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# Roadside Vegetation Management Research – 2023 Report

ANNUAL REPORT

June 30, 2023

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THE PENNSYLVANIA STATE UNIVERSITY

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| **16. Abstract**<br><br>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 TerraVue Applications to Amur Honeysuckle *(Lonicera maackii)*-Third Year, Evaluation of Foliar Applications to Shrub Honeysuckle *(Lonicera spp.)* During Flowering-Third Year, Evaluation of Foliar Applications to Callery Pear *(Pyrus calleryana)*-Second Year, Evaluation of PennDOT Formula R, Evaluation of Native Grass and Pollinator Seed Mixes and Seeding Methods for Conversion and Establishment Along Roadsides-Third Year, Efficacy of Herbicides and Herbicide Mixes on Poison Hemlock *(Conium maculatum)*, Efficacy of Herbicides and Herbicide Mixes on Wild Parsnip *(Pastinaca sativa)*, Evaluation of Alternative Bareground Herbicide Mixes, Evaluation of Bareground Herbicide Mixes Without Glyphosate. | | | |
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## 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

Report # PA-2022-017-PSU RVM Roadside Vegetation Management Research – 2022 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 |
| Fusilade II | fluazifop-P-butyl | 2 EC | Syngenta |
| 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 |
| Pendulum Aquacap | pendimethalin | 3.8 ME | BASF Corp. |
| Plainview SC | indaziflam+aminocyclopyrachlor+imazapyr | 0.18+0.5+1.51 SC | Bayer Environmental Science |
| Plateau | imazapic | 2 S | BASF Corp. |
| ProClipse | prodiamine | 65 WDG | NuFarm Inc. |
| RoundUp Pro Concentrate | glyphosate | 5 S | Monsanto Company |
| Segment II | sethoxydim | 1.5 EC | BASF |
| SFM Extra | sulfometuron + metsulfuron | 56.25 + 15 WDG | Alligare LLC |
| Telar XP | chlorsulfuron | 75 DF | Bayer Environmental Science |
| 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 TERRAVUE APPLICATIONS TO AMUR HONEYSUCKLE (*Lonicera maackii*), 3rd 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 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 67.4% injury while the untreated check displayed 1% leaf and stem injury due to biotic and abiotic stress. One year after treatment, TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac resulted in 14.5% living leaf canopy, TerraVue at 2.85 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac resulted in 21% living leaf canopy, and TerraVue at 2.85 oz/ac resulted in 64.5% living leaf canopy. Two years after treatment no herbicide treatment produced a 100% control in the treated plants. As a matter of fact, the living leaf canopy increased among the herbicide treatments meaning regrowth was occurring. TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac resulted in 21% living leaf canopy compared to 14.5% one year after treatment, TerraVue at 2.85 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac resulted in 34% living leaf canopy compared to 21%, and TerraVue at 2.85 oz/ac showed 69.4% living leaf canopy.


## 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[1]. Amur honeysuckle can reach heights of 15 feet tall and has a white flower changing to yellow, 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 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.

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

## 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, 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 1). During 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 where 0 = no injury–100 = complete injury on October 2, 2020, 23 days after treatment (DAT) and for percent living leaf canopy where 0 = 0% living leaf canopy–100 = 100% living leaf canopy reduction on September 8, 2021, 364 DAT and September 8, 2022, 729 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 + Freelexx at 64 oz/ac + 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 + Freelexx at 64 oz/ac + 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 living leaf canopy ranged from 96.3% for the untreated check to 14.5 % 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 21% living leaf canopy and TerraVue at 2.85 oz/ac resulted in 64.5% living leaf canopy. By September 8, 2022, 729 DAT, the untreated check had 93.7% living leaf canopy naturally occurring leaf damage. All herbicide treatments were showing reduced activity with treated plants showing regrowth at variable rates with TerraVue at 2.85 oz/ac resulting in 69.4% living leaf canopy. TerraVue at 2.85 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac resulted in 34% living leaf canopy. Finally, TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac resulted in 21% living leaf canopy.

An objective at the onset of the experiment was to determine the effectiveness of TerraVue as a standalone treatment on honeysuckle. It appears that TerraVue alone is ineffective but the addition of Vastlan and Freelexx or Freelexx and MSM 60 will increase its effectiveness. Since, none of the treatments resulted in complete control of honeysuckle a second, follow-up treatment will be required.

## CONCLUSIONS

All herbicide treatments resulted in variable rates of injury to Amur honeysuckle. TerraVue at 2.85 oz/ac should not be considered as a treatment for Amur honeysuckle. The addition of Vastlan and Freelexx or Freelexx and MSM 60 to TerraVue increases leaf and stem damage. No treatment resulted in 100% control.

## MANAGEMENT IMPLICATIONS

TerraVue as a standalone treatment for honeysuckle is not recommended. The mixes of TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac and TerraVue at 2.85 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac provided marginal canopy reduction of amur honeysuckle 2 years after treatment. Since the honeysuckle was not completely controlled a follow up treatment is required adding additional costs. There are other foliar herbicide treatment combinations that appear more effective for canopy reduction of shrub honeysuckle after two years including Freelexx (96 oz/ac) + Garlon 3A (64 oz/ac) + MSM 60 (0.5 oz/ac)[2]. Past work by the roadside project shows complete honeysuckle control two years after treatment with a single treatment of glyphosate at 128 oz/ac or 2,4-D at 128 oz/ac[3]. Caution should be exercised while using glyphosate, as it will damage or kill existing desirable groundcovers. Glyphosate as a targeted application or broadcast over sites with little or no desirable vegetation maybe an option in certain situations. If applications create or increase bareground, integrated vegetation management practices recommend seeding a competitive grass groundcover such as formula L.

[2] Jeffrey C Jodon Jr. et. al. 2023. Evaluation of Foliar Applications to Shrub Honeysuckle (*Lonicera spp.*) During Flowering-3rd Year. Roadside Vegetation Management Research 2023 Report. 5-11.

[3] Jeffrey C Jodon et. al. 2021. Evaluation of Brush Control Herbicides on Exotic Shrub Honeysuckle-3rd Year. Roadside Vegetation Management Research 2021 Report. pp 1-4.

Table 1. Percent injury and living leaf canopy cover of Amur honeysuckle (*Lonicera maackii)*. The experiment was visually rated for percent injury where 0 = no injury - 100 = complete injury on October 2, 2020, 23 days after treatment (DAT) and percent living leaf canopy where 0 = 0 % leaf canopy cover – 100 = 100 % living leaf canopy cover on September 8, 2021, 364 DAT and September 8, 2022, 729 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 | % Living Leaf Canopy 9/8/21 364 DAT | % Living Leaf Canopy 9/8/22 730 DAT |
|---|---|---|---|---|
| Untreated | -- | 1 a | 96.3 c | 93.7 c |
| TerraVue | 2.85 | 67.4 b | 64.5 b | 69.4 bc |
| TerraVue<br>Freelexx<br>MSM 60 | 2.85<br>96<br>0.5 | 99.6 c | 21 a | 34 ab |
| TerraVue<br>Vastlan<br>Freelexx | 2.85<br>64<br>64 | 95.6 c | 14.5 a | 21 a |

# EVALUATION OF FOLIAR APPLICATIONS TO SHRUB HONEYSUCKLE *(Lonicera spp.)* DURING FLOWERING-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*), 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 treatments included an untreated check; 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; Pre-Rain TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac; Freelexx at 128 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. Treatments 1-10 were applied on June 4, 2020. A heavy rainstorm developed about 20-30 minutes after the Pre-Rain TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac treatment was sprayed, so no further treatments were applied. The following day, June 5, 2020, Freelexx at 128 oz/ac and MSM 60 at 0.5 oz/ac treatments were applied. The potential rain compromise of the first Pre-Rain TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac treatment, compelled a reapplication of that treatment to additional honeysuckle shrubs on June 8, 2020, designated as Post Rain, TerraVue 2.85 oz/ac + Freelexx 64 oz/ac + Vastlan 64 oz/ac. 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. Two-years after treatment, no treatment resulted in 100% canopy reduction, however, Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac was the most effective at 97.2% canopy reduction. Treatments with at least 90% canopy reduction included: TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac; Freelexx at 96 oz/ac + TerraVue at 2.85 oz/ac + MSM 60 at 0.5 oz/ac; and Freelexx at 96 oz/ac + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac.

## 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[4].

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[5]. 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[6]. 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[7]. 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[8]. 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 treatments included: an untreated check; 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; and TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac +

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[4] 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.

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

[6] 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

[7] 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

[8] 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

Freelexx at 64 oz/ac. 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 2). 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 herbicide wash off from leaf surfaces, this treatment (TerraVue at 2.85 oz/ac + Freelexx 64 oz/ac + Vastlan 64 oz/ac), was applied to additional set of 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 treatment not impacted by the rain event. In Appendix Table 2, plants A1 through A10 represent the honeysuckles treated in treatment 13. 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 for percent canopy reduction where 0 = 0% living leaf canopy–100 = 100% living leaf canopy on June 14, 2021, 377 DAT and June 8, 2022, 734 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%), Pre-Rain TerraVue at 2.85 oz/ac + Vastlan 64 oz/ac + Freelexx at 64 oz/ac (62%), 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%), treatments produced less injury. The untreated check showed 1% injury.

By 375 DAT, living leaf canopy ranged from 99.5% for the untreated check to 3% for the Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac treatment. Other treatments with less than 10% living leaf canopy included: Post Rain TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac (3.6%), Freelexx at 96 oz/ac +TerraVue at 2.85 oz/ac + MSM 60 at 0.5 oz/ac (8.5%) and Garlon 3A at 64 oz/ac + Freelexx at 128 oz/ac (9%). The percent living leaf canopy for the remaining treatments were Garlon 3A at 128 oz/ac (10.5%), Freelexx at 128 oz/ac (12.1%), RoundUp Pro Concentrate at 104 oz/ac (28.3%), Pre-Rain TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac (30.5%), Vanquish at 64 oz/ac (38%), MSM 60 at 0.5 oz/ac (55.5%), and TerraVue at 2.85 oz/ac (62%). All treatments that resulted in less than 10% living leaf canopy were herbicide combination mixes and all contained Freelexx at various rates ranging from 64 oz/ac to 128 oz/ac. Interestingly the individual components of the combination mixes applied alone resulted in more living leaf canopy (e.g., Freelexx at 128 oz/ac, 12.1%; Garlon 3A at 128 oz/ac, 10.5%; MSM 60 at 0.5 oz/ac, 55.5%; and TerraVue at 2.85 oz/ac, 62%) when compared to the herbicide mixes.

By June 8, 2022, 735 DAT, living leaf canopy ranged from 96.3% for the untreated check to 2.8% for the Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac treatment. Other treatments with 10% or less of living leaf canopy included Post Rain TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac (5.5%), Freelexx at 96 oz/ac +TerraVue at 2.85 oz/ac + MSM 60 at 0.5 oz/ac (9%), and Freelexx at 96 oz/ac + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac (10%). Evaluating herbicide mixes compared to the individual herbicides showed that most mixes resulted in less living leaf canopy than treatments consisting of an individual herbicide. For example, Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac resulted in 2.8% living leaf canopy whereas Freelexx at 128 oz/ac showed 11.5%, Garlon 3A at 128 oz/ac had 12.5%, and MSM 60 alone had 56% living leaf canopy.

The June 4$^{th}$ treatments were applied in order 2 through 10 (Table 1). Three treatments may have been impacted by the rainstorm: Pre-Rain 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 at 104 oz/ac (treatment 8).

In comparing the Pre-Rain and Post Rain TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx 64 oz/ac treatments, it appears the rainstorm did compromise the Pre-Rain 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 Pre-Rain 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 and two years after treatment. Percent living leaf canopy of the Post Rain TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx 64 oz/ac treatment was 3.6% where the Pre-Rain TerraVue treatment at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx 64 oz/ac was 30.5% one year after treatment. By two years after treatment, percent living leaf canopy of the Post Rain TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx 64 oz/ac treatment was 5.5% where the Pre-Rain TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx 64 oz/ac treatment was 34.5%. It appears from the data presented

that Pre-Rain 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[9]. In comparison the canopy reduction one year after treatment for the current experiment TerraVue at 2.85 oz/ac resulted in 38% canopy reduction (62 % living leaf canopy) 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 (i.e., less % living leaf canopy) for 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 differences in the seasonal timing of application between the two experiments. Based on field notes, the RoundUp Pro Concentrate treatment was completed approximately 2-2.5 hours before the rainstorm.

## CONCLUSIONS

Freelexx at 96 oz/ac + Garlon 3A at 64 oz/ac + MSM 60 at 0.5 oz/ac was most effective at 2.8% living leaf canopy while Post Rain TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac was similar in overall living leaf canopy at 5.5%. Additional treatments that were statistically similar but on average less effective based on percentage living leaf canopy included Freelexx at 96 oz/ac +TerraVue at 2.85 oz/ac + MSM 60 at 0.5 oz/ac, Freelexx at 96 oz/ac + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac, Freelexx at 128 oz/ac, Garlon 3A at 128 oz/ac, Garlon 3A at 64 oz/ac + Freelexx at 128 oz/ac, RoundUp Pro Concentrate at 104 oz/ac, and Pre-Rain TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac. TerraVue at 2.85 oz/ac, MSM 60 at 0.5 oz/ac, and Vanquish at 64 oz/ac are treatments that should not be consider for use due to poor performance. We have noticed in comparing these results to other woody invasive species experiments that in this experiment the combination herbicide mixes proved more effective, whereas with other experiments (e.g., autumn olive and previous honeysuckle) the components alone were more effective in long-term canopy reduction or control[10,11]. We have not determined where or why an antagonism may be occurring with the combination herbicide mixes in those previous experiments, but not with the current non-native honeysuckle at flowering experiment. One of the unintended consequences of this experiment was that we learned that TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac was not rain fast when applied 30 minutes before a rainstorm resulting in 0.38 inches of rain.

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[9] 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.

[10] 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.

[11] 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.

However, when TerraVue at 2.85 oz/ac + Vastlan at 64 oz/ac + Freelexx at 64 oz/ac applications are allowed to dry completely, this treatment resulted in nearly 30% less living leaf canopy.

## MANAGEMENT IMPLICATIONS

Two-years after treatment, no herbicide treatment resulted in 100% control. Freelexx at 96 oz/ac + Garlon 3A at 64 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; Freelexx at 96 oz/ac + Method 240SL at 16 oz/ac + MSM 60 at 0.5 oz/ac and Freelexx at 96 oz/ac + TerraVue at 2.85oz/ac + MSM 60 at 0.5 oz/ac are mixes to consider for applications to honeysuckle during flowering. All herbicide treatments showed resprouts from dormant buds. While none of the mixes may completely control honeysuckle these should provide acceptable live leaf canopies or canopy reductions of honeysuckle but will require a follow up treatment the next season. Garlon 3A and Vastlan both contain triclopyr; however, the pounds of acid equivalent per gallon is different. Garlon 3A at 64 oz/ac applies 1.5 pounds of acid per acre. Vastlan at 64 oz/ac applies 2 pounds of acid per acre. So, Vastlan applied at 48 oz/ac is equivalent to Garlon 3A at 64 oz/ac. MSM 60 (metsulfuron-methyl), Method 240SL (aminocyclopyrachlor), and TerraVue (aminopyralid) 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[12]. The Method 240SL label cautions that exceeding the rates of 8 oz/ac may result in unacceptable injury to desirable turfgrasses and the addition of MSO adjuvant may increase the potential injury to turfgrass and to desirable trees and plants where their roots may extend into treated areas[13]. The TerraVue label states the following: trees adjacent to or in a treated area can occasionally be affected by root uptake, do not apply within the rootzone of desirable trees unless injury can be tolerated, and use special caution near roses and/or leguminous trees[14].

