrate at 64 oz/ac resulted in 8.6% grass cover, the two highest percent grass cover among herbicide treatments. Treatments with a low percent grass cover included: Pendulum Aquacap at 128 oz/ac + Hyvar X-L at 256 oz/ac + Round Up Pro Concentrate at 64 oz/ac (0.8%); Milestone VM at 7 oz/ac + Esplanade 200 SC at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (2.3%); TerraVue at 5 oz/ac + Esplanade 200 SC at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (2.3%); and Esplanade Sure at 5 oz/ac + SFM Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (3%).

Broadleaf weed cover ranged from 0 to 1.4% for the herbicide treatments and the untreated check showed 30.5% on June 23, 61 DAT (Table 3). There was a significant difference between the untreated check and the herbicide treatments. By 178 DAT, three treatments produced less than 1% broadleaf weed cover included: TerraVue at 5 oz/ac + Esplanade 200 SC at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (0.4%); Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8

oz/ac + Plateau at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (0.5%) and Method 240SL at 16 oz/ac + Esplanade Sure at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (0.7%). Esplanade Sure at 5 oz/ac + SFM Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac at 3% was the next lowest in total broadleaf cover. The remaining treatments were statistically like the untreated check.

Treatments including Piper (*flumioxazin* SOA 14*)*, Pendulum Aquacap (*pendimethalin SOA 3)* and ProClipse (*prodiamine* SOA 3*)* offer alternative pre-emergence products in place of products like Esplanade 200 SC or Esplanade Sure *(indaziflam* SOA 29*)* (Table 4). Likewise, Hyvar X-L (*bromacil* SOA 5*)* offers an alternative broad-spectrum residual to Arsenal Powerline *(imazapyr* SOA 2*)* or SFM Extra *(sulfometuron-methyl* SOA 2). Although the total percent cover of herbicide treatments by 178 DAT were statistically similar, one can argue there is a difference between 2.9% cover and 28.9% cover for bareground applications. Further experiments utilizing *flumioxazin*, *prodiamine*, and *pendimethalin* with tank mix partners for bareground applications will broaden our knowledge base and add to future recommendations for pre-emergence herbicide rotations in place of *indaziflam.*

Comparing Method 240SL at 16 oz/ac + Esplanade Sure at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac to Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Plateau at 8 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac, both treatments showed similar percent total cover. One difference between these treatments is the Esplanade Sure and Esplanade 200 SC. Both offer similar rates of active ingredient *indaziflam* per acre with Esplanade Sure offering *rimsulfuron* as well. Another difference between treatments was the presence of Plateau. The Milestone VM at 7 oz/ac + Esplanade 200 SC 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac treatment resulted in more total cover than TerraVue at 5 oz/ac + Esplanade 200 SC 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac. TerraVue and Milestone VM both contain *aminopyralid.* However, TerraVue at 5 oz/ac contains 2.13 oz/ac of the active ingredient *aminopyralid* whereas Milestone VM at 7 oz/ac has 1.75 oz/ac active ingredient *aminopyralid.* Additionally, TerraVue also contains *florpyrauxifen-benzyl.* The higher rate of the *aminopyralid* active ingredient and *florpyrauxifen-benzyl* may have led to better total vegetation control for the TerraVue treatment.

CONCLUSIONS

None of the herbicide treatments provided complete season-long bareground weed control. Alternative bareground mixes that resulted in similar or less total vegetative cover to the two standard PennDOT mixes containing Method 240SL + Esplanade 200 SC + Arsenal Powerline + Plateau + RoundUp Pro Concentrate or Milestone VM + Esplanade 200 SC + Arsenal Powerline + RoundUp Pro Concentrate during this experiment included: Pendulum Aquacap at 128 oz/ac + Hyvar XL at 256 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Method 240SL at 16 oz/ac + Esplanade Sure at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Esplanade Sure at 5 oz/ac + SFM Extra at 4oz/ac + RoundUp Pro Concentrate at 64 oz/ac; and TerraVue at 5 oz/ac + Esplanade 200SC at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac. Based on the results of this experiment TerraVue at 5oz/ac is more efficacious than Milestone VM at 7 oz/ac in a bareground

mix. The addition of Hyvar X-L to Pendulum Aquacap or ProClipse mixes resulted in lower percent total vegetative cover when compared to other mixes containing Pendulum Aquacap or ProClipse; however, Hyvar is an expensive alternative. Evaluation of mixes that utilize the same broad-spectrum residual Spyder Extra or SFM Extra *(sulfometuron-methyl + metsulfuron-methyl)* and post emergence herbicide RoundUp Pro Concentrate *(glyphosate),* but different pre-emergence herbicides showed that Esplanade Sure *(indaziflam + rimsulfuron)* resulted in less total vegetive cover than similar treatments containing Piper *(flumioxazin + pyroxasulfone)*, Pendulum Aquacap *(pendimethalin)*, or ProClipse *(prodiamine).*

MANAGEMENT IMPLICATIONS

Developing alternative mixes that rotate the site of action of each herbicide component utilized in standard PennDOT bareground mixes are necessary to reduce the possibility of herbicide resistant weeds. *Indaziflam* is the standard pre-emergence herbicide, and rotations to *pendimethalin or prodiamine* (SOA 3) as well as *flumioxazin* (SOA 14) offer alternative pre-emergence herbicides. *Bromacil* (SOA 5) is an alternative broad-spectrum residual to the commonly used *imazapyr* (SOA 2) or *sulfometuron* (SOA 2). Based on the results of this experiment, a few alternative bareground mixes to consider include: 1) Pendulum Aquacap (*pendimethalin*) at 128 oz/ac + Hyvar XL (*bromacil*) at 256 oz/ac + RoundUp Pro at 64 oz/ac. This mix rotates the SOA of the pre-emergence and broad-spectrum residual components compared to a standard PennDOT mix. 2) Piper (*flumioxazin + pyroxasulfone)* at 10 oz/ac + Spyder Extra (*sulfometuron-methyl + metsulfuron-methyl*) at 4 oz/ac + RoundUp Pro at 64 oz/ac offers an alternative preemergence SOA. 3) Esplanade Sure at 5 oz/ac + SFM Extra at 4oz/ac + RoundUp Pro Concentrate at 64 oz/ac offers a mix that does not contain Milestone (*aminopyralid*) or Method 240SL (*aminocyclopyrachlo*r). Roadside specialist that use Milestone in a bareground mix should consider TerraVue in its place. Caution with all the bareground mixes must be observed. Method 240SL[29], Milestone VM[30], TerraVue[31], Arsenal Powerline[32], and Hyvar X-L[33] labels all contain statements warning of potential injury to trees and desirable plants with root systems extending into the treated area. Products containing *sulfometuron* such as SFM Extra or Spyder Extra has the potential of moving offsite after application. A careful evaluation of the site must be made to determine if soil texture, slope, and drainage patterns may cause offsite movement by wind or water erosion[34]. The use of these herbicide combinations may be considered for use on interstate or limited access routes with wide right of ways to minimize potential offsite damage.

[29] Bayer CropScience LP. Method 240SL label. http://www.cdms.net/ldat/ldCFU019.pdf
[30] Corteva Agriscience. Dow AgroSciences LLC Milestone VM label. http://www.cdms.net/ldat/ld7I2005.pdf
[31] Corteva Agriscience. Dow Agrosciences LLC TerraVue label. http://www.cdms.net/ldat/ld2IB008.pdf
[32] BASF Corporation. Arsenal Powerline label. http://www.cdms.net/ldat/ld86K002.pdf
[33] Bayer CropScience LP. Hyvar X-L label. http://www.cdms.net/ldat/ldCFT000.pdf
[34] NuFarm Americas Inc. Spyder Extra label. http://www.cdms.net/ldat/ld99R004.pdf

Table 1. Effectiveness of treatments based on percent total vegetative cover at 0, 31, 61, 91, 122, 150, & 178 days after treatment (DAT). The site was visually rated for percent total cover on April 19, May 24, June 23, July 23, August 23, September 20, & October 18, 2021. A non-ionic surfactant was added to all treatments at 0.25% v/v. Each value is the mean of four replications. Column means followed by the same letter are not significantly different.

Product	Rate oz/acre	% total cover 04/19/21 0 DAT	% total cover 05/24/21 31 DAT	% total cover 06/23/21 61 DAT	% total cover 07/23/21 91 DAT	% total cover 08/23/21 122 DAT	% total cover 09/20/21 150 DAT	% total cover 10/18/21 178 DAT
Untreated	---	14.5	22.5 b	50 b	53.8 b	58.8 b	60 b	60 b
Method 240SL Esplanade Sure Arsenal Powerline RoundUp Pro Concentrate	16 5 8 64	14.5	1 a	2.8 a	3.5 a	5.8 a	7 a	7 a
Method 240SL Esplanade 200 SC Arsenal Powerline Plateau RoundUp Pro Concentrate	16 6 8 8 64	17.9	0.9 a	1.9 a	3.2 a	4.5 a	5.6 a	5.8 a
Milestone VM Esplanade 200 SC Arsenal Powerline RoundUp Pro Concentrate	7 5 8 64	19.5	0.6 a	2.1 a	5.4 a	9 a	10.8 a	10.8 a
TerraVue Esplanade 200 SC Arsenal Powerline RoundUp Pro Concentrate	5 5 8 64	20.5	0.5 a	0.4 a	1.1 a	2.3 a	2.8 a	2.9 a
Piper Spyder Extra RoundUp Pro Concentrate	10 4 64	14.5	0.3 a	0.7 a	2.3 a	6.9 a	13.4 a	13.4 a
Pendulum Aquacap SFM Extra RoundUp Pro Concentrate	128 4 64	15.1	1.5 a	2.7 a	5.6 a	9.1 a	15.8 a	16.4 a
Pendulum Aquacap Hyvar XL RoundUp Pro Concentrate	128 256 64	22	0.7 a	0.7 a	2.2 a	4.3 a	8.3 a	8.4 a
Pendulum Aquacap Plateau Arsenal Powerline RoundUp Pro Concentrate	128 12 8 64	17.5	1.3 a	3.3 a	6.4 a	14.9 a	19.2 a	19.2 a
ProClipse SFM Extra RoundUp Pro Concentrate	32 4 64	22.8	0.8 a	1.6 a	4.1 a	11.4 a	17.3 a	18 a
ProClipse Hyvar XL RoundUp Pro Concentrate	32 256 64	17.3	0.4 a	1.6 a	6.9 a	8.8 a	12.7 a	12.7 a
ProClipse Arsenal Powerline RoundUp Pro Concentrate	32 24 64	25	2.1 a	5.3 a	13.6 a	22.9 a	28.9 a	28.9 a
Esplanade Sure SFM Extra RoundUp Pro Concentrate	5 4 64	24.8	0.6 a	1.1 a	3.1 a	4.7 a	6 a	6 a
		n.s.						