[12] 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.
[13] Bayer CropScience LP. Method 240SL label. https://www.cdms.net/ldat/ldCFU019.pdf Internet August 30, 2022
[14] Corteva agriscience. TerraVue label. https://www.cdms.net/ldat/ld2IB008.pdf Internet August 30, 2022

Table 1. Percent injury and living leaf canopy 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 = 0% living leaf canopy – 100 = 100% living leaf canopy on June 14, 2021, 375 DAT & June 8, 2022, 734 DAT. Herbicide treatments 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 | % Living Leaf Canopy 6/14/21 375 DAT | % Living Leaf Canopy 6/8/22 734 DAT |
|---|---|---|---|---|---|---|
| 1 | Untreated | -- | 1.1 a | 1 a | 99.5 d | 96.3 e |
| 2 | Freelexx<br>Method 240 SL<br>MSM 60 | 96<br>16<br>0.5 | 94.9 def | 99 d | 10.5 ab | 10 ab |
| 3 | Freelexx<br>Garlon 3A<br>MSM 60 | 96<br>64<br>0.5 | 96 ef | 97.5 d | 3 a | 2.8 a |
| 4 | Freelexx<br>TerraVue<br>MSM 60 | 96<br>2.85<br>0.5 | 90.9 def | 95 d | 8.5 ab | 9 ab |
| 5 | Garlon 3A<br>Freelexx | 64<br>128 | 94 def | 95.5 d | 9 ab | 14 ab |
| 6 | Garlon 3A | 128 | 83.5 def | 92.5 d | 10.5 ab | 12.5 ab |
| 7 | Vanquish | 64 | 67 cde | 72 cd | 38 bc | 41.5 bcd |
| 8 | RoundUp Pro Concentrate | 104 | 26 ab | 40 b | 28.3 abc | 21 abc |
| 9 | TerraVue | 2.85 | 35.5 b | 48 bc | 62 c | 74.1 de |
| 10 | TerraVue-Pre-Rain<br>Vastlan<br>Freelexx | 2.85<br>64<br>64 | 43.5 bc | 62 bc | 30.5 abc | 34.5 abc |
| 11 | Freelexx | 128 | 97.5 f | 99.3 d | 12.1 ab | 11.5 ab |
| 12 | MSM 60 | 0.5 | 66 cd | 56.9 bc | 55.5 c | 56 cd |
| 13 | TerraVue-Post Rain<br>Vastlan<br>Freelexx | 2.85<br>64<br>64 | 98.2 f | 99 d | 3.6 a | 5.5 ab |

# EVALUATION OF FOLIAR APPLICATIONS TO CALLERY PEAR *(Pyrus calleryana)*- 2ND YEAR

Herbicide trade and common names: TerraVue (*aminopyralid + florpyrauxifen-benzyl*), 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 been identified in many states as an invasive species and populations have increased dramatically along Pennsylvania roadsides. In November 2021, Callery pear was added to Pennsylvania's class B noxious weed list. An experiment was conducted at the I-99 northbound Atherton Street 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 + Vastlan at 48 oz/ac; Freelexx at 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 + 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. By 62 days after treatment, all treatments except for Terra Vue at 2.85 oz/ac provided a minimum of 99% injury to Callery pear. One year after treatments of MSM 60 at 1 oz/ac and Method 240SL at 16 oz/ac + MSM 60 at 2 oz/ac resulted in 0% living leaf canopy of Callery pear. Additional noteworthy treatments include Accord XRT II at 96 oz/ac + Vastlan at 48 oz/ac with 0.2% living leaf canopy and Freelexx at 96 oz/ac + Vastlan at 48 oz/ac + MSM 60 at 0.5 oz/ac with 3.5% living leaf canopy.


## INTRODUCTION

Native to Asia, Callery pear (*Pyrus calleryana*) was originally introduced into the United States in the early 1900's as a potential fire blight resistant root stock for common pear. Later in the 1960's due to its beautiful flowering, disease resistance and outstanding fall leaf color several varieties of Callery pear were planted throughout landscapes and as street trees. Callery pear was considered self-sterile when originally introduced in the United States; however, the introductions of other varieties have resulted in the opportunity for cross pollination between the different varieties and the production of viable seed. This viability combined with its fruit being attractive to birds and mammals has resulted in the ready spread of the seed and dispersal of the species. *Pyrus calleryana* is a small tree reaching 40 feet in height and can be found naturalizing along the edges of fields, forests, and roadsides[15]. In November 2021, Callery pear was added to Pennsylvania's class B noxious weed list. With this designation, Callery pear may no longer be sold, propagated, or cultivated in Pennsylvania as of February 2024.

The goal of this experiment was to compare seven common brush control herbicide treatments to determine their efficacy as a foliar application thoroughly applied throughout the canopy to injure and ultimately control Callery pear as determined by percent living leaf canopy.

[15] Penn State Extension 2020. Invasive Plant Fact Sheet, Callery Pear *(Pyrus calleryana)*. Available at https://extension.psu.edu/callery-pear Accessed August 31, 2022.

## MATERIALS AND METHODS

The experiment was established near the interchange of I-99 northbound at North Atherton Street in State College, Pennsylvania. With ten trees per replication, each tree was measured to determine the canopy area. The formula used to calculate canopy areas was the surface area of a cylinder ((2 x pi x radius x height) + (2 x pi x radius$^2$)) (Appendix Table 3). The herbicide application amounts were based on the calculated canopy area. The experiment evaluated eight treatments: 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 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. 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 PSI (pounds per square inch). 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. The treatments were applied on July 7, 2021.

Treatments were visually rated for percent injury where 0 = no injury – 100 = complete injury on August 5, 2021, 29 days after treatment (DAT) and on September 7, 2021, 62 DAT, and percent living leaf canopy where 0= 0% living leaf canopy – 100 = 100% living leaf canopy on July 7, 2022, 365 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

Injury to Callery pear from all herbicide treatments ranged from 74.6 to 100%, while the untreated check exhibited natural leaf damage of 9.5% on August 5, 2021, 29 DAT (Table 1). By 62 DAT, a similar percent injury range of 71% to 100% was observed amongst herbicide treatments while the untreated check recorded 8.1% injury. Treatments resulting in 100% injury were Freelexx at 96 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; and Method 240SL at 16 oz/ac + MSM 60 at 2 oz/ac. Freelexx alone at 128 oz/ac resulted in 99.8% injury, while Accord XRT II at 96 oz/ac + Vastlan at 48 oz/ac resulted 99.7% injury. TerraVue at 2.85 oz/ac resulted in the lowest injury with 71%.

On July 7, 2022, 365 DAT, the percent living leaf canopy ranged from 98.5% for the untreated check to 0% for two different herbicide treatments. MSM 60 at 1 oz/ac and Method 240SL at 16 oz/ac + MSM 60 at 2 oz/ac resulted in 0% living leaf canopy. Accord XRT II at 96 oz/ac + Vastlan at 48 oz/ac resulted in 0.2% living leaf canopy reduction while Freelexx at 96 oz/ac + Vastlan at 48 oz/ac + MSM 60 at 0.5 oz/ac resulted in 3.5% living leaf canopy. Freelexx at 96 oz/ac + Vastlan at 48 oz/ac + MSM 60 at 0.5 oz/ac resulted in 10% living leaf canopy, Freelexx at 128 oz/ac resulted in 15% canopy reduction and TerraVue at 2.85 oz/ac resulted in 16.7% living leaf canopy.

## CONCLUSIONS

By September 7, 2021, 62 DAT, all herbicide treatments resulted in injury of more than 99% except TerraVue at 2.85 oz/ac which showed a lower injury of 71%. However, one year after treatment, only MSM 60 at 1 oz/ac and Method 240SL at 16 oz/ac + MSM 60 at 2 oz/ac resulted in 0% living leaf canopy. Further data collection and analysis, two years after treatment, will determine long-term canopy reduction and future recommendations. In addition, it will be interesting to learn if Accord XRT II at 96 oz/ac +Vastlan at 48 oz/ac and Freelexx at 96 oz/ac + Vastlan at 48 oz/ac + MSM 60 at 0.5 oz/ac treatments were long lasting enough to decrease living leaf canopy to 0 percent 2 years after treatment.

## MANAGEMENT IMPLICATIONS

Based on the results of the experiment to date, 1 year after treatment, MSM 60 at 1 oz/ac and Method 240SL at 16 oz/ac + MSM 60 at 2 oz/ac are two treatments to consider for control of Callery pear. Further evaluations will determine long term percent living leaf canopy and future recommendations. Caution should be exercised when using MSM 60 or any metsulfuron methyl product. Past work by the project indicates that rates of MSM 60 above 0.5 oz/ac may cause injury to grass ground cover[16]. The Method 240SL label cautions that exceeding the rates of 8 oz/ac may result in unacceptable injury to desirable turfgrasses and the addition of MSO adjuvant may further increase the potential for turfgrass injury. In addition, caution must be taken with Method 240SL as it has the potential to injure desirable trees and plants when their roots extend into treated areas[17].

[16] 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.
[17] Bayer CropScience LP. Method 240SL label. https://www.cdms.net/ldat/ldCFU019.pdf Internet September 19, 2022.

Table 1. Percent injury and living leaf canopy of Callery pear *(Pyrus calleryana)*. The experiment was visually rated for percent injury where 0 = no injury - 100 = complete injury on August 5, 2021, 32 days after treatment (DAT) & September 7, 2020, 63 DAT and percent canopy reduction where 0 = 0% living leaf canopy – 100 = 100% living leaf canopy on July 7, 2022. 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 $p \leq 0.05$.

| Product | Rate oz/ac | % Injury 8/5/21 29 DAT | % Injury 9/7/21 62 DAT | % Living Leaf Canopy 7/7/22 365 DAT |
|---|---|---|---|---|
| Untreated | -- | 9.5 a | 8.1 a | 98.5 b |
| TerraVue | 2.85 | 74.6 b | 71 b | 16.7 a |
| Accord XRT II<br>Vastlan | 96<br>48 | 99.6 c | 99.7 c | 0.2 a |
| Freelexx | 128 | 99.4 c | 99.8 c | 15 a |
| Freelexx<br>Method 240SL<br>MSM 60 | 96<br>16<br>0.5 | 99.8 c | 100 c | 10 a |
| Freelexx<br>Vastlan<br>MSM 60 | 96<br>48<br>0.5 | 100 c | 100 c | 3.5 a |
| MSM 60 | 1 | 99.7 c | 100 c | 0 a |
| Method 240SL<br>MSM 60 | 16<br>2 | 100 c | 100 c | 0 a |

# EVALUATION OF PENNDOT FORMULA R-2ND YEAR

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 created a seed mix committee to review and recommend new seed mix formulas for PennDOT. Formula R (Table 1) is designed for use in seasonally flooded areas or basin bottoms. Each component chosen offers unique benefits to the site. The components include: creeping bentgrass (*Agrostis stolonifera*) which is a sod forming grass useful in erosion control and tolerant of wide soil pH (5-7.5) ;redtop (*Agrostis alba*) a quick cover rhizomatous species; cosmos sedge (*Carex comosa*) a wildlife food and cover rhizomatous species fox sedge (*Carex vulpinoides*) an easy sedge to establish while also providing wildlife food and cover; alkaligrass (*Puccinellia distans*) a bunchgrass tolerant of salt runoff and useful in erosion control; and riverbank wildrye (*Elymus riparius*) a reclamation and conservation species useful in soil stabilization and as food and cover.

## 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 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 a committee recommended rate of 5.2 lbs. per 1000 square yards which was the equivalent of 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-1 erosion 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 within the basin to conduct plant counts of the seeded species. Each subplot is a square meter. Plant counts were conducted on November 9, 2021, and September 21, 2022.

## 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 the lack of standard seed bed preparation to eliminate the

established ground cover with a non-selective herbicide treatment (i.e., glyphosate-properly labeled) before seeding. A portion of the basin was reinfested with soft rush which which was present before seeding Formula R. On September 21, 2022, a second plant count (Table 3) was conducted. Unfortunately, mowing operations destroying subplot stakes were conducted prior to the plant count making it difficult to accurate record differences in plots. Subplots 4 and 8 were destroyed and so no data was collected. The most common species found in the subplots were creeping bentgrass in four of the subplots. Riverbank wildrye was found in two subplots and redtop was found in one subplot. This reseeding of Formula R into an existing basin shows the importance of proper seedbed establishment. It appears the fact that glyphosate was not used to kill existing species impacted the site. We recommend that future plantings apply an aquatic glyphosate formulation to areas prior to seeding. This will eliminate existing vegetation and allow for the seeded species to establish within the basin.

## CONCLUSIONS

Establishment of Formula R species, in the basin bottom, appears slow. In the second year, more of the seeded species were identified and spread within the subplots. Not all subplots contained seeded species. Since 2 of the 8 subplots had plot locators destroyed by mowing operations, no future data collection and evaluation will occur.

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 11/9/21 | redtop 11/9/21 | cosmos sedge 11/9/21 | fox sedge 11/9/21 | alkaligrass 11/9/21 | riverbank wildrye 11/9/21 |
| 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 |

Table 3. 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 September 21, 2022. No data was collected for subplots 4 and 8 due to mowing operations that destroyed plot locators.

| | SPECIES | | | | | |
|---|---|---|---|---|---|---|
| subplot | creeping bentgrass 9/21/22 | redtop 9/21/22 | cosmos sedge 9/21/22 | fox sedge 9/21/22 | alkaligrass 9/21/22 | riverbank wildrye 9/21/22 |
| 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| 3 | 8 | 5 | 0 | 0 | 0 | 2 |
| 4 | | | | | | |
| 5 | 3 | 0 | 0 | 0 | 0 | 2 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | | | | | | |

# EVALUATION OF NATIVE GRASS AND POLLINATOR SEED MIXES AND SEEDING METHODS FOR CONVERSION AND ESTABLISHMENT ALONG ROADSIDES-3rd YEAR

Herbicide trade and common names: Accord XRT II (*glyphosate*), Triplet LO (*2, 4-D, mecoprop, dicamba*), Freelexx (*2, 4-D choline)*
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 Susan (*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

Disturbances to the vegetation and soils along the roadside due to road construction and redevelopment continually impacts the roadside rights-of-way in Pennsylvania. Utilizing native grasses and pollinator species in roadside revegetation and new construction projects has gained momentum and is being promoted as a viable option. For this new revegetation program to be successful, soil stability, seed germination rate, speed of cover, vehicular safe site distance conditions, and ease of maintenance are all essential factors in which roadside managers must consider when selecting seed mixes. An experiment was established with two native seed mixes code named Formula N consisting of a mix of cool and warm season grasses and pollinator species (i.e., Black-eyed Susan, New England Aster, and Ox-eye Daisey) and modified Formula N consisting solely of cool and warm season grasses. Both mixes were seeded at a pure live seed (PLS) rate and PennDOT's standard bulk rate. Once established, half of the site was subjected to standard maintenance practices whereas the other half was allowed to develop without maintenance. Over the three-year period of study, the Formula N mix started out with a higher average plant count per four-foot subplots across the plots for both seeding rates compared to the modified Formula N mix. Black-eyed Susan was the greatest component at both seeding rates, followed by Indiangrass and the fine fescue. During the second season the unmaintained bulk seeded Formula N plots had a higher count of fine fescue, little bluestem, and black-eyed Susan than the maintained plots for both seeding rates as well as the PLS rate of the unmaintained Formula N plots. Switchgrass was most prominent in the modified Formula N bulk rate seeded and maintained plots followed by Indiangrass and little bluestem. By the end of the third growing season, plant counts changed with the unmaintained Formula N plots diverging between the two seeding rates. The PLS plots showed less fine fescue and black-eyed-Susan while the bulk rate plots also showed less fine fescue but greater black-eyed-Susan plant counts. The maintained Formula N plots at both seeding rates showed a greater number of fine fescue and black-eyed Susan while the bulk rate showed an increase in black-eyed Susan and a decrease in presence of little bluestem. The maintained modified Formula N plots seeded at the bulk rate resulted in fewer fine fescue and switchgrass plants but an increase in big bluestem. The unmaintained PLS plots showed an increase of fine fescue while the bulk rate unmaintained plots resulted in fewer little bluestem by year three. Broadleaf and grass weeds increased from year to year within all plots.