Table 2. Effectiveness of treatments based on percent grass cover at 61, 91, 122, 150, & 178 days after treatment (DAT). The site was visually rated for percent total cover on June 23, July 23, August 23, September 20, & October 18, 2021. A non-ionic surfactant was added to all treatments at 0.25% v/v. Each value is the mean of four replications. Column means followed by the same letter are not significantly different.

Product	Rate oz/acre	% grass cover 06/23/21 61 DAT	% grass cover 07/23/21 91 DAT	% grass cover 08/23/21 122 DAT	% grass cover 09/20/21 150 DAT	% grass cover 10/18/21 178 DAT
Untreated	---	19.5 b	23.8 b	23.8 b	26.3 b	26.3 b
Method 240SL Esplanade Sure Arsenal Powerline RoundUp Pro Concentrate	16 5 8 64	2.8 a	3.4 a	5.5 a	6.4 a	6.4 a
Method 240SL Esplanade 200 SC Arsenal Powerline Plateau RoundUp Pro Concentrate	16 6 8 8 64	1.8 a	3.1 a	4.3 a	5.1 a	5.3 a
Milestone VM Esplanade 200 SC Arsenal Powerline RoundUp Pro Concentrate	7 5 8 64	0.8 a	1.4 a	2.4 a	2.3 a	2.3 a
TerraVue Esplanade 200 SC Arsenal Powerline RoundUp Pro Concentrate	5 5 8 64	0.3 a	0.9 a	2.1 a	2.4 a	2.3 a
Piper Spyder Extra RoundUp Pro Concentrate	10 4 64	0.5 a	1.8 a	3.7 a	3.7 a	5.1 a
Pendulum Aquacap SFM Extra RoundUp Pro Concentrate	128 4 64	2.6 a	3.8 a	4.1 a	4.6 a	4.6 a
Pendulum Aquacap Hyvar XL RoundUp Pro Concentrate	128 256 64	0.4 a	0.8 a	0.9 a	0.8 a	0.8 a
Pendulum Aquacap Plateau Arsenal Powerline RoundUp Pro Concentrate	128 12 8 64	2.3 a	3 a	5.1 a	5.9 a	5.9 a
ProClipse SFM Extra RoundUp Pro Concentrate	32 4 64	1.4 a	2.8 a	4.8 a	8.8 a	8.8 a
ProClipse Hyvar XL RoundUp Pro Concentrate	32 256 64	0.2 a	0.4 a	0.4 a	0.4 a	0.4 a
ProClipse Arsenal Powerline RoundUp Pro Concentrate	32 24 64	3.4 a	5.8 a	6.6 a	8.6 a	8.6 a
Esplanade Sure SFM Extra RoundUp Pro Concentrate	5 4 64	0.8 a	1.9 a	2.3 a	3 a	3 a

Table 3. Effectiveness of treatments based on percent broadleaf weed (BLW) cover at 61, 91, 122, 150, & 178 days after treatment (DAT). The site was visually rated for percent total cover on June 23, July 23, August 23, September 20, & October 18, 2021. A non-ionic surfactant was added to all treatments at 0.25% v/v. Each value is the mean of four replications. Column means followed by the same letter are not significantly different.

Product	Rate oz/acre	% BLW cover 06/23/21 61 DAT	% BLW cover 07/23/21 91 DAT	% BLW cover 08/23/21 122 DAT	% BLW cover 09/20/21 150 DAT	% BLW cover 10/18/21 178 DAT
Untreated	---	30.5 b	30 b	35 b	33.8 b	33.8 b
Method 240SL Esplanade Sure Arsenal Powerline RoundUp Pro Concentrate	16 5 8 64	0 a	0.1 a	0.3 a	0.6 a	0.7 a
Method 240SL Esplanade 200 SC Arsenal Powerline Plateau RoundUp Pro Concentrate	16 6 8 8 64	0.09 a	0.1 a	0.3 a	0.5 a	0.5 a
Milestone VM Esplanade 200 SC Arsenal Powerline RoundUp Pro Concentrate	7 5 8 64	1.3 a	4.1 a	6.6 a	8.5 ab	8.5 ab
TerraVue Esplanade 200 SC Arsenal Powerline RoundUp Pro Concentrate	5 5 8 64	0.03 a	0.1 a	0.2 a	0.4 a	0.4 a
Piper Spyder Extra RoundUp Pro Concentrate	10 4 64	0.14 a	0.5 a	3.2 a	8.3 ab	8.3 ab
Pendulum Aquacap SFM Extra RoundUp Pro Concentrate	128 4 64	0.15 a	1.8 a	4.9 a	11.3 ab	11.8 ab
Pendulum Aquacap Hyvar XL RoundUp Pro Concentrate	128 256 64	0.36 a	1.4 a	3.4 a	7.5 ab	7.6 ab
Pendulum Aquacap Plateau Arsenal Powerline RoundUp Pro Concentrate	128 12 8 64	1 a	3.4 a	9.8 a	13.3 ab	13.3 ab
ProClipse SFM Extra RoundUp Pro Concentrate	32 4 64	0.23 a	1.4 a	6.6 a	8.5 ab	9.3 ab
ProClipse Hyvar XL RoundUp Pro Concentrate	32 256 64	1.4 a	6.6 a	8.5 a	12.3 ab	12.3 ab
ProClipse Arsenal Powerline RoundUp Pro Concentrate	32 24 64	1.2 a	7.9 a	16.3 ab	20.3 ab	20.3 ab
Esplanade Sure SFM Extra RoundUp Pro Concentrate	5 4 64	0.31 a	1.2 a	2.4 a	3 a	3 a

Table 4. Bareground herbicide mixes listed by product name, rate, common name, Weed Science Society of America (WSSA) site of action (SOA) group, and component within a bareground mix: pre-emergence herbicide (pre); post emergence (post) (post + residual); and broad-spectrum residual (bsr).

Product	Rate oz/acre	Common Name	WSSA SOA group	Component
Untreated	---	--	--	
Method 240SL	16	*aminocyclopyrachlor*	4	post + residual
Esplanade Sure	5	*indaziflam + rimsulfuron*	29+2	pre + post
Arsenal Powerline	8	*imazapyr*	2	bsr
RoundUp Pro Concentrate	64	*glyphosate*	9	post + residual
Method 240SL	16	*aminocyclopyrachlor*	4	post + residual
Esplanade 200 SC	6	*indaziflam*	29	pre
Arsenal Powerline	8	*imazapyr*	2	bsr
Plateau	8	*imazapic*	2	pre
RoundUp Pro Concentrate	64	*glyphosate*	9	post + residual
Milestone VM	7	*aminopyralid*	4	post + residual
Esplanade 200 SC	5	*indaziflam*	29	pre
Arsenal Powerline	8	*imazapyr*	2	bsr
RoundUp Pro Concentrate	64	*glyphosate*	9	post
TerraVue	5	*aminopyralid+florpyrauxifen*	4+4	post + residual
Esplanade 200 SC	5	*indaziflam*	29	pre
Arsenal Powerline	8	*imazapyr*	2	bsr
RoundUp Pro Concentrate	64	*glyphosate*	9	post
Piper	10	*flumioxazin+pyroxasulfone*	14+15	pre+post
Spyder Extra	4	*sulfometuron+metsulfuron*	2+2	bsr
RoundUp Pro Concentrate	64	*glyphosate*	9	post
Pendulum Aquacap	128	*pendimethalin*	3	pre
SFM Extra	4	*sulfometuron+metsulfuron*	2+2	bsr
RoundUp Pro Concentrate	64	*glyphosate*	9	post

Table 4 (continued). Bareground herbicide mixes listed by product name, rate, common name, Weed Science Society of America (WSSA) site of action (SOA) group, and component within a bareground mix: pre-emergence herbicide (pre); post emergence (post) (post + residual); and broad-spectrum residual (bsr).

Product	Rate oz/acre	Common Name	WSSA SOA group	Component
Pendulum Aquacap	128	*pendimethalin*	3	pre
Hyvar XL	256	*bromacil*	5	bsr
RoundUp Pro Concentrate	64	*glyphosate*	9	post
Pendulum Aquacap	128	*pendimethalin*	3	pre
Plateau	12	*imazapic*	2	pre+post
Arsenal Powerline	8	*imazapyr*	2	bsr
RoundUp Pro Concentrate	64	*glyphosate*	9	post
ProClipse	32	*prodiamine*	3	pre
SFM Extra	4	*sulfometuron+metsulfuron*	2+2	bsr
RoundUp Pro Concentrate	64	*glyphosate*	9	post
ProClipse	32	*prodiamine*	3	pre
Hyvar XL	256	*bromacil*	5	bsr
RoundUp Pro Concentrate	64	*glyphosate*	9	post
ProClipse	32	*prodiamine*	3	pre
Arsenal Powerline	24	*imazapyr*	2	bsr
RoundUp Pro Concentrate	64	*glyphosate*	9	post
Esplanade Sure	5	*indaziflam + rimsulfuron*	29+2	pre
SFM Extra	4	*sulfometuron+metsulfuron*	2+2	bsr
RoundUp Pro Concentrate	64	*glyphosate*	9	post

APPENDIX

Appendix Table 1. Canopy area of autumn olive (*Elaeagnus umbellata*) and dose amount per plant. The experiment evaluated 11 treatments, with 10 plants per treatment.