# INTRODUCTION

Native grasses and pollinator species offer greater diversity in providing a more natural ecosystem that is more appealing to wildlife including pollinating insects[18]. Pennsylvania's grasslands and field habitats have been steadily declining over the past decades, partially due to development and succession, a process where fields naturally grow back into forests[19]. These circumstances have increased concerns for the survival needs of wildlife species and soil erosion[20]. With a growing call to employ native species along the PennDOT right-of-way while continuing to consider adaptability to site conditions and maintain soil stability during establishment, traveler safety, and ease of future maintenance, we evaluated alternative grass and pollinator 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 due to its potential to spread away from the roadside right-of-way[21].

The current 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 deep roots. The seed mix's hard and creeping red fescue components 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 for foraging bees, butterflies, and insects, and seeds for birds. However, the 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. It thus increased opportunities for erosion and weed pressure. This slow establishment may be partially due to seed dormancy constraints requiring natural cold stratification to germinate and the variation in dormancy levels within seed lots.

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[22] while assuring a better stand of WSG. The Canada and Virginia wildrye, black-eyed Susan, oxeye sunflower, and New England aster were replaced with big bluestem and switchgrass to help achieve a better stand of WSG. In addition, the cold-season grass (CSG) component was enhanced by adding sheep and chewing's red fescue to provide better gap

[18] Meadows and Prairies : Wild-life Friendly Alternatives to Lawns Penn State Extension. https://extension.psu.edu/downloadable/download/sample_id/224/

[19] Warm Season Grasses and Wildlife. Penn State Extension. https://extension.psu.edu/warm-season-grasses-and-wildlife

[20] Warm Season Grasses and Wildlife. Penn State Extension. https://extension.psu.edu/warm-season-grasses-and-wildlife

[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] Johnson et. al. 2014. Evaluation of Native Seed Mixes For Roadside Application – Year Three. Roadside Vegetation Management Research-2014 Report. pp. 27-28.

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. In addition, 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 PLS rates. Traditionally, PennDOT has seeded new and revegetated sites using bulk weight seed rates. However, the current view by forage, field production, and natural area seed industry professionals is that PLS seeding rates are more effective and assure better quality stand development and seedling survival. The decision to compare these two seeding rates resulted from 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 PLS rate.

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

## MATERIALS AND METHODS

A 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. Several cool-season grass species were onsite, including fine fescue, tall fescue, Kentucky bluegrass, and reed canary grass, along with several broadleaf weed species. Four 60' x 160' replicate plots 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 divided into 30' x 20' subplots to compare maintenance vs. non-maintenance. Plants were counted within four subplots that were 2' x 2' in size and were arranged on a diagonal line running along the center of each treatment replication to measure the performance. 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 CO2-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. 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 in seeding rates, seed purity, and acceptable cover. 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 and at the PLS rate of 50.4 lbs./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.

During the second growing season, on June 25, 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 CO2 powered backpack sprayer with a six-foot boom equipped with four 8004VS nozzles to eliminate broadleaf weeds. In addition, 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 3, 2021, all plots receiving maintenance were mowed using a Kubota with a mower attachment at the height of 6 inches to prevent further infestation of weeds, including thistle and several grass weeds.

Later during the second growing season, on October 19, 2021, the plots included in the maintenance program were sprayed with Freelexx 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 CO2 powered backpack sprayer with a six-foot boom equipped with four 8004VS nozzles to eliminate broadleaf weeds. In addition, 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 10-12 mph, air temperature of 71° F, and 35% relative humidity. Soil temperatures at the surface, 1-inch, 3-inch, and 6-inch depths, were 60° F, 60° F, 59°, and 59° F, respectively. Local rain events occurred on October 22, 25, and 27, 2021, measuring 0.17", 0.26", and 0.17", respectively, according to http://newa.cornell.edu. The nearest weather station was located at Rock Springs, PA.

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

### Seeding Rate and Seedling Development

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 considered a drought season with little precipitation. The dry conditions likely inhibited seed germination and represent what may happen in roadside

plantings where supplemental irrigation is not available or financially justified. All treatments (Tables 3 & 4) showed the presence of broadleaf and 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 in maintained plots and 4.13 unmaintained plots based on 4-square foot subsampling units per plot (Table 3).

In contrast, black-eyed Susan among the PLS seeded Formula N plots averaged 0.06 and 0.19 in maintained and unmaintained plots, respectively. Among the WSG seedlings counted, Indiangrass was highest at 0.19 seedlings per subplot at the bulk seed rate compared to 0.06 in the PLS plots under the maintenance regime with no Indiangrass in the unmaintained plots for both 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 and grass weeds.

Within the bulk rate of the modified Formula N seed mix, the 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 big bluestem. Fine fescue was the most prominent among the PLS plots at 0.13 and 0.31.

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 5). 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, in the first year (Table 3). Fine fescue also dropped average seedling numbers compared to first-year data under the bulk and PLS seedings maintenance regime. The unmaintained 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 number drops may be due to the damage caused by the maintenance program on black-eyed Susan; however, the unmaintained plots also saw a decline in plant count. The weather may have also been a factor and may have affected little bluestem and fine fescue counts, at least under the maintenance regime.

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. The amount of little

bluestem was reduced 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 maintained plots compared to the bulk rate unmaintained subplots and the PLS rate maintained plots. The unmaintained bulk rate plots saw a decrease in the average number of plants, of 0.06, compared to the first-year data of 0.31 (Tables 4 & 6). In addition, a small amount of Indiangrass was found among the bulk rate maintained plots for the first time.

Overall, the percent cover across the whole experiment was low during the second year. In past experiments with WSG seedings, we have found that the 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 significant 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. In that experiment, 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 were most favorable in establishing that WSG cover. Results of the 2009 study are comparable to this experiment two years later in that the late seeding inhibited reasonable cover and showed a low percent cover.

By the end of the third growing season, in general Formula N produced a significantly higher plant count. Black-eyed Susan was the most prominent, followed by fine fescue, Canada wildrye, and little bluestem (Table 7). On average black-eyed Susan increased in the plots receiving maintenance with 9.19 seedlings per subplot at the bulk seed rate and 0.75 seedlings per subplot at the PLS rate. The total average presence of black-eyed Susan in the unmaintained plots increased on average to 14.25 seedlings per subplot at the bulk seed rate but decreased to no seedlings per subplot at the PLS rate. The total average presence of fine fescue in the plots receiving maintenance increased to an average of 1.75 seedlings per subplot at the bulk seed rate and 0.81 seedlings per subplot at the PLS rate but decreased to 0.81 seedlings per subplot at the bulk rate, and to no seedlings per subplot at the PLS rate. The total average presence of Canada wildrye in the plots receiving maintenance increased with an average of 0.25 seedlings per subplot at the bulk seed rate. And finally, the total average presence of little bluestem in the plots receiving maintenance decreased to no seedlings per subplot at the bulk seed rate. No other WSG or flowers were found in the plots. Over the three-year period Ox-eye sunflower and New England aster failed to appear in the plots. Two questions arise as to whether this is an environment issue or seed dormancy issue? The dry seasons may have played a role, but equally important is the three-month cold stratification requirement for the germination of Ox-eye sunflower and New England aster. Both pollinator species makeup less than 10% of both seeding rates. Such a low percent and potential predation may have played a role in failure to germinate. These two pollinator species suffer the same slow to establish potential as the warm season grasses found in the mix. It may be helpful to increase their percentage in the mix to enhance the potential for establishment. Finally, a question remains as to whether maintenance or lack of maintenance and weed pressure were factors in the lack of identifiable New England aster and Ox-eye sunflower in the plots.

Among the modified Formula N plots, fine fescue was more prevalent in both the maintained and non-maintained PLS plots. While big bluestem in the maintained bulk rate plots was more prevalent (Table 8). Counts of fine fescue and switchgrass in the maintained bulk seed rate plots were less. Whereas in the unmaintained bulk rate plots little bluestem numbers were also reduced. Among the maintained PLS plots, fine fescue increased by an average of 1.69 seedlings per subplot while the unmaintained plots produce 1 seedling per subplot. A very low number of big bluestem (0.06 seedlings per subplot) were found in the maintained and non-maintained plots. Overall, fine fescue increased in the PLS plots and decreased in the bulk seeded plots. Switchgrass decreased with an average 0.06 seedlings per subplot even with maintenance. Lastly, in the unmaintained bulk rate plots, the total average presence of little bluestem decreased to 0.06 seedlings per subplot. No other WSGs were found in the plots.

Weed Competition and Maintenance Impact

After the first year, the broadleaf weeds in the Formula N plots ranged on average from 7.06 to 14.16 (Table 3) in the maintained and unmaintained plots and varied widely between PLS and bulk seeded plots with no apparent trend. Similarly, the modified Formula N plots ranged on average from 5.94 to 16.88 plants (Table 4) in the subplots. In both cases there were no significant difference between plots, seeding rates, and maintenance regimes. For the grassy weeds, a significant difference was found among the seeding rates for the modified Formula N plots (Table 4) with a higher weed count found in the PLS subplots compared to the bulk seeded plots. In contrast, there was no significant difference found among the Formula N plots across seeding rates and maintenance regimes (Table 3).

The broadleaf and grassy 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 and modified Formula N plots at both seeding rates for both broadleaf and grass weeds in the second year nor was there an obvious trend in weed count between the maintenance regimes (Table 5). Broadleaf and grass weed pressure was obviously high across all subplots by the end of the third year and no plant count was taken due to the overabundance of weeds in the subplots. It appears obvious that a single season of herbicide application early and again late in the second growing year is not enough to reduce weed pressure to allow either seeding mix or rate to take hold. In the future, a different approach to weed management will need to be devised.

The concern that a standard broadleaf weed management strategy would harm the pollinator-friendly components within the Formula N seed mix also proved true. One question that arises is what impact did mowing in August of the second year prior to the October Freelexx application have on both seed mix performance and weed control? Overall, the Formula N plots that received maintenance during the second growing season showed an overall decrease in plant count for black-eyed Susan (Table 5). Was this decrease due to reduction in the weed canopy cover allowing more of the herbicide to reach the black-eyed Susan? The fact that all seeding rates and maintenance regimes showed a general reduction in black-eyed Susan coverage compared to the first growing season, except for the PLS rate with no maintenance, which showed a slight increase suggests that the mowing was not a factor in the drop in seedling numbers. By the end of the third growing season, Formula N plots seeded at the bulk rate under

both maintenance regimes showed an obvious increase in black-eye Susan plants. The increase in the third year in maintained and unmaintained bulk rate plots also suggests that the mowing and herbicide application in October was not drastically detrimental to black-eyed susan numbers but may have had a slight effect on the black-eyed susan numbers in the maintained plot compared to the unmaintained plots. The maintained Formula N PLS plots showed a very slight increase while the unmaintained PLS plots produced no black-eyed Susan (Table 7).

The increase in black-eyed Susan in the third year (Table 7) is a positive outcome; however, the weed pressure also increased in plots which demonstrates that a weed control program still needs to be defined and weed control may be required beyond a single growing season to assure the plots survive and thrive. The success of a pollinator friendly seeding program may hinge of the development of an effective weed control program. A further refining of a weed management plan will be important in the success of a pollinator friendly seeding program. Conversely, applying the pollinator seeding program to new construction or roadside redevelopment projects rather than trying to retrofit it into established roadside landscapes may reduce the immediate weed pressure and seed bank that would compete with the seeding programs success.

## CONCLUSIONS

At this time there is no obvious benefit to PLS over the bulk seeding rates used by PennDOT. As for species choices for a native plant mix among the pollinator species, black-eyed Susan appears to be a resilient enough plant for the mix, although based on this experiment New England aster and Ox-eye sunflower were not successful after three years. This may be a site specific issue, an installation timing issue, or a cold stratification requirement and they should not be counted out after one experiment. It may be helpful to increase their percentage in the seed mix to assure recognizable presence in the plots. Among the grasses, fine fescue remains a positive component followed by big bluestem and little bluestem. Indiangrass may not be an effective cover in these situations and switchgrass may be useful over time as it is readily found along roadside margins.

Managing broadleaf and grassy weed pressure in newly seeded plots remains an issue to be resolved. A single season application does not appear to be effective and also possibly harms pollinator species in the mix. The substantial increase in weed pressure in the third year with limited increase among the desired species means further work needs to be done in weed control and in enhancing seedling success. The late season establishment and low precipitation are also possible factors to the low germination and establishment results and increased weed pressure. Furthermore, the use and timing of mowing as part of the establishment of the plots and in reducing weed pressure also needs to be evaluated.

Finally, this experiment has provided a clearer view of the difficulties of establishing pollinators in a roadside setting and the variables that need to be examined further including timing and type of maintenance, species selected as part of the pollinator component, pollinator seed pregermination requirements for successful presence in the mix and the percentage of that seed to be in the pollinator mix. Based on this experiment the bulk seed rate appears to be the most effective in assuring establishment in the short term of a planting. This experiment will continue to be evaluated to see if the seeding rates and seed mixes continue to increase in the plots and whether over time the PLS seeding rate demonstrates any change compared to the bulk rate. At this time a second round of weed control is not planned.

**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 | *Fescue 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 Susan 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: 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. 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 | 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 5: 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 Susan 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 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. 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 | 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. |

**Table 7: Formula N 3rd 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 Freelexx at 64 oz/ac on October 19, 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 |
|---|---|---|---|---|---|---|---|---|---|
| Formula N- Maint. | 105.10 | 1.75 | 0 | 0 | 0.25 | 0 | 9.19 | 0 | 0 |
| Formula N- Maint. | 4.91 | 0.81 | 0 | 0 | 0 | 0 | 0.75 | 0 | 0 |
| Formula N- No maint. | 105.10 | 0.81 | 0.06 | 0 | 0 | 0 | 14.25 | 0 | 0 |
| Formula N- No maint. | 4.91 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |

**Table 8: Modified Formula N 3rd 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 Freelexx at 64 oz/ac on October 19, 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. 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 | Big bluestem Count 10/21 | Little bluestem Count 10/21 | Indiangrass Count 10/21 | Switchgrass Count 10/21 |
|---|---|---|---|---|---|---|
| Modified Formula N- Maint. | 40.00 | 0.25 | 0.06 | 0.19 | 0 | 0.06 |
| Modified Formula N- Maint. | 5.04 | 1.69 | 0 | 0 | 0 | 0 |
| Modified Formula N- No maint. | 40.00 | 0.25 | 0 | 0.06 | 0 | 0 |
| Modified Formula N- No maint. | 5.04 | 1 | 0 | 0 | 0 | 0 |
| | | n.s. | n.s. | n.s. | n.s. | n.s. |

# EFFICACY OF HERBICIDES AND HERBICDE MIXES ON POISON HEMLOCK *(Conium maculatum)*

Herbicide trade and common names: Method 240SL *(aminocyclopyrachlor)*, Freelexx *(2,4-D)*, MSM 60 *(metsulfuron-methyl)*, Vastlan *(triclopyr)*, TerraVue *(aminopyralid + florpyrauxifen-benzyl)*, Vanquish *(dicamba)*, Plateau *(imazapyr)*, Telar XP *(chlorsulfuron)*

Plant common and scientific names: poison hemlock *(Conium maculatum)*

## ABSTRACT

Poison hemlock, a PA class B noxious weed, can be found in low lying areas along roadsides, field edges, creeks, and streams. Since all parts of this plant are poisonous, poison hemlock should be managed to eliminate its spread. This experiment evaluated the efficacy herbicide treatments applied to poison hemlock rosettes prior to flowering. Treatments include Method 240SL at 10 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac; Vastlan at 48 oz/ac + Freelexx at 96 oz/; TerraVue at 2.85 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac; Terra Vue at 2.85 oz/ac; Method 240SL at 10 oz/ac; Vastlan 48 oz/ac; Method 240SL at 8 oz/ac + Freelexx at 64 oz/ac; Freelexx at 96 oz/ac; MSM 60 at 0.5 oz/ac; Vanquish at 64 oz/ac; Plateau at 12 oz/ac; Telar XP at 1 oz/ac; and an untreated check. Two months after herbicide applications were applied, six treatments resulted in 0% poison hemlock cover: Method 240SL at 10 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac; Vastlan at 48 oz/ac + Freelexx at 96 oz/; Method 240SL at 10 oz/ac; Vastlan at 48 oz/ac; Freelexx at 96 oz/ac; and Telar XP at 1 oz/ac.

## INTRODUCTION

Poison hemlock is an invasive biennial weed found along roadsides throughout Pennsylvania. This coarse, branched plant with fern like leaves, will grow 6-8 feet tall, has whitish-green hollow stems covered with purple blotches and umbels of small white flowers atop[23]. The life cycle of poison hemlock begins with the germination of seeds from August through early fall. The first-year seedling will overwinter as a rosette with small fern-like leaves. The following spring the rosette continues to grow, and the plant will bolt, sending up a stalk with white umbel flowers. Poison hemlock typically flowers between June and July. After flowering the ripe seeds will drop to the soil continuing its propagation of future plants. Understanding the life cycle of poison hemlock is necessary to selecting management strategies for optimal control. Applications made prior to flowering are necessary to prevent seed set. Like all biennials, poison hemlock only spreads by seed. Since all parts of this plant is poisonous as well as a Pennsylvania class B noxious weed, infestations of poison hemlock should be managed along roadsides to limit human interactions but also livestock. This experiment evaluated the efficacy of herbicide treatments prior to flowering for management of poison hemlock.

[23] Rhoades, A. F., and T.A. Block. 2000. The Plants of Pennsylvania. Philadelphia: University of Pennsylvania Press

## MATERIALS AND METHODS

The experiment was established as a randomized complete design with four replications along the on ramp from Plank Road to I-99 southbound in Altoona, PA. Treatments included Method 240SL at 10 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac; Vastlan at 48 oz/ac + Freelexx at 96 oz/; TerraVue at 2.85 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac; Terra Vue at 2.85 oz/ac; Method 240SL at 10 oz/ac; Vastlan at 48 oz/ac; Method 240SL at 8 oz/ac + Freelexx at 64 oz/ac; Freelexx at 96 oz/ac; MSM 60 at 0.5 oz/ac; Vanquish at 64 oz/ac; Plateau at 12 oz/ac; Telar XP at 1 oz/ac; and an untreated check. Induce, a non-ionic surfactant, was added to all herbicide treatments at 0.25% v/v. Plots were 20 by 6 feet in size. Treatments were pre-measured, mixed, and applied on May 5, 2022, using a $CO_2$ powered backpack sprayer with a six-foot boom equipped with four 8004 nozzles at 30 PSI (pounds per square inch), and delivered at 35 gallons per acre. Weather at the time of application consisted of clear, sunny skies, winds at 5-10 MPH, 37% relative humidity, air temperature of 66°F and soil temperatures of 64°F, 64°F, 63°F, and 62°F, at 0-, 1-, 3-, and 6-inch depths, respectively.

Initial percent poison hemlock cover was visually rated on May 2, 2022, prior to treatment and designated as 0 days after treatment (DAT). Percent poison hemlock injury was visually rated on May 19 and June 6, 2022, 14 and 32 DAT. The experiment was visually rated for percent poison hemlock cover on July 6, August 5, September 6, October 6, and November 8, 2022, 62, 92, 124, 154 and 187 DAT, respectively. Additionally, percent grass cover was visually rated on May 2, July 6, October 6, and November 8, 2022, 0, 62, 154 and 187 DAT, respectively. 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 DISCUSSIONS

Initial percent poison hemlock cover on May 2 ranged between 17.8 and 36.8 with no significant difference among plots (Table 1). On May 19, 14 DAT, percent injury ranged from 61.3 to 100 for the herbicide treatments and 18.3% for the untreated plots. Percent injury remained similar by 32 DAT, except the untreated check increased to 78.3%. One possible reason for this increase was spray drift from adjacent treated plots, effecting the edge of untreated check plot in replication 1. Another reason for high injury was the fact the poison hemlock was beginning to senesce, and this was reported as injury. By July 6, 62 DAT poison hemlock cover ranged between 0 to 1.5 percent with the untreated check at 6.8 percent. Several treatments resulted in 0 percent cover including Method 240SL at 10 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac; Vastlan at 48 oz/ac + Freelexx at 96 oz/; Method 240SL at 10 oz/ac; Vastlan at 48 oz/ac; Freelexx at 96 oz/ac; and Telar XP at 1 oz/ac. The remaining herbicide treatments resulted in minimal poison hemlock cover. These treatments included Plateau at 12 oz/ac 0.03% poison hemlock cover, TerraVue at 2.85 oz/ac 0.06% poison hemlock cover, TerraVue at 2.85 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac 0.13% poison hemlock cover, MSM 60 at 0.5 oz/ac 0.13 poison hemlock cover; and Vanquish at 64 oz/ac 1.5% poison hemlock cover. July 6 provided the best evaluation of herbicide efficacy to poison

hemlock since the plants started to senesce at the end of their lifecycle by the August 5 evaluation. By this time, 92 DAT, all treatments including the untreated check were statistically similar based on percent poison hemlock cover ranging from 0 to 2.1%. The trend continued through the last rating on November 8. By 187 DAT, the untreated check showed 1.1% cover. Herbicide treatments with less than 5% poison hemlock cover included Vastlan 48 oz/ac 0.3%, Method 240SL 10 oz/ac 0.5%, TerraVue at 2.85 oz/ac 1.8%, Method 240SL at 8 oz/ac + Freelexx 64 oz/ac 2.1%, MSM 60 at 0.5 oz/ac 2.1%, Plateau at 12 oz/ac 2.1%, Telar XP at 1 oz/ac 2.6%, and Vastlan at 48 oz/ac + Freelexx at 96 oz/ac 3.6%. Treatments with more than 5% poison hemlock cover included TerraVue at 2.85 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac 5.6%, Method 240Sl at 10 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac 6%, Freelexx at 96 oz/ac 7.5% and Vanquish at 64 oz/ac 9.6%.

The experiment was visually rated for percent grass cover and monitored throughout the experiment to determine if treatments negatively impacted desirable grass cover (Table 2). On May 2, 0 DAT, grass cover ranged between 16 and 27.5% with no significant difference between treatments. Overall, a slight variation occurred between the initial grass cover rating on May 2 (0 DAT) and the last grass cover rating on November 8, 187 DAT for most treatments. By 187 DAT, percent grass cover ranged from 21.5 to 30%, with no significant difference in grass cover.

## CONCLUSIONS

All herbicide treatments showed various degrees of injury to poison hemlock 14 days after application. Two months after herbicide applications, six treatments resulted in 0% poison hemlock cover and included Method 240SL at 10 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac; Vastlan at 48 oz/ac + Freelexx at 96 oz/; Method 240SL at 10 oz/ac; Vastlan at 48 oz/ac; Freelexx at 96 oz/ac; and Telar XP at 1 oz/ac.

## MANAGEMENT IMPLICATIONS

The most important key in managing poison hemlock is to manage seed production. Like all biennials, poison hemlock reproduces only by seed, so herbicide applications should target the rosette before flowering. This technique will reduce the likelihood of flowers developing and setting seed. All treatments evaluated may be considered when selecting an herbicide or mix. If targeting specifically poison hemlock before flowering, a treatment of Freelexx at 96 oz/ac may be a cost-effective option. However, if applications during a routine weed and brush program are applied, target poison hemlock colonies in late summer and early fall after poison hemlock germinates and grows into a first-year rosette. As this experiment demonstrated even as herbicide treatments reduced poison hemlock cover to near zero in July, by November, poison hemlock seedlings and rosettes were still present due to seeds germinating from the seedbank in the soil. Effective management of poison hemlock will take several years to eliminate the seedbank of viable poison hemlock seed. Additionally, a proactive cultural tool to consider is the establishment of low growing grass species such as a fine fescue.

Table 1. Percent injury and cover of poison hemlock (*Conium maculatum*). The experiment was visually rated for percent injury on May 19, 14 DAT and June 6, 32 DAT and for percent cover on May 2, July 6, August 5, September 6, October 6, and November 8. 2022, 0, 62, 92, 124, 154, and 187 DAT. All treatments contained 0.25% v/v of non-ionic surfactant. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

| Product | Rate oz/acre | % poison hemlock cover 5/2/22 0 DAT | % poison hemlock injury 5/19/22 14 DAT | % poison hemlock injury 6/6/22 32 DAT | % poison hemlock cover 7/6/22 62 DAT | % poison hemlock cover 8/5/22 92 DAT | % poison hemlock cover 9/6/22 124 DAT | % poison hemlock cover 10/6/22 154 DAT | % poison hemlock cover 11/8/22 187 DAT |
|---|---|---|---|---|---|---|---|---|---|
| Untreated | --- | 17.8 | 18.3 a | 78.3 a | 6.8 b | 0.2 | 0.3 | 1.1 | 1.1 |
| Method 240SL<br>Freelexx<br>MSM 60 | 10<br>96<br>0.5 | 35 | 100 d | 100 b | 0 a | 0 | 2.5 | 6 | 6 |
| Vastlan<br>Freelexx | 48<br>96 | 33 | 100 d | 99.8 b | 0 a | 0.8 | 2.3 | 3.6 | 3.6 |
| TerraVue<br>Freelexx<br>MSM 60 | 2.85<br>96<br>0.5 | 30.8 | 100 d | 100 b | 0.13 a | 1.3 | 3.1 | 5.6 | 5.6 |
| TerraVue | 2.85 | 31.8 | 100 d | 99.8 b | 0.06 a | 0.4 | 1.6 | 1.8 | 1.8 |
| Method 240SL | 10 | 29 | 93.8 d | 99.5 b | 0 a | 0 | 0.2 | 0.5 | 0.5 |
| Vastlan | 48 | 36.8 | 92.5 d | 97.5 b | 0 a | 0.1 | 0.3 | 0.3 | 0.3 |
| Method 240SL<br>Freelexx | 8<br>64 | 28 | 100 d | 98.8 b | 0.13 a | 0.3 | 2 | 2.1 | 2.1 |
| Freelexx | 96 | 32.8 | 95 d | 91 ab | 0 a | 0.8 | 4 | 7.5 | 7.5 |
| MSM 60 | 0.5 | 28.8 | 61.3 b | 83.8 ab | 0.13 a | 1.3 | 1.8 | 2.1 | 2.1 |
| Vanquish | 64 | 19.9 | 87.5 cd | 94.5 ab | 1.5 a | 2.1 | 5.1 | 9.6 | 9.6 |
| Plateau | 12 | 29.5 | 68.8 bc | 94.8 ab | 0.03 a | 0.03 | 0.3 | 2.1 | 2.1 |
| Telar XP | 1 | 27 | 63.8 b | 96.3 ab | 0 a | 0 | 0.6 | 2.6 | 2.6 |
| | | n.s. | | | | n.s. | n.s. | n.s. | n.s. |

Table 2. Percent grass cover. The experiment was visually rated for percent grass cover on May 2, July 6, October 6, and November 8. 2022, 0, 62, 154, and 187 DAT. All treatments contained 0.25% v/v of non-ionic surfactant. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

| Product | Rate oz/acre | % grass cover 5/2/22 0 DAT | % grass cover 7/6/22 62 DAT | % grass cover 10/6/22 154 DAT | % grass cover 11/8/22 187 DAT |
|---|---|---|---|---|---|
| Untreated | --- | 23.5 | 24.3 | 23.8 | 23.8 |
| Method 240SL<br>Freelexx<br>MSM 60 | 10<br>96<br>0.5 | 27.5 | 31.8 | 30 | 30 |
| Vastlan<br>Freelexx | 48<br>96 | 24.4 | 26.9 | 23 | 23 |
| TerraVue<br>Freelexx<br>MSM 60 | 2.85<br>96<br>0.5 | 16 | 25 | 25.5 | 25.5 |
| TerraVue | 2.85 | 31.5 | 33.1 | 29.5 | 29.5 |
| Method 240SL | 10 | 23 | 25 | 24.8 | 24.8 |
| Vastlan | 48 | 22.5 | 30 | 30 | 30 |
| Method 240SL<br>Freelexx | 8<br>64 | 24.3 | 26.9 | 24 | 24 |
| Freelexx | 96 | 22.5 | 28.8 | 21.5 | 21.5 |
| MSM 60 | 0.5 | 23.8 | 29.4 | 26.8 | 26.8 |
| Vanquish | 64 | 27.3 | 27.8 | 24.5 | 24.5 |
| Plateau | 12 | 25.3 | 27.5 | 28.8 | 28.8 |
| Telar XP | 1 | 25.5 | 26.3 | 25.5 | 25.5 |
| | | n.s. | n.s. | n.s. | n.s. |

# EFFICACY OF HERBICIDES AND HERBICDE MIXES ON WILD PARSNIP
*(Pastinaca sativa)*

Herbicide trade and common names: Method 240SL *(aminocyclopyrachlor)*, Freelexx *(2,4-D)*, MSM 60 *(metsulfuron-methyl)*, Vastlan *(triclopyr)*, TerraVue *(aminopyralid + florpyrauxifen-benzyl)*, Vanquish *(dicamba)*, Telar XP *(chlorsulfuron)*

Plant common and scientific names: wild parsnip *(Pastinaca sativa)*

## ABSTRACT

Wild parsnip is a Pennsylvania class B noxious weed, which grows along roadsides, field edges, and disturbed sites. With its spread throughout the commonwealth, human interactions have increased resulting in burns or blisters to exposed skin. This experiment evaluated the efficacy of herbicide treatments applied in late spring before flowering. Treatments included Method 240SL at 10 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac; Vastlan at 48 oz/ac + Freelexx at 96 oz/; TerraVue at 2.85 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac; Terra Vue at 2.85 oz/ac; Method 240SL at 10 oz/ac; Vastlan at 48 oz/ac; Method 240SL at 8 oz/ac + Freelexx at 64 oz/ac; Freelexx at 96 oz/ac; MSM 60 at 0.5 oz/ac; Vanquish at 64 oz/ac; Telar XP at 1 oz/ac; and an untreated check. Sixty-one days after application, eight herbicide treatments resulted in less than 1% wild parsnip cover: Method 240SL at 10 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac; Vastlan at 48 oz/ac + Freelexx at 96 oz/; TerraVue at 2.85 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac; Method 240SL at 10 oz/ac; Method 240SL at 8 oz/ac + Freelexx at 64 oz/ac; Freelexx at 96 oz/ac; MSM 60 at 0.5 oz/ac; and Telar XP at 1 oz/ac.

## INTRODUCTION

Wild Parsnip (*Pastinaca sativa)* is a poisonous, noxious, invasive weed found throughout the commonwealth. Care should be exercised while working around this plant as severe dermal burns may occur from skin exposure. The plant sap can cause phytophotodermitis, a sunlight activated chemical burn resulting in blisters[24]. While working around this plant, it is recommended that vegetation managers wear gloves, long pants, boots, and long-sleeve shirts to minimize possible exposure. Wild parsnip is a biennial weed originating from Eurasia[25] and brought to the U.S. as an edible root. As with most biennials, first-year wild parsnip seeds germinate forming a rosette of 10-15 pinnately compound leaves with ovate to oblong toothed leaflets. After overwintering, rosettes will bolt and reach heights of 2-5 feet with smooth grooved stems of alternately attached compound leaves. Each leaf has 2-5 pairs of oppositely arranged and toothed leaflets. During the flowering phase, a yellow flat topped umbel flower of 4-8 inches across appears with 15-25 ray flowers per umbel atop of the plant. Individual ray

[24] Cornell Weed Identification. Wild Parsnip. 2023. Available at https://blogs.cornell.edu/weedid/wild-parsnip/
[25] Rhoads, A.F. & T.A. Block. 2000. The Plants of Pennsylvania. Philadelphia: University of Penn Press.

flowers carry five small petals. In a population of seedlings not all vernalized plants flower in the same year. Wild parsnip plants must reach a critical size greater than 5 millimeters in root crown diameter by the end of the growing season for the flowering phase to begin by the following spring[26]. The seed is a quarter inch oval smooth on one side with ribbed edges on the other. Wild parsnip has a long germination window occurring between late September once seed is ripe and dispersed to November and early spring in some situations. Most fall germinated seedlings may not survive winter[3]. Due to its potential human hazard and its tendency to survive and thrive in roadsides, wild parsnip proper identification is very important and necessary control measures taken to manage its spread along roadsides. This experiment evaluated the efficacy of herbicide treatments applied in late spring before flowering.