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft.sq.)	Dose (ml.)
1	8	60	48	54	96	72	219
2	9	60	60	60	96	80	243
3	2	48	48	48	84	56	170
4*	1	24	36	30	84	35	106
5*	6	24	24	24	60	20	61
6	3	18	18	18	72	18	55
7	7	72	72	72	72	72	219
8	10	84	96	90	72	90	274
9	11	48	36	42	60	35	106
10	4	108	60	84	84	98	298
11	5	60	60	60	72	60	182
12	7	60	36	48	48	32	97
13	4	60	48	54	72	54	164
14	5	48	24	36	60	30	91
15	11	48	48	48	78	52	158
16	6	30	24	27	60	23	68
17	1	36	42	39	60	33	99
18	8	36	60	48	84	56	170
19	3	72	96	84	90	105	319
20	2	84	42	63	60	53	160
21	10	60	54	57	72	57	173
22	9	60	60	60	84	70	213
23	8	48	60	54	72	54	164
24	2	24	24	24	72	24	73
25	11	36	72	54	84	63	192
26	10	30	48	39	84	46	138
27*	4	84	96	90	96	120	365
28	9	60	108	84	138	161	490
29	3	72	60	66	72	66	201
30	5	48	60	54	78	59	178

Appendix Table 1 (continued). Canopy area of autumn olive (*Elaeagnus umbellata*) and dose amount per plant. The experiment evaluated 11 treatments, with 10 plants per treatment.

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft.sq.)	Dose (ml.)
31	6	72	96	84	78	91	277
32	1	24	24	24	96	32	97
33	7	78	104	91	111	140	427
34	7	48	96	72	108	108	328
35*	9	36	40	38	38	20	61
36	8	58	36	47	48	31	95
37*	5	48	60	54	54	41	123
38	10	40	72	56	80	62	189
39	1	48	96	72	108	108	328
40	6	128	108	118	90	148	449
41	4	48	32	40	60	33	101
42	2	60	60	60	110	92	279
43	11	40	28	34	56	26	80
44	3	30	30	30	40	17	51
45	6	80	72	76	72	76	231
46	11	24	36	30	60	25	76
47	3	40	58	49	77	52	159
48	9	69	36	52.5	65	47	144
49	4	56	36	46	54	35	105
50	10	41	52	46.5	64	41	126
51	5	20	36	28	50	19	59
52	7	48	72	60	44	37	112
53	8	48	50	49	80	54	166
54	1	32	42	37	55	28	86
55	2	48	36	42	96	56	170
56	11	48	42	45	107	67	203
57	2	57	40	48.5	70	47	143
58	9	72	48	60	80	67	203
59	7	75	90	82.5	147	168	512
60	3	60	40	50	86	60	182

Appendix Table 1 (continued). Canopy area of autumn olive (*Elaeagnus umbellata*) and dose amount per plant. The experiment evaluated 11 treatments, with 10 plants per treatment.

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft.sq.)	Dosage (ml.)
61	10	24	24	24	72	24	73
62	5	30	48	39	72	39	119
63	6	48	48	48	102	68	207
64	1	70	82	76	108	114	347
65	8	48	72	60	74	62	188
66	4	42	36	39	77	42	127
67	6	24	24	24	72	24	73
68*	4	36	48	42	60	35	106
69	10	36	48	42	70	41	124
70	2	60	61	60.5	90	76	230
71	11	43	46	44.5	74	46	139
72	1	24	32	28	69	27	82
73	5	30	32	31	49	21	64
74	7	48	48	48	74	49	150
75	8	39	58	48.5	72	49	147
76	3	66	72	69	104	100	303
77	9	40	40	40	67	37	113
78	9	64	47	55.5	64	49	150
79	4	64	36	50	78	54	165
80	5	32	20	26	56	20	61
81	7	32	42	37	52	27	81
82	10	30	36	33	51	23	71
83	1	35	52	43.5	48	29	88
84	11	24	24	24	84	28	85
85	2	46	48	47	48	31	95

Appendix Table 1 (continued). Canopy area of autumn olive (*Elaeagnus umbellata*) and dose amount per plant. The experiment evaluated 11 treatments, with 10 plants per treatment.

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft.sq.)	Dosage (ml.)
86	8	52	72	62	64	55	168
87	6	42	26	34	39	18	56
88	3	36	30	33	48	22	67
89*	2	43	53	48	100	67	203
90	6	112	60	86	100	119	363
91	3	106	78	92	90	115	350
92	11	20	55	37.5	30	16	48
93*	4	46	48	47	55	36	109
94*	10	40	44	42	44	26	78
95*	9	40	48	44	78	48	145
96	8	55	48	51.5	134	96	291
97	7	90	84	87	137	166	503
98	1	56	74	65	77	70	211
99*	5	87	90	88.5	78	96	292
100	3	26	30	28	63	25	75
101	1	30	36	33	68	31	95
102	2	83	56	69.5	62	60	182
103	11	56	36	46	50	32	97
104	4	36	54	45	56	35	106
105	5	32	42	37	49	25	77
106*	6	54	40	47	53	35	105
107*	7	64	42	53	66	49	148
108*	10	24	24	24	48	16	49
109	9	92	102	97	74	100	303
110	8	72	54	63	77	67	205

*= missing plants by last rating September 15, 2021

Appendix Table 2. Canopy area of each plant and species. A total of four treatments were evaluated. Each plant is an individual treatment, and each treatment was replicated 10 times.