## METHODS AND MATERIALS

The experiment was established as a randomized complete design with four replications along I-99 northbound about ½ mile north of the Bellefonte, PA/SR550 exit. Treatments included Method 240SL at 10 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac; Vastlan at 48 oz/ac + Freelexx at 96 oz/; TerraVue at 2.85 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac; Terra Vue at 2.85 oz/ac; Method 240SL at 10 oz/ac; Vastlan at 48 oz/ac; Method 240SL at 8 oz/ac + Freelexx at 64 oz/ac; Freelexx at 96 oz/ac; MSM 60 at 0.5 oz/ac; Vanquish at 64 oz/ac; Telar XP at 1 oz/ac; and an untreated check. Induce, a non-ionic surfactant, was added to all herbicide treatments at 0.25% v/v. Plots were 12 by 6 feet in size. Treatments were pre-measured, mixed, and applied on May 18, 2022, using a $CO_2$ powered backpack sprayer with a six-foot boom equipped with four 8004 nozzles at 32 PSI (pounds per square inch), and delivered at 35 gallons per acre. Weather at the time of application consisted of sunny skies, winds at 0-5 MPH, 39% relative humidity, air temperature of 63°F and soil temperatures of 58°F, at all soil depths 0-, 1-, 3-, and 6-inch.

Initial percent wild parsnip cover was visually rated on May 17, 2022, prior to treatment and designated as 0 days after treatment (DAT). Percent wild parsnip injury was visually rated on June 1 and 22, 2022, 14 and 35 DAT. The experiment was visually rated for percent wild parsnip cover on July 18, August 24, September 20, and October 18, 2022, 61, 98, 125, and 153 DAT, respectively. Additionally, the experiment was visually rated for percent grass cover on May 17, July 18, and October 18, 2022, 0, 61, and 153 DAT, respectively. 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

Initial percent wild parsnip cover ranged from 38.8 to 56.3 percent on May 17 (0 DAT) with no significant difference among plots (Table1). On June 1 (14 DAT) the percent wild parsnip injury ranged between 52.5 and 97 percent for the herbicide treatments and 1.8 percent for the untreated plots. By 35 DAT percent injury increased for most treatments and ranged

[26] Doll, J & Renz. M. 2007. Agronomy Advice. Wild Parsnip. University of Wisconsin. http://agronomy.wisc.edu

between 30 and 100 percent, with the untreated check plots at 4.5 percent. Interestingly the Vanquish treatment percent injury decreased from 71.3 at 14 DAT to 30 at 35 DAT suggesting more of short-term burndown effect. By July 18, (61 DAT), the percent wild parsnip cover amongst herbicide treatments ranged between 0 and 41.3 percent. Method 240SL at 10 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac; MSM 60 at 0.5 oz/ac; and Telar XP at 1 oz/ac resulted in 0% wild parsnip cover. TerraVue at 2.85 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac and Method 240SL at 10 oz/ac showed 0.1% wild parsnip cover. Method 240SL at 8 oz/ac + Freelexx at 64 oz/ac showed 0.3%, Freelexx at 96 oz/ac showed 0.4% and Vastlan 48 oz/ac + Freelexx at 96 oz/ac showed 0.5% wild parsnip cover. TerraVue at 2.85 oz/ac showed 1.8%, Vastlan at 48 oz/ac showed 14.5%, and Vanquish at 64 oz/ac showed 41.3% wild parsnip cover. The 61 DAT rating is the best evaluation of herbicide treatments because at this point wild parsnip was living and flowering in the intreated plots. By August 24, 98 DAT, wild parsnip cover ranged between 0 and 1.1 percent for herbicide treatments whereas the untreated check showed 6.3 percent. The August rating shows that wild parsnip died after flowering in July. We believe that the reduction in percent wild parsnip cover for the herbicide treatments from between 61 DAT to 98 DAT was not due to the herbicide treatments but rather to the wild parsnip completing its lifecycle and dying after flowering. By the last rating on October 18, 153 DAT, the following treatments showed 0% wild parsnip cover: Method 240SL at 10 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac; TerraVue at 2.85 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac; Method 240SL at 10 oz/ac; Method 240SL at 10 oz/ac; Method 240SL at 8 oz/ac + Freelexx at 64 oz/ac; MSM 60 at 0.5 oz/ac; and Telar XP at 1 oz/ac. Treatments with 0.1% wild parsnip cover included: Vastlan at 48 oz/ac + Freelexx at 96 oz/ac; TerraVue at 2.85 oz/ac; and Freelexx at 96 oz/ac. Vastlan at 48 oz/ac showed 0.5% and Vanquish showed 1.1% wild parsnip cover. The untreated check showed 7 percent wild parsnip cover. By this rating the wild parsnip remaining are most likely not the same plants identified before treatment because those would have flowered and died. The wild parsnip identified are either seedlings that germinated or small rosettes from previous season that did not reach the critical root diameter to be vernalized and flower.

The experiment was visually rated for percent grass cover and monitored throughout the experiment to determine if treatments negatively impacted desirable grass cover (Table 2). On May 17, 0 DAT, grass cover ranged between 30 and 46.8 percent with no significant difference between treatments. By 61 DAT, the untreated check remained the same at 40 percent grass cover with the herbicide treatment plots ranging from 50 to 88.8 percent grass cover. For all herbicide treatments and the untreated check, the percent grass cover increased by the last grass cover rating on October 18, 153 DAT compared to the initial grass cover rating. By 153 DAT, percent grass cover ranged from 70 to 82.5%, with no significant difference in grass cover. In comparing 61 DAT to 153 DAT among the grass cover ratings, seven treatments decreased in percent grass cover with reductions ranging from 10 to 3 percent reduction. Three treatments showed a higher percent grass cover during the same period. It appears that none of the herbicide treatments showed a reduction in overall grass cover. In fact, this experiment demonstrates the ability of desirable grasses to fill in voids and compete with undesirable weeds.

## CONCLUSIONS

Most herbicide treatments resulted in 90 percent injury to wild parsnip 35 days after application except Vastlan at 48 oz/ac and Vanquish at 64 oz/ac. Sixty-one days after application, eight herbicide treatments produced less than 1 percent wild parsnip cover: Method 240SL at 10 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac; Vastlan at 48 oz/ac + Freelexx at 96 oz/; TerraVue at 2.85 oz/ac + Freelexx at 96 oz/ac + MSM 60 at 0.5 oz/ac; Method 240SL at 10 oz/ac; Method 240SL at 8 oz/ac + Freelexx at 64 oz/ac; Freelexx at 96 oz/ac; MSM 60 at 0.5 oz/ac; and Telar XP at 1 oz/ac. TerraVue at 2.85 oz/ac showed 1.8 percent wild parsnip cover. The results of this experiment demonstrates that there are several herbicide options and combinations for control of wild parsnip while releasing the existing grass cover to fill in the gaps and to act as a competitive inhibitor of greater wild parsnip spread.

## MANAGEMENT APPLICATION

Areas infested with wild parsnip are best managed with herbicide applications targeting the plant prior to flowering. In Pennsylvania, wild parsnip flowers from June to late July. Proper herbicide timing will eliminate seed set and addition to the seed bank. With most sites one treatment will not eliminate wild parsnip, repeat applications are necessary to exhaust the seed bank source of wild parsnip. A proactive cultural practice to consider is the establishment of low growing grasses such as fine fescues to fill in bare spots with the goal of outcompeting not only wild parsnip but other undesirable weeds.

Table 1. Percent injury and cover of wild parsnip (*Pastinaca sativa*). The experiment was visually rated for percent injury on June 1, 14 DAT and June 22, 35 DAT and for percent cover on May 17, July 18, August 24, September 20, and October 18, 2022, 0, 61, 98, 125, and 153 DAT. All treatments contained 0.25% v/v of non-ionic surfactant. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

| Product | Rate oz/acre | % wild parsnip cover 5/17/22 0 DAT | % wild parsnip injury 6/1/22 14 DAT | % wild parsnip injury 6/22/22 35 DAT | % wild parsnip cover 7/18/22 61 DAT | % wild parsnip cover 8/24/22 98 DAT | % wild parsnip cover 9/20/22 125 DAT | % wild parsnip cover 10/18/22 153 DAT |
|---|---|---|---|---|---|---|---|---|
| Untreated | --- | 47.5 | 1.8 a | 4.5 a | 50 b | 6.3 b | 6.8 b | 7 b |
| Method 240SL<br>Freelexx<br>MSM 60 | 10<br>96<br>0.5 | 45 | 97 e | 97.5 d | 0 a | 0 a | 0 a | 0 a |
| Vastlan<br>Freelexx | 48<br>96 | 48.8 | 81.3 cde | 96 d | 0.5 a | 0 a | 0.1 a | 0.1 a |
| TerraVue<br>Freelexx<br>MSM 60 | 2.85<br>96<br>0.5 | 55 | 96.5 e | 99.8 d | 0.1 a | 0 a | 0 a | 0 a |
| TerraVue | 2.85 | 43.8 | 98 e | 90 d | 1.8 a | 0.1 a | 0.1 a | 0.1 a |
| Method 240SL | 10 | 38.8 | 89.8 de | 95 d | 0.1 a | 0 a | 0 a | 0 a |
| Vastlan | 48 | 56.3 | 52.5 b | 61.3 c | 14.5 a | 0.4 a | 0.4 a | 0.5 a |
| Method 240SL<br>Freelexx | 8<br>64 | 47.5 | 93.5 de | 100 d | 0.3 a | 0 a | 0 a | 0 a |
| Freelexx | 96 | 50 | 85 cde | 89.8 d | 0.4 a | 0.1 a | 0.1 a | 0.1 a |
| MSM 60 | 0.5 | 55 | 61.3 bc | 94.8 d | 0 a | 0 a | 0 a | 0 a |
| Vanquish | 64 | 42.5 | 71.3 bcd | 30 b | 41.3 b | 1.1 a | 1.3 a | 1.1 a |
| Telar XP | 1 | 48.8 | 55 b | 98 d | 0 a | 0 a | 0 a | 0 a |
| | | n.s. | | | | | | |

Table 2. Percent grass cover. The experiment was visually rated for percent grass cover on May 17, July 18, and October 18, 2022, 0, 61, and 153 DAT. All treatments contained 0.25% v/v of non-ionic surfactant. Each value is the mean of four replications. Column means followed by the same letter are not significantly different at $p \leq 0.05$.

| Product | Rate oz/acre | % grass cover 5/17/22 0 DAT | % grass cover 7/18/22 61 DAT | % grass cover 10/18/22 153 DAT |
|---|---|---|---|---|
| Untreated | --- | 40 | 40 a | 71.3 |
| Method 240SL<br>Freelexx<br>MSM 60 | 10<br>96<br>0.5 | 33.8 | 86.3 bc | 77.5 |
| Vastlan<br>Freelexx | 48<br>96 | 41.3 | 82.5 bc | 76.3 |
| TerraVue<br>Freelexx<br>MSM 60 | 2.85<br>96<br>0.5 | 30 | 83.8 bc | 81.3 |
| TerraVue | 2.85 | 41.3 | 88.8 c | 82.5 |
| Method 240SL | 10 | 43.8 | 81.3 bc | 77.5 |
| Vastlan | 48 | 31.3 | 61.3 abc | 70 |
| Method 240SL<br>Freelexx | 8<br>64 | 36.3 | 72.5 abc | 75 |
| Freelexx | 96 | 36.3 | 85 bc | 81.3 |
| MSM 60 | 0.5 | 36.3 | 85 bc | 80 |
| Vanquish | 64 | 46.8 | 50 ab | 71.3 |
| Telar XP | 1 | 37.5 | 72.5 abc | 77.5 |
| | | n.s. | | n.s. |

# EVALUATION OF ALTERNATIVE BAREGROUND HERBICIDE MIXES

Herbicide trade and common names: Method 240SL *(aminocyclopyrachlor)*, Esplanade 200 SC *(indaziflam)*, Arsenal Powerline *(imazapyr)*, RoundUp Pro Concentrate (*glyphosate*), Esplanade Sure *(indaziflam + rimsulfuron)*, SFM Extra *(sulfometuron-methyl + metsulfuron-methyl)*, Pendulum Aquacap (*pendimethalin*), Hyvar XL (*bromacil*), TerraVue *(aminopyralid + florpyrauxifen-benzyl)*, ProClipse (*prodiamine*)

Plant common and scientific names: kochia *(Kochia scoparia)*, spotted knapweed *(Centaurea stoebe* L. spp*. microanthus)*, golden rod (*Solidago spp.*) prostrate knotweed *(Polygonum aviculare)*, white sweetclover *(Melilotus alb*a*)*, American burnweed *(Erechtites hieraciifolius)*, teasel *(Dipsacus fullonum),* Pennsylvania smartweed *(Polygonum pensylvanicum)*, barnyardgrass *(Echinochloa crus-galli)*, foxtail *(Setaria spp.)*, poverty dropseed *(Sporobolus vaginiflorus),* fall panicum *(Panicum dichotomiflorum)*

## ABSTRACT

Roadside areas that require season long bareground weed control include signs, guiderails, concrete barriers, and traffic islands, as well as other fixed structures. In developing bareground weed control program herbicide mixes, managers must consider alternative mixes which rotate site of action (SOA) of the various components to reduce potential herbicide resistance by the target plant populations. This experiment evaluated alternative bareground pre-emergence and broad-spectrum residual herbicide mixes with differing SOA. Treatments included: Method 240SL at 12 oz/ac + Esplanade 200 SC 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 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 XL at 128 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Method 240SL at 12 oz/ac + Pendulum Aquacap at 128 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; TerraVue at 5 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 XL at 128 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Method 240SL at 12 oz/ac + ProClipse at 32 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Esplanade Sure at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac and an untreated check. By 152 DAT, the untreated check showed 60 percent total vegetative cover and was significantly different from all herbicide treatments. The treatment with the lowest total cover, 0.12%, was Pendulum Aquacap at 128 oz/ac + SFM Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac. Additional treatments with less than 1% total cover included Esplanade Sure at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (0.33%) and Esplanade Sure at 5 oz/ac + SFM Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (0.45%). Treatments showing between 1 and approximately 2 percent total cover were ProClipse at 32 oz/ac + Hyvar XL at 128 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (1.03%), Pendulum Aquacap at 128 oz/ac + Hyvar XL at 128 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (1.42%), Method 240SL at 12 oz/ac + Esplanade 200 SC at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64

oz/ac (1.9%), Method 240SL at 12 oz/ac + ProClipse at 32 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (2.04%). The remaining treatments resulted in less than 4% total vegetative cover included TerraVue at 5 oz/ac + ProClipse at 32 oz/ac + SFM Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (3.33%) and Method 240SL at 12 oz/ac + Pendulum Aquacap at 128 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (3.58%). No treatment produced season long control; however, this experiment shows that herbicides with alternative sites of action can be effective at reducing weed regrowth to below 5% total cover in bareground sites during the growing season.

## INTRODUCTION

Bareground weed control is an essential part of a roadside vegetation management program and include signs, under 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 pre-emergence herbicide. Pre-emergence 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 in developing a bareground program. Depending on the component within bareground mix, it is necessary to rotate the SOA of each component 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 SOA for bareground applications. In a continuing effort to develop alternative bareground mixes that rotate SOA, this experiment evaluated mixes that utilize different pre-emergence and broad-spectrum residual SOA herbicides.

## MATERIALS AND METHODS

The experiment was established as a randomized complete design with three replications beneath a guiderail site adjacent to I-99 southbound along the off ramp to Port Matilda, PA. Treatments include Method 240SL at 12 oz/ac + Esplanade 200 SC 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 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 XL at 128 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Method 240SL at 12 oz/ac + Pendulum Aquacap at 128 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; TerraVue at 5 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 XL at 128 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Method 240SL at 12 oz/ac + ProClipse at 32 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Esplanade Sure at 5 oz/ac + Arsenal

Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac and an untreated check. Induce, a non-ionic 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 29, 2022, 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, 18% relative humidity, air temperature of 47°F and soil temperatures of 60°F, 58°F, 55°F, and 54°F, at 0-, 1-, 3-, and 6-inch depths, respectively. Local rain events occurred on May 1, 3, 6, and 7, 2022 with 0.29", 0.33", 1.7", and 0.88" respectively, according to http://newa.cornell.edu. The nearest weather station was in Rock Springs, PA.