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft. sq.)	Dosage (ml.)	Plant ID
1	1	74	72	73	124	126	382	L. maackii
2	2	83	98	90.5	130	163	497	L. maackii
3	4	51	71	61	71	60	183	L. maackii
4	3	71	73	72	94	94	286	L. maackii
5	4	48	73	60.5	95	80	243	L. maackii
6	1	89	65	77	118	126	384	L. maackii
7	2	78	62	70	94	91	278	L. maackii
8	3	89	70	79.5	98	108	329	L. maackii
9	3	73	56	64.5	83	74	226	L. maackii
10	4	52	58	55	66	50	153	L. maackii
11	1	47	46	46.5	71	46	139	L. maackii
12	2	116	114	115	121	193	588	L. maackii
13	4	164	114	139	143	276	840	L. maackii
14	1	95	130	112.5	160	250	760	L. maackii
15	2	85	81	83	89	103	312	L. maackii
16	3	91	106	98.5	105	144	437	L. maackii
17	2	47	55	51	95	67	205	L. maackii
18	4	58	98	78	89	96	293	L. maackii
19	3	68	38	53	83	61	186	L. maackii
20	1	57	71	64	95	84	257	L. maackii
21	2	35	70	52.5	114	83	253	L. maackii
22	3	78	40	59	88	72	219	L. maackii
23	4	54	43	48.5	71	48	145	L. maackii
24	1	75	49	62	109	94	285	L. maackii
25	1	73	50	61.5	62	53	161	L. maackii
26	2	27	94	60.5	110	92	281	L. maackii
27	4	73	93	83	121	139	424	L. maackii
28	3	121	73	97	98	132	402	L. maackii
29	1	131	55	93	93	120	365	L. maackii
30	4	68	99	83.5	104	121	367	L. maackii
31	3	55	47	51	85	60	183	L. maackii
32	2	56	62	59	76	62	189	L. maackii
33	3	67	65	66	109	100	304	L. maackii
34	1	54	73	63.5	98	86	263	L. maackii

Appendix Table 2 (continued). Canopy area of each plant and species. A total of four treatments were evaluated. Each plant is an individual treatment, and each treatment was replicated 10 times.

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft. sq.)	Dosage (ml.)	Plant ID
35	2	94	67	80.5	90	101	306	L. maackii
36	4	62	58	60	81	68	205	L. maackii
37	4	75	80	77.5	72	78	236	L. maackii
38	1	52	70	61	86	73	222	L. maackii
39	2	47	49	48	60	40	122	L. maackii
40	3	89	61	75	88	92	279	L. maackii

Appendix Table 3. Canopy area of amur honeysuckle (*Lonicera maackii*) or morrow's honeysuckle (*Lonicera morrowii*) and dose amount per plant. The experiment evaluated 13 treatments, with 10 plants per treatment.

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft. sq.)	Dose (ml.)	Plant ID
1	10	70	48	59	76	62	189	L. maackii
2	5	62	50	56	79	61	187	L. maackii
3	8	48	56	52	72	52	158	L. maackii
4	12	68	72	70	92	89	272	L. maackii
5	11	114	85	99.5	92	127	387	L. maackii
6	7	89	65	77	78	83	254	L. maackii
7	3	72	48	60	86	72	218	L. maackii
8	2	108	77	92.5	84	108	328	L. maackii
9	4	60	75	67.5	82	77	234	L. maackii
10	9	62	48	55	84	64	195	L. maackii
11	6	120	84	102	90	128	388	L. maackii
12	1	90	80	85	89	105	320	L. maackii
13	6	38	44	41	65	37	113	L. maackii
14	4	60	55	57.5	67	54	163	L. maackii
15	9	34	60	47	56	37	111	L. maackii
16	8	55	30	42.5	75	44	135	L. maackii
17	7	43	70	56.5	67	53	160	L. maackii
18	12	148	120	134	96	179	543	L. morrowii
19	3	106	84	95	96	127	385	L. maackii
20	10	84	80	82	88	100	305	L. maackii
21	11	80	40	60	82	68	208	L. maackii
22	5	100	72	86	96	115	349	L. maackii
23	1	108	72	90	114	143	433	L. maackii
24	2	65	94	79.5	72	80	242	L. maackii
25	4	67	40	53.5	100	74	226	L. maackii
26	6	84	64	74	92	95	288	L. maackii
27	2	36	30	33	70	32	98	L. maackii
28	11	53	72	62.5	90	78	238	L. maackii
29	1	69	48	58.5	100	81	247	L. maackii
30	7	72	45	58.5	97	79	240	L. maackii
31	3	42	48	45	77	48	146	L. maackii
32	5	64	52	58	66	53	162	L. maackii
33	10	96	80	88	94	115	349	L. morrowii

Appendix Table 3 (continued). Canopy area of amur honeysuckle (*Lonicera maackii*) or morrow's honeysuckle (*Lonicera morrowii*) and dose amount per plant. The experiment evaluated 13 treatments, with 10 plants per treatment.