The experiment was visually rated for percent total vegetative cover on April 25, May 26, June 29, July 28, August 29, and September 28, 2022, 0, 27, 61, 90, 122 and 152 days after treatment (DAT). Additionally, percent broadleaf weed cover and gras cover were visually rated on June 29, July 28, August 29, and September 28, 2022, 61, 90, 122 and 152 DAT. On October 9, 2022, a killing frost occurred at the guiderail site effectively ending the experiment. 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 DISCUSSIONS

Prior to treatment application, the plots were visually rated on April 25 and ranged from 0.1 to 4.1% total cover with no significance between treatments (Table 1). Total cover diminished and ranged from 0 to 0.17% total cover for the herbicide treatments and 2.5% for the untreated check on May 26, 27 DAT. Percent total cover continued to increase through July 28, 90 DAT, with six treatments resulting in less than 1% total cover. Those treatments included: Esplanade Sure at 5 oz/ac + SFM 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; Esplanade Sure at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; ProClipse at 32 oz/ac + Hyvar XL at 128 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; Pendulum Aquacap at 128 oz/ac + Hyvar XL at 128 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; and Method 240SL at 12 oz/ac + Esplanade 200 SC at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac. On August 29, 122 DAT, all treatments continued to increase in total vegetative cover. While herbicide treatments were statistically similar, these treatments were significantly different when compared to the untreated check. By 152 DAT, the untreated check showed 60 percent total vegetative cover and was significantly different from all herbicide treatments. Common plant species identified in the untreated plots included kochia, spotted knapweed, golden rod, prostrate knotweed, white sweetclover, American burnweed, teasel, Pennsylvania smartweed, barnyardgrass, poverty dropseed, and fall panicum. Also, by 152 DAT, all herbicide treatments were statistically similar. The treatment with the lowest total cover, 0.12% was Pendulum Aquacap at 128 oz/ac + SFM Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac. Additional treatments with less than 1% total cover included Esplanade Sure at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (0.33%) and Esplanade Sure at 5 oz/ac + SFM Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (0.45%). Treatments between 1 and approximately 2 percent total cover

were ProClipse at 32 oz/ac + Hyvar XL at 128 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (1.03%), Pendulum Aquacap at 128 oz/ac + Hyvar XL at 128 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (1.42%), Method 240SL at 12 oz/ac + Esplanade 200 SC at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (1.9%), Method 240SL at 12 oz/ac + ProClipse at 32 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (2.04%). The remaining treatments resulted in the following percent total vegetative cover TerraVue at 5 oz/ac + ProClipse at 32 oz/ac + SFM Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (3.33%) and Method 240SL at 12 oz/ac + Pendulum Aquacap at 128 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (3.58%).

Broadleaf weed cover ranged from 0.02 to 0.75% for the herbicide treatments and the untreated check showed 30.5% on June 29, 61 DAT (Table 2). There was a significant difference between the herbicide treatments and the untreated check. This trend continued through the last evaluation on September 28, 152 DAT. By that time, four treatments resulted in 1% or less broadleaf weed cover included Pendulum Aquacap at 128 oz/ac + SFM Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (0.12%), Esplanade Sure at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (0.33%), Esplanade Sure at 5 oz/ac + SFM Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (0.45%), ProClipse at 32 oz/ac + Hyvar XL at 128 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (1%). The remaining treatments resulted in the following % broadleaf weed cover Method 240SL at 12 oz/ac + ProClipse at 32 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (1.37%), Pendulum Aquacap at 128 oz/ac + Hyvar XL at 128 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (1.42%), Method 240SL at 12 oz/ac + Esplanade 200 SC at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (1.9%), TerraVue at 5 oz/ac + ProClipse at 32 oz/ac + SFM Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (3.3%) and Method 240SL at 12 oz/ac + Pendulum Aquacap at 128 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac (3.5%).

Grass cover between the herbicide treatments ranged from 0% to 0.08% and the untreated check showed 1.83% on June 29, 61 DAT (Table 3). By September 28, 152 DAT, six treatments resulted in 0% grass cover: Method 240SL at 12 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 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; 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 XL at 128 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; TerraVue at 5 oz/ac + ProClipse at 32 oz/ac + SFM Extra at 4 oz/ac + RoundUp Pro Concentrate at 64 oz/ac; and Esplanade Sure at 5 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac. ProClipse at 32 oz/ac + Hyvar XL at 128 oz/ac + RoundUp Pro Concentrate at 64 oz/ac resulted in 0.03% while Method 240SL at 12 oz/ac + Pendulum Aquacap at 128 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac resulted in 0.08% grass cover. Finally, Method 240SL at 12 oz/ac + ProClipse at 32 oz/ac + Arsenal Powerline at 8 oz/ac + RoundUp Pro Concentrate at 64 oz/ac resulted in 0.67% grass cover. All herbicide treatments were significantly different from the untreated check which had 9.3% grass cover.

The guiderail site selected for this experiment had previously been treated with a standard PennDOT bareground mix and was considerably clean under the guiderail. This site provided an opportunity to demonstrate the effectiveness of alternative bareground mixes used in conjunction with a standard PennDOT mix. Based on the results, all the herbicide treatments could be used as alternative bareground mixes to a standard PennDOT mix. If considering rotation of site of action of herbicides of each component a baseline or standard mix needs to be established and then herbicide rotations can be determined.

Table 4 outlines each bareground mix describing the common name of herbicides, site of action, and how each product is used in the mix. For example, Esplanade 200 SC, *indaziflam* is a pre-emergence herbicide and *SOA 29*. The Weed Science Society of America WSSA groups herbicides based on site of action of each herbicide. This can be used to easily rotate herbicides based on SOA as a tool to manage herbicide resistance.

## CONCLUSIONS

No herbicide treatments provided complete season-long bareground weed control by the end of the experiment. If 5% total vegetative cover is an acceptable threshold by the end of the growing season, all herbicide mixes evaluated may be considered as options to use in a bareground program. This experiment demonstrates the effectiveness of alternative bareground mixes used within a program that rotates SOA of pre-emergence and broad-spectrum residual herbicides to manage herbicide resistance treated with a standard bareground mix the previous year. Future work should continue to evaluate combinations and rates that can used to replace standard pre-emergence, broad-spectrum residual, and post emergence products in bareground mixes. Additionally, future research should evaluate a site over several years with an intentional SOA rotation based on this and previous research. Data collection over 4 years would build historical data and confidence with future recommendations.

## MANAGEMENT IMPLICATIONS

One goal of the project is to develop bareground mixes that can be used in a bareground program the rotates the SOA of all herbicide components. A mix is what is used for a particular year. A program involves bareground mixes used over several years in sequence that rotates SOA of pre-emergence, broad-spectrum residual, and post emergence herbicides. Based on this experiment and previous work, *prodiamine* or *pendimethalin* are pre-emergence herbicides that can be used as a rotation for *indaziflam*. Additionally, *bromacil* a broad-spectrum residual that can be deployed in place of *imazapyr* or *sulfometuron-methyl*. This experiment combined with the experiment on herbicide mix SOA rotation recommendations for *glyphosate* found in this report can be helpful in choosing alternative bareground mixes. All bareground mixes and

components (e.g., Method 240SL[27], TerraVue[28], Arsenal Powerline[29] and Hyvar XL[30] labels) have the potential to do unintended damage to non-target plant root systems which extend into treated areas and caution in choice and use is advised. Products containing *sulfometuron-methyl* such as SFM Extra or Oust Extra and *bromacil,* Hyvar XL, also 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[31]. 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. In developing a bareground program the following would rotate herbicide SOA for each component. Over a 3-year period, the mixes may include: 1) Method 240SL + Esplanade 200 SC + Arsenal Powerline + RoundUp Pro 2) Pendulum Aquacap + Hyvar XL + RoundUp Pro 3) Method 240SL + Esplanade 200 SC + Arsenal Powerline + Fusilade II. This is one possible scenario and other herbicides can be used in place of one's listed with similar SOA. For example, TerraVue could be used instead of Method 240SL, ProClipse can be used instead of Pendulum Aquacap, and Oust XP can be used instead of Arsenal. As mentioned above some herbicides have potential to move off site so the roadside specialist needs to exercise care to be sure bareground treatments are not creating additional bareground than necessary. This issue may be the key focus once herbicide SOA rotations are developed.

[27] Bayer CropScience LP. Method 240SL label. http://www.cdms.net/ldat/ldCFU019.pdf
[28] Corteva Agriscience. Dow Agrosciences LLC TerraVue label. http://www.cdms.net/ldat/ld2IB008.pdf
[29] BASF Corporation. Arsenal Powerline label. http://www.cdms.net/ldat/ld86K002.pdf
[30] Bayer CropScience LP. Hyvar X-L label. https://www.cdms.net/ldat/ldCFT000.pdf
[31] Bayer CropScience LP. Oust Extra label. https://www.cdms.net/ldat/ldCJ3001.pdf

Table 1. Effectiveness of treatments based on percent total vegetative cover at 0, 27, 61, 90, 122, & 152 days after treatment (DAT). The site was visually rated for % total cover on April 25, May 36, June 29, July 28, August 29, & September 28, 2022. Treatments were applied April 29, 2022. A non-ionic surfactant was added to all treatments at 0.25% v/v. Each value is the mean of three replications. Column means followed by the same letter are not significantly different.

| Product | Rate oz/acre | % total cover 4/25/22 0 DAT | % total cover 5/26/22 27 DAT | % total cover 6/29/22 61 DAT | % total cover 7/28/22 90 DAT | % total cover 8/29/22 122 DAT | % total cover 9/28/22 152 DAT |
|---|---|---|---|---|---|---|---|
| Untreated | -- | 0.6 | 2.5 b | 32.3 b | 55 b | 60 b | 60 b |
| Method 240SL<br>Esplanade 200 SC<br>Arsenal Powerline<br>RoundUp Pro Concentrate | 12<br>5<br>8<br>64 | 4.1 | 0.8 a | 0.27 a | 0.9 a | 1.8 a | 1.9 a |
| Esplanade Sure<br>SFM Extra<br>RoundUp Pro Concentrate | 5<br>4<br>64 | 0.1 | 0 a | 0.03 a | 0.02 a | 0.42 a | 0.45 a |
| Pendulum Aquacap<br>SFM Extra<br>RoundUp Pro Concentrate | 128<br>4<br>64 | 0.3 | 0 a | 0.05 a | 0.03 a | 0.09 a | 0.12 a |
| Pendulum Aquacap<br>Hyvar XL<br>RoundUp Pro Concentrate | 128<br>128<br>64 | 0.3 | 0 a | 0.08 a | 0.8 a | 1.33 a | 1.42 a |
| Method 240SL<br>Pendulum Aquacap<br>Arsenal Powerline<br>RoundUp Pro Concentrate | 12<br>128<br>8<br>64 | 0.9 | 0.08 a | 0.78 a | 2.45 a | 3.58 a | 3.58 a |
| TerraVue<br>ProClipse<br>SFM Extra<br>RoundUp Pro Concentrate | 5<br>32<br>4<br>64 | 3.7 | 0 a | 0.17 a | 1.3 a | 3.33 a | 3.33 a |
| ProClipse<br>Hyvar XL<br>RoundUp Pro Concentrate | 32<br>128<br>64 | 0.2 | 0.03 a | 0.07 a | 0.37a | 1.03 a | 1.03 a |
| Method 240SL<br>ProClipse<br>Arsenal Powerline<br>RoundUp Pro Concentrate | 12<br>32<br>8<br>64 | 2.3 | 0.17 | 0.76 a | 2 a | 2.02 a | 2.04 a |
| Esplanade Sure<br>Arsenal Powerline<br>RoundUp Pro Concentrate | 5<br>8<br>64 | 0.2 | 0.07 a | 0.02 a | 0.08 a | 0.33 a | 0.33 a |
| | | n.s. | | | | | |

Table 2. Effectiveness of treatments based on percent broadleaf weed (BLW) cover at 61, 90, 122, & 152 days after treatment (DAT). The site was visually rated for percent broadleaf weed cover on June 29, July 28, August 29, & September 28, 2022. Treatments were applied April 29, 2022. A non-ionic surfactant was added to all treatments at 0.25% v/v. Each value is the mean of three replications. Column means followed by the same letter are not significantly different.

| Product | Rate oz/acre | % BLW cover 6/29/22 61 DAT | % BLW cover 7/28/22 90 DAT | % BLW cover 8/29/22 122 DAT | % BLW cover 9/28/22 152 DAT |
|---|---|---|---|---|---|
| Untreated | -- | 30.5 b | 50 b | 50.7 a | 50.7 b |
| Method 240SL<br>Esplanade 200 SC<br>Arsenal Powerline<br>RoundUp Pro Concentrate | 12<br>5<br>8<br>64 | 0.27 a | 0.85 a | 1.8 a | 1.9 a |
| Esplanade Sure<br>SFM Extra<br>RoundUp Pro Concentrate | 5<br>4<br>64 | 0.03 a | 0.02 a | 0.42 a | 0.45 a |
| Pendulum Aquacap<br>SFM Extra<br>RoundUp Pro Concentrate | 128<br>4<br>64 | 0.05 a | 0.03 a | 0.09 a | 0.12 a |
| Pendulum Aquacap<br>Hyvar XL<br>RoundUp Pro Concentrate | 128<br>128<br>64 | 0.08 a | 0.80 a | 1.25 a | 1.42 a |
| Method 240SL<br>Pendulum Aquacap<br>Arsenal Powerline<br>RoundUp Pro Concentrate | 12<br>128<br>8<br>64 | 0.75 a | 2.42 a | 3.5 a | 3.5 a |
| TerraVue<br>ProClipse<br>SFM Extra<br>RoundUp Pro Concentrate | 5<br>32<br>4<br>64 | 0.17 a | 1.33 a | 3.33 a | 3.33 a |
| ProClipse<br>Hyvar XL<br>RoundUp Pro Concentrate | 32<br>128<br>64 | 0.07 a | 0.35 a | 0.87 a | 1 a |
| Method 240SL<br>ProClipse<br>Arsenal Powerline<br>RoundUp Pro Concentrate | 12<br>32<br>8<br>64 | 0.68 a | 1.7 a | 1.35 a | 1.37 a |
| Esplanade Sure<br>Arsenal Powerline<br>RoundUp Pro Concentrate | 5<br>8<br>64 | 0.02 a | 0.08 a | 0.33 a | 0.33 a |

Table 3. Effectiveness of treatments based on percent grass cover at 61, 90, 122, & 152 days after treatment (DAT). The site was visually rated for percent grass cover on June 29, July 28, August 29, & September 28, 2022. Treatments were applied April 29, 2022. A non-ionic surfactant was added to all treatments at 0.25% v/v. Each value is the mean of three replications. Column means followed by the same letter are not significantly different.