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft. sq.)	Dose (ml.)	Plant ID
34	8	72	60	66	65	60	181	L. maackii
35	12	70	70	70	84	82	248	L. maackii
36	9	66	48	57	55	44	132	L. maackii
37	12	120	104	112	104	162	492	L. maackii
38	2	45	57	51	62	44	134	L. maackii
39	3	68	44	56	55	43	130	L. maackii
40	10	59	48	53.5	87	65	197	L. maackii
41	8	48	48	48	90	60	182	L. maackii
42	9	54	72	63	90	79	239	L. maackii
43	1	44	48	46	71	45	138	L. maackii
44	6	40	32	36	79	40	120	L. maackii
45	5	48	33	40.5	82	46	140	L. maackii
46	7	96	72	84	86	100	305	L. maackii
47	4	80	60	70	84	82	248	L. maackii
48	11	64	40	52	58	42	127	L. maackii
49	8	32	22	27	36	14	41	L. maackii
50	2	30	27	28.5	56	22	67	L. maackii
51	7	66	80	73	80	81	247	L. maackii
52	1	101	70	85.5	85	101	307	L. maackii
53	10	60	46	53	52	38	116	L. maackii
54	3	76	57	66.5	92	85	258	L. maackii
55	9	84	54	69	88	84	256	L. maackii
56	12	80	86	83	98	113	344	L. maackii
57	4	39	27	33	70	32	98	L. maackii
58	6	55	34	44.5	60	37	113	L. maackii
59	11	66	60	63	63	55	168	L. maackii
60	5	46	39	42.5	61	36	110	L. maackii
61	10	50	55	52.5	70	51	155	L. maackii
62	12	35	20	27.5	27	10	31	L. maackii
63	8	34	27	30.5	22	9	28	L. maackii
64	6	58	41	49.5	70	48	146	L. maackii
65	7	54	58	56	88	68	208	L. maackii
66	2	25	27	26	22	8	24	L. maackii
67	5	84	55	69.5	66	64	194	L. maackii
68	4	41	34	37.5	70	36	111	L. maackii

Appendix Table 3 (continued). Canopy area of amur honeysuckle (*Lonicera maackii*) or morrow's honeysuckle (*Lonicera morrowii*) and dose amount per plant. The experiment evaluated 13 treatments, with 10 plants per treatment.

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft. sq.)	Dose (ml.)	Plant ID
69	9	45	60	52.5	75	55	166	L. maackii
70	1	32	22	27	34	13	39	L. maackii
71	3	36	36	36	56	28	85	L. maackii
72	11	54	52	53	80	59	179	L. maackii
73	9	75	101	88	104	127	387	L. maackii
74	1	63	56	59.5	70	58	176	L. maackii
75	11	84	65	74.5	85	88	267	L. maackii
76	3	53	40	46.5	65	42	128	L. maackii
77	8	50	35	42.5	82	48	147	L. maackii
78	6	52	38	45	82	51	156	L. maackii
79	5	60	43	51.5	58	41	126	L. maackii
80	10	63	58	60.5	73	61	187	L. maackii
81	7	51	59	55	87	66	202	L. maackii
82	4	101	45	73	113	115	348	L. maackii
83	12	63	47	55	65	50	151	L. maackii
84	2	76	60	68	76	72	218	L. maackii
85	3	57	50	53.5	80	59	181	L. maackii
86	4	54	60	57	74	59	178	L. maackii
87	7	72	92	82	75	85	260	L. maackii
88	9	64	42	53	70	52	157	L. maackii
89	6	48	60	54	90	68	205	L. maackii
90	1	80	65	72.5	87	88	266	L. maackii
91	8	33	46	39.5	80	44	133	L. maackii
92	5	56	40	48	65	43	132	L. maackii
93	10	48	60	54	58	44	132	L. maackii
94	2	64	30	47	76	50	151	L. maackii
95	12	60	54	57	76	60	183	L. maackii
96	11	44	36	40	54	30	91	L. maackii
97	4	49	55	52	65	47	143	L. maackii
98	1	44	57	50.5	77	54	164	L. maackii
99	6	44	37	40.5	70	39	120	L. maackii
100	12	66	53	59.5	80	66	201	L. maackii
101	7	49	44	46.5	67	43	132	L. maackii
102	2	25	24	24.5	69	23	71	L. maackii
103	10	84	77	80.5	94	105	320	L. maackii

Appendix Table 3 (continued). Canopy area of amur honeysuckle (*Lonicera maackii*) or morrow's honeysuckle (*Lonicera morrowii*) and dose amount per plant. The experiment evaluated 13 treatments, with 10 plants per treatment.

Plant	Treatment	Width 1 (in.)	Width 2 (in.)	Average Width (in.)	Height (in.)	Area (ft. sq.)	Dose (ml.)	Plant ID
104	8	84	52	68	70	66	201	L. maackii
105	3	35	38	36.5	74	38	114	L. maackii
106	9	48	72	60	90	75	228	L. maackii
107	11	60	65	62.5	78	68	206	L. maackii
108	5	50	48	49	75	51	155	L. maackii
109	6	108	74	91	92	116	354	L. maackii
110	9	80	71	75.5	103	108	328	L. maackii
111	1	60	84	72	90	90	274	L. maackii
112	4	34	55	44.5	70	43	132	L. maackii
113	8	42	72	57	84	67	202	L. maackii
114	2	60	80	70	100	97	296	L. maackii
115	12	36	42	39	52	28	86	L. maackii
116	10	36	68	52	84	61	184	L. maackii
117	11	46	64	55	86	66	200	L. maackii
118	5	42	44	43	68	41	124	L. maackii
119	7	36	24	30	46	19	58	L. maackii
120	3	56	40	48	59	39	120	L. maackii
A1	13	130	65	97.5	125	169	515	L. maackii
A2	13	46	72	59	70	57	174	L. maackii
A3	13	60	45	52.5	72	53	160	L. maackii
A4	13	16	38	27	46	17	52	L. maackii
A5	13	84	45	64.5	66	59	180	L. maackii
A6	13	67	80	73.5	87	89	270	L. maackii
A7	13	48	72	60	68	57	172	L. maackii
A8	13	27	36	31.5	62	27	82	L. maackii
A9	13	100	90	95	140	185	562	L. maackii
A10	13	72	48	60	80	67	203	L. maackii

Appendix Table 4. Canopy area of each plant. A total of eight treatments were evaluated. Each plant is an individual treatment, and each treatment was replicated 10 times.

Plant #	Treatment	Radius (in.)	Height (in.)	Area (ft. sq.)	Dosage (ml.)
1	4	42	108	274.89	836
2	1	24	60	87.96	268
3	8	38	80	195.65	595
4	2	49	108	335.67	1021
5	5	22	48	67.20	204
6	7	32	102	187.10	569
7	6	18	50	53.41	162
8	3	46	94	281.00	855
9	4	13	45	32.90	100
10	1	12	45	29.85	91
11	5	32	109	196.87	599
12	2	11	82	44.64	136
13	8	13	55	38.57	117
14	7	22	70	88.31	269
15	6	32	108	195.48	594
16	3	30	96	164.93	502
17	7	33	102	194.39	591
18	3	45	109	302.38	920
19	4	32	60	128.46	391
20	5	28	60	107.51	327
21	8	36	102	216.77	659
22	1	16	60	53.06	161
23	2	16	89	73.30	223
24	6	36	128	257.61	783
25	2	24	60	87.96	268
26	8	36	89	196.35	597
27	7	26	80	120.25	366
28	5	44	112	299.50	911
29	4	16	51	46.77	142
30	6	11	45	26.88	82
31	1	20	43	54.98	167
32	3	12	60	37.70	115
33	8	24	73	101.58	309
34	2	17	50	49.70	151
35	1	13	47	34.03	104
36	5	17	62	58.60	178

Appendix Table 4. Canopy area of each plant. A total of eight treatments were evaluated. Each plant is an individual treatment, and each treatment was replicated 10 times.

Plant #	Treatment	Radius (in.)	Height (in.)	Area (ft. sq.)	Dosage (ml.)
37	6	24	87	116.24	354
38	3	18	50	53.41	162
39	7	36	120	245.04	745
40	4	36	122	248.19	755
41	8	18	40	45.55	139
42	3	12	50	32.46	99
43	7	15	64	51.71	157
44	4	22	72	90.23	274
45	6	19	60	65.49	199
46	5	10	52	27.05	82
47	2	18	68	67.54	205
48	1	30	62	120.43	366
49	6	56	76	322.54	981
50	7	24	82	111.00	338
51	8	30	110	183.26	557
52	2	9	69	30.63	93
53	3	12	77	46.60	142
54	5	35	88	187.84	571
55	1	26	78	117.98	359
56	4	42	82	227.24	691
57	5	22	50	69.12	210
58	2	12	59	37.18	113
59	4	30	65	124.35	378
60	1	18	91	85.61	260
61	8	30	70	130.90	398
62	3	24	62	90.06	274
63	7	39	77	197.40	600
64	6	34	102	201.76	614
65	6	12	46	30.37	92
66	7	26	55	91.89	279
67	8	30	64	123.05	374
68	3	32	60	128.46	391
69	1	26	72	111.18	338
70	4	36	110	229.34	697
71	5	40	96	237.36	722
72	2	36	103	218.34	664

Appendix Table 4. Canopy area of each plant. A total of eight treatments were evaluated. Each plant is an individual treatment, and each treatment was replicated 10 times.

Plant #	Treatment	Radius (in.)	Height (in.)	Area (ft. sq.)	Dosage (ml.)
73	5	30	70	130.90	398
74	8	40	92	230.38	701
75	1	40	94	233.87	711
76	6	48	106	322.54	981
77	4	24	73	101.58	309
78	7	32	53	118.68	361
79	3	55	107	388.77	1182
80	2	30	54	109.96	334