| Product | Rate oz/acre | % grass cover 6/29/22 61 DAT | % grass cover 7/28/22 90 DAT | % grass cover 8/29/22 122 DAT | % grass cover 9/28/22 152 DAT |
|---|---|---|---|---|---|
| Untreated | -- | 1.83 b | 5 b | 9.3 b | 9.3 b |
| Method 240SL<br>Esplanade 200 SC<br>Arsenal Powerline<br>RoundUp Pro Concentrate | 12<br>5<br>8<br>64 | 0 a | 0 a | 0 a | 0 a |
| Esplanade Sure<br>SFM Extra<br>RoundUp Pro Concentrate | 5<br>4<br>64 | 0 a | 0 a | 0 a | 0 a |
| Pendulum Aquacap<br>SFM Extra<br>RoundUp Pro Concentrate | 128<br>4<br>64 | 0 a | 0 a | 0 a | 0 a |
| Pendulum Aquacap<br>Hyvar XL<br>RoundUp Pro Concentrate | 128<br>128<br>64 | 0 a | 0 a | 0.08 a | 0 a |
| Method 240SL<br>Pendulum Aquacap<br>Arsenal Powerline<br>RoundUp Pro Concentrate | 12<br>128<br>8<br>64 | 0.03 a | 0.03 a | 0.08 a | 0.08 a |
| TerraVue<br>ProClipse<br>SFM Extra<br>RoundUp Pro Concentrate | 5<br>32<br>4<br>64 | 0 a | 0 a | 0 a | 0 a |
| ProClipse<br>Hyvar XL<br>RoundUp Pro Concentrate | 32<br>128<br>64 | 0 a | 0.02 a | 0.17 a | 0.03 a |
| Method 240SL<br>ProClipse<br>Arsenal Powerline<br>RoundUp Pro Concentrate | 12<br>32<br>8<br>64 | 0.08 a | 0.3 a | 0.67 a | 0.67 a |
| Esplanade Sure<br>Arsenal Powerline<br>RoundUp Pro Concentrate | 5<br>8<br>64 | 0 a | 0 a | 0 a | 0 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 | |
|---|---|---|---|---|
| Untreated | -- | -- | -- | |
| Method 240SL | 12 | *aminocyclopyrachlor* | 4 | post +residual |
| Esplanade 200 SC | 5 | *indaziflam* | 29 | pre |
| Arsenal Powerline | 8 | *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 |
| Pendulum Aquacap | 128 | *pendimethalin* | 3 | pre |
| SFM Extra | 4 | *sulfometuron+metsulfuron* | 2+2 | bsr |
| RoundUp Pro Concentrate | 64 | *glyphosate* | 9 | post |
| Pendulum Aquacap | 128 | *pendimethalin* | 3 | pre |
| Hyvar XL | 128 | *bromacil* | 5 | bsr |
| RoundUp Pro Concentrate | 64 | *glyphosate* | 9 | post |
| Method 240SL | 12 | *aminocyclopyrachlor* | 4 | post +residual |
| Pendulum Aquacap | 128 | *pendimethalin* | 3 | pre |
| Arsenal Powerline | 8 | *imazapyr* | 2 | bsr |
| RoundUp Pro Concentrate | 64 | *glyphosate* | 9 | post |
| TerraVue | 5 | *aminopyralid+florpyrauxifen* | 4+4 | post +residual |
| 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 | 128 | *bromacil* | 5 | bsr |
| RoundUp Pro Concentrate | 64 | *glyphosate* | 9 | post |
| Method 240SL | 12 | *aminocyclopyrachlor* | 4 | post +residual |
| Proclipse | 32 | *prodiamine* | 3 | pre |
| Arsenal Powerline | 8 | *imazapyr* | 2 | bsr |
| RoundUp Pro Concentrate | 64 | *glyphosate* | 9 | post |
| Esplanade Sure | 5 | *indaziflam+rimsulfuron* | 29+2 | pre |
| Arsenal Powerline | 8 | *imazapyr* | 2 | bsr |
| RoundUp Pro Concentrate | 64 | *glyphosate* | 9 | post |

EVALUATION OF BAREGROUND HERBICIDE MIXES WITHOUT GLYPHOSATE

Herbicide trade and common names: Method 240SL *(aminocyclopyrachlor)*, Esplanade 200 SC *(indaziflam)*, Arsenal Powerline *(imazapyr)*, Plateau *(imazapic)*, Fusilade II *(fluazifop-P-butyl)*, Segment II *(sethoxydim)*, TerraVue *(aminopyralid + florpyrauxifen-benzyl)*, Esplanade Sure *(indaziflam + rimsulfuron)*, SFM Extra *(sulfometuron-methyl + metsulfuron-methyl)*, Plainview SC *(indaziflam + aminocyclopyrachlor + imazapyr)*

Plant common and scientific names: kochia *(Kochia scoparia)*, pineapple-weed *(Matricaria matricariodes)*, birdsfoot trefoil *(Lotus corniculatus)*, wild carrot *(Daucus carota)*, barnyardgrass *(Echinochloa crus-galli)*, switchgrass *(Panicum virgatum)*, witchgrass *(Panicum capillare)*, foxtail *(Setaria spp.)*, poverty dropseed (*Sporobolus vaginiflorus*)


ABSTRACT

Bareground weed control programs rely on three components to provide season-long control, a pre-emergence herbicide, a broad-spectrum residual herbicide, and a post emergence herbicide. Glyphosate is continuously used as a post emergence product in bareground mixes. This experiment was designed to evaluate combinations of post emergence broadleaf and grass herbicides in a bareground mix for effectiveness and as an herbicide SOA (site of action) rotation for glyphosate. Treatments include Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Plateau at 12 oz/ac; Method 240SL at 16 oz/ac + Esplanade 200 at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac; Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac; Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Segment II at 32 oz/ac; TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Segment II at 32 oz/ac; TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac; TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Plateau at 6 oz/ac; Esplanade Sure at 5 oz/ac + SFM Extra at 4 oz/ac; Plainview SC at 48 oz/ac; and an untreated check. Induce, a non-ionic surfactant, was added to all herbicide treatments at 0.25% v/v. Plots were 20 by 4 feet in size. Treatments were pre-measured, mixed, and applied on May 11, 2022, using a $CO_2$ powered backpack sprayer equipped with one OC-06 nozzle at 31 PSI (pounds per square inch), and delivered at 50 gallons per acre. On September 12, 124 DAT, the untreated check showed 67.8% total cover. Three treatments resulted in 5% or less total vegetative cover with Plainview SC at 48 oz/ac showing 5% total vegetative cover, TerraVue at 5 oz/ac + Esplanade 200 at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac producing in 4.6% total vegetative cover, while Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac with the greatest reduction of cover at 3.6% total vegetative cover. By 124 DAT, several treatments resulted in roughly 2% grass cover including Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Plateau at 12 oz/ac (2.1%), TerraVue at 5 oz/ac + Esplanade 200 at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Segment II at 32 oz/ac (2.1%), Plainview SC at 48 oz/ac (2%), Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8

oz/ac +Fusilade II at 24 oz/ac (1.4%) and, TerraVue at 5 oz/ac + Esplanade 200 at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac (1.1%). Method 240SL at 16 oz/ac + Esplanade 200SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Segment II at 32 oz/ac resulted in the least broadleaf cover at 1.7%. Most other herbicide treatments resulted in less than 5% broadleaf weed cover including: Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac (2.2%), Plainview SC at 48 oz/ac (3%), TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac (3%), TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Plateau at 6 oz/ac (3.5%), Method 240SL at 16 oz/ac + Esplanade 200SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac (4.4%), TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Segment II at 32 oz/ac (4.5%), and Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Plateau at 12 oz/ac (4.9%). None of the herbicide treatments provided season-long bareground control. However dependent on the level of tolerance for weeds by the end of the season, there are a few options that may work as rotational options out of glyphosate.

## INTRODUCTION

Bareground weed control programs rely on three components incorporated into an herbicide mix to provide season-long control under guiderails and around signposts or delineators. The three components include a pre-emergence herbicide, a broad-spectrum residual herbicide, and a post emergence herbicide. Glyphosate, a non-selective herbicide, has been the product of choice as a post emergence herbicide due to effectiveness on most herbaceous species and low cost. These characteristics has made glyphosate a standard for years as a post emergence herbicide in bareground mixes. In general, glyphosate has been used continuously year after year in bareground mixes. According to the Weed Science Society of America (WSSA) *glyphosate* is a group 9 site of action (SOA) herbicide. This categorization makes it handy for managers to determine alternatives based on SOA. The goal of this experiment was to evaluate products in place of *glyphosate* as an effective postemergence product. Typical bareground mixes include *aminocyclopyrachlor* or *aminopyralid* (SOA group 4) which are effective post emergence products on broadleaf weeds plus both have varying degrees of residual activity. Based on glyphosates broad label the question remains would the addition of grass herbicides help broaden the spectrum of controlled species post emergence and offer a potential herbicide mix rotation from *glyphosate*? Several grass herbicides exist in the industry. Since the objective is to mix it with a broadleaf herbicide compatibility becomes an issue. Possible grass herbicides that may be an effective addition include Segment II (*sethoxydim*) and Fusilade II (*fluazifop P-butyl*). Both Segment II and Fusilade II are WSSA group 1 SOA and are compatible with broadleaf weed herbicides. Other potential products based on effectiveness on grasses include Esplanade Sure, Plateau, and Arsenal Powerline. Esplanade Sure is a combination product containing *indaziflam* and *rimsulfuron*. *Rimsulfuron* offers both post and preemergence control of weeds, however, application timing is critical. Plateau (*imazapic)* has a wide range of uses including preemergence and post emergence control of annual broadleaf weeds and annual and perennial grasses depending on application rates and timing. Arsenal Powerline (*imazapyr*) is commonly added to bareground mixes as a broad-spectrum residual and has activity on annual and perennial grasses which varies due to rate. This experiment was designed to evaluate

combinations of post emergence broadleaf and grass herbicides in a bareground mix for effectiveness and as an herbicide SOA rotation for *glyphosate*.

## MATERIALS AND METHODS

The experiment was established as a randomized complete design with four replications beneath a guiderail site along I-99 northbound, 2 miles north of Port Matilda, PA. Treatments include Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Plateau at 12 oz/ac; Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac; Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac; Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Segment II at 32 oz/ac; TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Segment II at 32 oz/ac; TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac; TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Plateau at 6 oz/ac; Esplanade Sure at 5 oz/ac + SFM Extra at 4 oz/ac; Plainview SC at 48 oz/ac; and an untreated check. Induce, a non-ionic surfactant, was added to all herbicide treatments at 0.25% v/v. Plots were 20 by 4 feet in size. Treatments were pre-measured, mixed, and applied on May 11, 2022, using a $CO_2$ powered backpack sprayer equipped with one OC-06 nozzle at 31 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, 15% relative humidity, air temperature of 65°F and soil temperatures of 58°F, 58°F, 56°F, and 56°F, at 0-, 1-, 3-, and 6-inch depths, respectively. Local rain events on May 14, 15, 16, 18, 19, and 20, 2022 with 0.19", 0.06", 0.26", 0.08, 0.09", and 0.31" respectively according to http://newa.cornell.edu. The nearest weather station was in Rock Springs, PA.

The experiment was visually rated for percent total vegetative cover on May 9, June 9, July 11, August 10, and September 12, 2022, 0, 29, 61, 92, and 124 days after treatment (DAT). Additionally, percent grass cover and broadleaf weed cover were visually rated on July 11, August 10, and September 12, 2022, 61, 92, and 124 DAT. On October 9, 2022, a killing frost occurred at the guiderail site effectively ending the experiment. 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, evaluated prior to the application on May 9, 2022, ranged between 10.3 and 21.6 percent total vegetative cover with no significant difference between treatments (Table 1). Total vegetative cover diminished and ranged between 0.2 and 2.1 percent for the herbicide treatments while the untreated was 36.8 percent by June 9, 29 DAT. On July 11, two treatments, Plainview SC at 48 oz/ac and Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac showed less then 1% total vegetative cover. By August 10, 92 DAT, percent total vegetive cover continued to increase for all treatments. Five herbicide treatments showed 5% or less total vegetative cover: Method

240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Plateau at 12 oz/ac; TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Segment II at 32 oz/ac; TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac; Plainview SC at 48 oz/ac and Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac. All herbicide treatments were rated significantly less in total vegetative cover than the untreated check. On September 12, 124 DAT, the untreated check showed 67.8% total vegetative cover, which was significantly more total vegetative cover compared to the herbicide treatments. Plant species consistently identified in the untreated plots included kochia, pineapple weed, birdsfoot trefoil, wild carrot, barnyardgrass, switchgrass, witchgrass, and foxtails. All herbicide treatments were statistically similar by the end of the experiment. Three treatments resulted in 5% or less total vegetative cover including Plainview SC at 48 oz/ac at 5% total vegetative cover, TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac with 4.6% total vegetative cover, and with the least total vegetative cover Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac at 3.6% total vegetative cover. Several treatments resulted in less than 10% total vegetative cover including TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Segment II at 32 oz/ac (6.6%), Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Plateau at 12 oz/ac (7%), TerraVue at 5 oz/ac + Esplanade 200 at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Plateau at 6 oz/ac (9.3%). The remaining herbicide treatments produced the following results Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Segment II at 32 oz/ac (11%), Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac (11.1%), and Esplanade Sure at 5 oz/ac + SFM Extra at 4 oz/ac (12.4%).

Grass cover between herbicide treatments ranged between 0.1 to 3.6 percent on July 11 61 DAT, while the untreated check had 23.8% (Table 2). On August 10, 92 DAT grass continued to increase and ranged from 0.5 to 7.2 percent. By 124 DAT, several treatments showed roughly 2% grass cover. These treatments included Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Plateau at 12 oz/ac (2.1%), TerraVue at 5 oz/ac + Esplanade 200 at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Segment II at 32 oz/ac (2.1%), Plainview SC at 48 oz/ac (2%), Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac +Fusilade II at 24 oz/ac (1.4%), and TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac (1.1%). The remaining herbicide treatments resulted in between 5% and 10% grass cover including Esplanade Sure at 5 oz/ac + SFM Extra at 4 oz/ac (4.9%), TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Plateau at 8 oz/ac (5.8%), Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac (6.7%), and Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Segment II at 32 oz/ac (9.3%). While comparing trends based on grass weeds identified, it became clear that poverty dropseed was identified in most plots regardless of herbicide treatment. While it was not the only grass weed species identified, poverty dropseed was the most common. Treatments were applied in May to allow the annual summer grasses to germinate and then to determine effectiveness of the grass herbicide in the mix. However, it was difficult to determine if the grass herbicide

controlled the grasses post emergence or if the preemergence herbicide was ineffective allowing some grass species to germinate. While none of the treatments resulted in total grass control, there appears to be some useful trends. Comparing the base mix of Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac, the addition of either Plateau at 12 oz/ac or Fusilade II at 24 oz/ac resulted in lower grass cover. Interestingly the addition of Segment II at 32 oz/ac to the above base mix showed higher grass cover. In comparing the base mix of TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac with the addition of Fusilade II at 24 oz/ac resulted in slightly lower grass cover compared to the addition of Segment II at 32 oz/ac. Treatments containing Fusilade II at 24 oz/ac showed less grass cover than treatments containing Segment II at 32 oz/ac. TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac resulted in slightly less grass cover than Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac. TerraVue at 5 oz/ac + Esplanade 200 at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Segment II at 32 oz/ac resulted in less grass cover than Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Segment II at 32 oz/ac. TerraVue is a combination product containing *aminopyralid* and *florpyrauxifen-benzyl*. *Florpyrauxifen-benzyl* has activity on grasses which may have increased percent grass control[32].

Broadleaf weed cover ranged from 0.5-3% for the herbicide treatments and the untreated check showed 25% on July 11, 61 DAT (Table 3). There was a significant difference between the herbicide treatments and the untreated check. By 124 DAT, Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Segment II at 32 oz/ac resulted in 1.7% broadleaf weed cover. Most other herbicide treatments resulted in less than 5% broadleaf weed cover and included: Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac (2.2%), Plainview SC at 48 oz/ac (3%), TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac (3%), TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Plateau at 6 oz/ac (3.5%), Method 240SL at 16 oz/ac + Esplanade 200SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac (4.4%), TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Segment II at 32 oz/ac (4.5%), and Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Plateau at 12 oz/ac (4.9%). Esplanade Sure at 5 oz/ac + SFM Extra at 4 oz/ac resulted in 7.5% broadleaf weed cover. Kochia was the common broadleaf weed present in most plots regardless of treatment.

When considering rotation of herbicides specifically in bareground mixes it is useful to have tables that includes information on the trade and common herbicide names, as well as the site of action of each active ingredient. Table 4 provides this information on the bareground herbicide mixes evaluated for this experiment.

[32] Miller MR, Norsworthy JK (2018) Florpyrauxifen-benzyl Weed Control Spectrum and Tank-Mix Compatibility with other Commonly Applied Herbicides in Rice. Weed Technol 32:319-325, doi: 10.1017/wet2017.107

## CONCLUSIONS

None of the herbicide treatments provided season-long bareground control. Based on a threshold of 5% or less total vegetative cover by the end of the growing season as acceptable, the following treatments should be considered for use: Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac, TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac, and Plainview SC at 48 oz/ac. Based on percent grass cover, treatments containing Fusilade II outperformed treatments containing Segment II. The higher acid equivalent rate of *imazapyr* in Plainview SC at 48 oz/ac most likely reduced percent total vegetative cover compared to the Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac treatment. Future work should continue to evaluate combinations and rates that can used to replace glyphosate as a post emergence product in bareground mixes. This will build historical data and confidence with future recommendations.

## MANAGEMENT IMPLICATIONS

This work is a continuation of experiments with the goal of providing products to rotate site of action of herbicides for bareground treatments. Here we focus on rotating out *glyphosate* while still providing acceptable season-long bareground control. Several mixes evaluated appeared to be effective, but the question must be asked, what is your threshold for acceptable total cover in a bareground site? If 5% or less total vegetative cover by the end of the season is preferred, consider Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac, TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Fusilade II at 24 oz/ac, or Plainview SC at 48 oz/ac. If 10% total vegetative cover is acceptable by the end of the season consider TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Segment II at 32 oz/ac, Method 240SL at 16 oz/ac + Esplanade 200 SC at 6 oz/ac + Arsenal Powerline at 8 oz/ac + Plateau at 12 oz/ac, TerraVue at 5 oz/ac + Esplanade 200 SC at 6 oz/ac + Plateau at 6 oz/ac. The grass herbicides evaluated were Fusilade II and Segment II. Based on the results of this experiment Fusilade II outperformed Segment II in comparing grass control. Also, Plateau at 12 oz/ac provided good grass control. Plateau may not be considered a grass herbicide because of its broad spectrum of activity but it is one to consider. Caution with all the bareground mixes must be observed. Method 240SL[33], TerraVue[34], Arsenal Powerline[35] and Plainview SC[36], labels all contain statements warning of potential injury to trees and desirable plants with root systems extending into the treated area. When considering products and comparing similar active ingredients determine acid equivalent per acre. For instance, Plainview SC at 48 oz/ac applies *indaziflam* acid at 1.1 ounces per acre, *aminocyclopyrachlor* acid at 3 ounces per acre, and *imazapyr* acid at 9.1 ounces per acre. Method 240SL at 16 oz/acre applies *aminocyclopyrachlor*

[33] Bayer CropScience LP. Method 240SL label. http://www.cdms.net/ldat/ldCFU019.pdf
[34] Corteva Agriscience. Dow Agrosciences LLC TerraVue label. http://www.cdms.net/ldat/ld2IB008.pdf
[35] BASF Corporation. Arsenal Powerline label. http://www.cdms.net/ldat/ld86K002.pdf
[36] Bayer CropScience LP. Plainview SC label. https://www.cdms.net/ldat/ldG3J004.pdf

acid at 4 ounces per acre while Esplanade 200 SC at 6 oz/ac applies *indaziflam* acid at 1.3 ounces per acre, and Arsenal Powerline at 8 oz/ac applies imazapyr acid at 2 ounces per acre. Caution should be used if selecting Plainview SC at 48 oz/ac because this will apply 4 times the rate of imazapyr acid that is commonly applied to bareground sites. Products containing *sulfometuron-methyl* such as SFM Extra or Oust 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[37]. 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.

[37] Bayer CropScience LP. Oust Extra label. https://www.cdms.net/ldat/ldCJ3001.pdf

Table 1. Effectiveness of treatments based on percent total vegetative cover at 0, 29, 61, 92, & 124 days after treatment (DAT). The site was visually rated for percent total cover on May 9, June 9, July 11, August 10, & September 12, 2022. Treatments were applied May 11, 2022. 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/ac | % TOTAL COVER 05/09/22 0 DAT | % TOTAL COVER 06/09/22 29 DAT | % TOTAL COVER 07/11/22 61 DAT | % TOTAL COVER 08/10/22 92 DAT | % TOTAL COVER 09/12/22 124 DAT |
|---|---|---|---|---|---|---|
| Untreated | --- | 14 | 36.8 b | 48.8 b | 57.5 b | 67.8 b |
| Method 240SL<br>Esplanade 200 SC<br>Arsenal Powerline<br>Plateau | 16<br>6<br>8<br>12 | 10.3 | 0.3 a | 1.7 a | 4.5 a | 7 a |
| Method 240SL<br>Esplanade 200 SC<br>Arsenal Powerline<br>Fusilade II | 16<br>6<br>8<br>24 | 12.3 | 0.3 a | 0.9 a | 2.2 a | 3.6 a |
| Method 240SL<br>Esplanade 200 SC<br>Arsenal Powerline | 16<br>6<br>8 | 21.6 | 2.1 a | 3.1 a | 8.8 a | 11.1 a |
| Method 240SL<br>Esplanade 200 SC<br>Arsenal Powerline<br>Segment II | 16<br>6<br>8<br>32 | 17.3 | 1.6 a | 4.3 a | 8 a | 11 a |
| TerraVue<br>Esplanade 200 SC<br>Arsenal Powerline<br>Segment II | 5<br>6<br>8<br>32 | 18.3 | 0.5 a | 1.6 a | 3.6 a | 6.6 a |
| TerraVue<br>Esplanade 200 SC<br>Arsenal Powerline<br>Fusilade II | 5<br>6<br>8<br>24 | 13 | 0.5 a | 1.1 a | 3.3 a | 4.6 a |
| TerraVue<br>Esplanade 200 SC<br>Plateau | 5<br>6<br>6 | 14.8 | 1.4 a | 5.1 a | 10.4 a | 9.3 a |
| Esplanade Sure<br>SFM Extra | 5<br>4 | 14 | 1.5 a | 4.5 a | 9.4 a | 12.4 a |
| Plainview SC | 48 | 20 | 0.2 a | 0.7 a | 2.8 a | 5 a |
| | | n.s. | | | | |

Table 2. Effectiveness of treatments based on percent grass cover at 61, 92, & 124 days after treatment (DAT). The site was visually rated for percent grass cover on July 11, August 10, & September 12, 2022. Treatments were applied May 11, 2022. 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/ac | % GRASS COVER 07/11/22 61 DAT | % GRASS COVER 08/10/22 92 DAT | % GRASS COVER 09/12/22 124 DAT |
|---|---|---|---|---|
| Untreated | --- | 23.8 b | 18.8 b | 30.5 b |
| Method 240SL<br>Esplanade 200 SC<br>Arsenal Powerline<br>Plateau | 16<br>6<br>8<br>12 | 0.6 a | 1.1 a | 2.1 a |
| Method 240SL<br>Esplanade 200 SC<br>Arsenal Powerline<br>Fusilade II | 16<br>6<br>8<br>24 | 0.1 a | 0.5 a | 1.4 a |
| Method 240SL<br>Esplanade 200 SC<br>Arsenal Powerline | 16<br>6<br>8 | 2 a | 5.7 a | 6.7 ab |
| Method 240SL<br>Esplanade 200 SC<br>Arsenal Powerline<br>Segment II | 16<br>6<br>8<br>32 | 3.6 a | 7.2 a | 9.3 ab |
| TerraVue<br>Esplanade 200 SC<br>Arsenal Powerline<br>Segment II | 5<br>6<br>8<br>32 | 0.4 a | 1.5 a | 2.1 a |
| TerraVue<br>Esplanade 200 SC<br>Arsenal Powerline<br>Fusilade II | 5<br>6<br>8<br>24 | 0.2 a | 0.6 a | 1.1 a |
| TerraVue<br>Esplanade 200 SC<br>Plateau | 5<br>6<br>6 | 2.1 a | 5.8 a | 5.8 a |
| Esplanade Sure<br>SFM Extra | 5<br>4 | 3.3 a | 5.3 a | 4.9 a |
| Plainview SC | 48 | 0.2 a | 1.2 a | 2 a |

Table 3. Effectiveness of treatments based on percent broadleaf weed (BLW) cover at 61, 92, & 124 days after treatment (DAT). The site was visually rated for percent broadleaf weed cover on July 11, August 10, & September 12, 2022. Treatments were applied May 11, 2022. 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/ac | % BLW COVER 07/11/22 61 DAT | % BLW COVER 08/10/22 92 DAT | % BLW COVER 09/12/22 124 DAT |
|---|---|---|---|---|
| Untreated | --- | 25 b | 38.7 b | 37.3 b |
| Method 240SL<br>Esplanade 200 SC<br>Arsenal Powerline<br>Plateau | 16<br>6<br>8<br>12 | 1.1 a | 3.4 a | 4.9 a |
| Method 240SL<br>Esplanade 200 SC<br>Arsenal Powerline<br>Fusilade II | 16<br>6<br>8<br>24 | 0.8 a | 1.7 a | 2.2 a |
| Method 240SL<br>Esplanade 200 SC<br>Arsenal Powerline | 16<br>6<br>8 | 1.1 a | 3.1 a | 4.4 a |
| Method 240SL<br>Esplanade 200 SC<br>Arsenal Powerline<br>Segment II | 16<br>6<br>8<br>32 | 0.7 a | 0.8 a | 1.7 a |
| TerraVue<br>Esplanade 200 SC<br>Arsenal Powerline<br>Segment II | 5<br>6<br>8<br>32 | 1.2 a | 2.1 a | 4.5 a |
| TerraVue<br>Esplanade 200 SC<br>Arsenal Powerline<br>Fusilade II | 5<br>6<br>8<br>24 | 0.9 a | 2.7 a | 3.5 a |
| TerraVue<br>Esplanade 200 SC<br>Plateau | 5<br>6<br>6 | 3 a | 4.6 a | 3.5 a |
| Esplanade Sure<br>SFM Extra | 5<br>4 | 1.2 a | 4.1 a | 7.5 a |
| Plainview SC | 48 | 0.5 a | 1.6 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 | |
|---|---|---|---|---|
| Untreated | --- | -- | -- | |
| Method 240SL | 16 | *aminocyclopyrachlor* | 4 | post +residual |
| Esplanade 200 SC | 6 | *indaziflam* | 29 | pre |
| Arsenal Powerline | 8 | *imazapyr* | 2 | bsr |
| Plateau | 12 | *imazapic* | 2 | pre+post+bsr |
| Method 240SL | 16 | *aminocyclopyrachlor* | 4 | post +residual |
| Esplanade 200 SC | 6 | *indaziflam* | 29 | pre |
| Arsenal Powerline | 8 | *imazapyr* | 2 | bsr |
| Fusilade II | 24 | *fluazifop-P-butyl* | 1 | post |
| Method 240SL | 16 | *aminocyclopyrachlor* | 4 | post +residual |
| Esplanade 200 SC | 6 | *indaziflam* | 29 | pre |
| Arsenal Powerline | 8 | *imazapyr* | 2 | bsr |
| Method 240SL | 16 | *aminocyclopyrachlor* | 4 | post +residual |
| Esplanade 200 SC | 6 | *indaziflam* | 29 | pre |
| Arsenal Powerline | 8 | *imazapyr* | 2 | bsr |
| Segment II | 32 | *sethoxydim* | 1 | post |
| TerraVue | 5 | *aminopyralid+florpyrauxifen* | 4+4 | post +residual |
| Esplanade 200 SC | 6 | *indaziflam* | 29 | pre |
| Arsenal Powerline | 8 | *imazapyr* | 2 | bsr |
| Segment II | 32 | *sethoxydim* | 1 | post |
| TerraVue | 5 | *aminopyralid+florpyrauxifen* | 4+4 | post +residual |
| Esplanade 200 SC | 6 | *indaziflam* | 29 | pre |
| Arsenal Powerline | 8 | *imazapyr* | 2 | bsr |
| Fusilade II | 24 | *fluazifop-P-butyl* | 1 | post |
| TerraVue | 5 | *aminopyralid+florpyrauxifen* | 4+4 | post +residual |
| Esplanade 200 SC | 6 | *indaziflam* | 29 | pre |
| Plateau | 6 | *imazapic* | 2 | pre+post+bsr |
| Esplanade Sure | 5 | *indaziflam+rimsulfuron* | 29+2 | pre + post |
| SFM Extra | 4 | *sulfometuron+metsulfuron* | 2+2 | bsr |
| Plainview SC | 48 | *aminocyclopyrachlor* | 4 | post +residual |
| | | *indaziflam* | 29 | pre |
| | | *imazapyr* | 2 | bsr |

# APPENDIX

Appendix Table 1. Canopy area of each Amur honeysuckle. 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 | 106 | 91 | 98.5 | 105 | 144 | 437 | L. maackii |
| 17 | 2 | 55 | 47 | 51 | 95 | 67 | 205 | L. maackii |
| 18 | 4 | 98 | 58 | 78 | 89 | 96 | 293 | L. maackii |
| 19 | 3 | 38 | 68 | 53 | 83 | 61 | 186 | L. maackii |
| 20 | 1 | 71 | 57 | 64 | 95 | 84 | 257 | L. maackii |
| 21 | 2 | 70 | 35 | 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 |

Appendix Table 1 (continued). Canopy area of each Amur honeysuckle. 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 |
|---|---|---|---|---|---|---|---|---|
| 33 | 3 | 67 | 65 | 66 | 109 | 100 | 304 | L. maackii |
| 34 | 1 | 54 | 73 | 63.5 | 98 | 86 | 263 | L. maackii |
| 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 2. Canopy area of Amur honeysuckle (*Lonicera maackii*) or Morrow's honeysuckle (*Lonicera morrowii*) and treatment dose 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.) | Dosage (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 2 (continued). Canopy area of Amur honeysuckle (*Lonicera maackii*) or Morrow's honeysuckle (*Lonicera morrowii*) and treatment dose 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.) | Dosage (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 |

Appendix Table 2 (continued). Canopy area of Amur honeysuckle (*Lonicera maackii*) or Morrow's honeysuckle (*Lonicera morrowii*) and treatment dose 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.) | Dosage (ml.) | Plant ID |
|---|---|---|---|---|---|---|---|---|
| 67 | 5 | 84 | 55 | 69.5 | 66 | 64 | 194 | L. maackii |
| 68 | 4 | 41 | 34 | 37.5 | 70 | 36 | 111 | L. maackii |
| 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 |

Appendix Table 2 (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.) | Dosage (ml.) | Plant ID |
|---|---|---|---|---|---|---|---|---|
| 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 |
| 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 | 10 | 130 | 65 | 97.5 | 125 | 169 | 515 | L. maackii |
| A2 | 10 | 46 | 72 | 59 | 70 | 57 | 174 | L. maackii |
| A3 | 10 | 60 | 45 | 52.5 | 72 | 53 | 160 | L. maackii |
| A4 | 10 | 16 | 38 | 27 | 46 | 17 | 52 | L. maackii |
| A5 | 10 | 84 | 45 | 64.5 | 66 | 59 | 180 | L. maackii |
| A6 | 10 | 67 | 80 | 73.5 | 87 | 89 | 270 | L. maackii |
| A7 | 10 | 48 | 72 | 60 | 68 | 57 | 172 | L. maackii |
| A8 | 10 | 27 | 36 | 31.5 | 62 | 27 | 82 | L. maackii |
| A9 | 10 | 100 | 90 | 95 | 140 | 185 | 562 | L. maackii |
| A10 | 10 | 72 | 48 | 60 | 80 | 67 | 203 | L. maackii |

Appendix Table 3. Canopy area of each Callery pear plant. The experiment evaluated 8 treatments. Each plant is an individual replication with 10 replications per treatment.

| 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 |

Appendix Table 3 (continued). Canopy area of each Callery pear. The experiment evaluated 8 treatments. Each plant is an individual replication with 10 replications per treatment.

| Plant # | Treatment | Radius (in.) | Height (in.) | Area (ft. sq.) | Dosage (ml.) |
|---|---|---|---|---|---|
| 34 | 2 | 17 | 50 | 49.70 | 151 |
| 35 | 1 | 13 | 47 | 34.03 | 104 |
| 36 | 5 | 17 | 62 | 58.60 | 178 |
| 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 |

Appendix Table 3 (continued). Canopy area of each Callery pear. The experiment evaluated 8 treatments. Each plant is an individual replication with 10 replications per treatment.

| Plant # | Treatment | Radius (in.) | Height (in.) | Area (ft. sq.) | Dosage (ml.) |
|---|---|---|---|---|---|
| 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 |
| 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 |