Final Report

Improving Vegetation Management Practices and Cost Effectiveness on NC Roadsides

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16. Abstract

Integrated vegetation management (IVM) is required on roadsides to ensure public safety and to provide aesthetically pleasing views. Research was conducted to evaluate techniques to improve IVM practices on North Carolina roadsides. For vegetation management under desirable pine trees, treatments provided up to 95% control of unwanted vegetation. In general brush control trials after a cut and mulch operation, control of up to 92% was observed at three years after initial treatment. Excellent control of Baccharis and pine species was also obtained with some treatments providing 100% control. A final trial compared defoliation from triclopyr in comparison to fosamine. The 1% solution of triclopyr was equivalent to, or greater than that obtained from fosamine. Results may be incorporated into NCDOT IVM practices to improve vegetation control and reduce the expenses of management.

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SUMMARY

Integrated vegetation management (IVM) is required on roadsides to ensure public safety and to provide aesthetically pleasing views. Research was conducted to evaluate techniques to improve IVM practices on North Carolina roadsides including the specific areas of: 1) vegetation management under desirable pine trees, 2) general brush control following cut and mulch operations, 3) Baccharis control, 4) pine control, and 5) woody defoliation. For vegetation management under desirable pine trees, treatments provided up to 95% control of unwanted vegetation. Several treatments including glyphosate, imazapyr, metsulfuron, and triclopyr all provided control good and equivalent control. In general brush control trials after a cut and mulch operation, control of up to 92% was observed at three years after initial treatment. Excellent control of Baccharis and pine species was also obtained with some treatments providing 100% control. Baccharis control was greatest with treatments containing aminocyclopyrachlor, while glyphosate alone provided excellent control of pines. A final trial compared defoliation from triclopyr in comparison to fosamine. The 1% solution of triclopyr was equivalent to, or greater than that obtained from fosamine and provided 99% defoliation at one year after treatment. These results may be used by the Roadside Environmental Unit of the North Carolina Department of Transportation to improve IVM programs and reduce the expenses of management while providing safe conduits for motorists.

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INTRODUCTION AND BACKGROUND

Vegetation management (VM) is a common practice used to promote better service while ensuring public safety (Nanita 2009). Also called integrated vegetation management (IVM), the goal of IVM is to promote the growth of desirable vegetation that is low growing, ecologically stable, and inexpensive to maintain by effectively managing unwanted and/or invasive species (Nowak 1992). In a broad context, the goals of IVM promote native species establishment, increase property values, provide better wildlife habitat, lessen pest populations, nurture more productive timber stands, and more aesthetically pleasing views (McWhorter et al. 2010; Nowak et al. 1992; Johnstone 2008).

There are several common ways in which vegetation can be controlled including cultural, biological, mechanical, chemical, and combinations thereof. Common methods include hand cutting, mowing, and herbicide application (Jackson and Finley, 2007; Johnstone, 2008). Herbicides may be applied in a variety of ways including basal bark, basal soil, cut stump, foliar, hack and squirt, and stem injection. Decisions about herbicide selection and application methods can be made easier by appropriate scouting and problem identification. Variables such as soil type, plant species presence, density and size, timing of application**,** and weather should all be taken into consideration in order to obtain desirable control (Jackson and Finley 2007; Nickerson 1992). In regards to application decisions, work by Nowak et al. (1992) indicates that cost effectiveness of treatments can be determined by density and height of undesirable species. If a stand is dense but short, a foliar application would be more economically feasible, but in the event of low density and increased heights, a more selective basal or cut stem application would be better.

IVM has been proven necessary for proper utility function. Tree limbs have been responsible for several major power outages by damaging high voltage transmission conductors. For instance, the 2003 Northeast blackout left 50 million people without power and was to blame for eleven deaths. Approximately $6 billion of damage was caused by power lines sagging into vegetation that had not be maintained at the proper height (Minkel 2008).These outages not only inconvenience the public but also weaken the electrical systems that enable the public to live as desired. In fact, in 2005, an Energy Policy Act was put in place to avoid power outages due to preventable tree related instances (Hurysz and Crider 2008). In the occurrence of wildfire, conductors must be de-energized for safety precaution because carbon particles in smoke can conduct electricity.

Many woody species produce stump sprouts including common North Carolina hardwoods such as black locust (*Robinia pseudoacacia*), red maple (*Acer rubrum*), sweetgum (*Liquidambar* *styraciflua*), yellow poplar (*Liriodendron tulipifera*), etc. Stump sprouts are a common occurrence after mechanical cuts leave a hardwood stump. One method that works well to combat such a problem is a cut stump herbicide application (Haymond and McNabb 1994). A major advantage to this technique is that it works on invasive hardwoods and woody vine species of various sizes with the exception of stems less than half an inch diameter. Application is simple however, it can be labor intensive. A stem should be cut between one and six inches from ground level and treated as soon as possible to ensure rapid translocation through the phloem. It should also be noted that if a stem is cut at the upper limit (~5in) that a future cut stump application can be made if not first successful (Enloe et al. 2010).

Definition of Problem/Need

The NCDOT is responsible for operation and maintenance of the 78,500 mile North Carolina highway system. VM along these roadsides is critical for highway safety and function. This roadside vegetation has a natural tendency to progress towards climatic species, which are usually trees. In order to maintain road safety and preserve the desired function of the recovery area, vegetation management is needed to keep roadside vegetation at a younger stage of succession.

Since January 2010, NCDOT has spent $46.7 million performing rights of way brush control to improve lines of sight, allow sunlight to reach paved surfaces to aide in snow and ice removal, maintain infrastructure health and improve general safety. In many cases, the long-term impact of these operations could have been sustained (and cost effectiveness enhanced) with improved brush control practices. In many cases stumps may not have been treated with herbicides following tree felling. Subsequently, the cut stumps resprouted (coppice or suckers) with multiple weak stems that were not treated. Coppice stems are characteristically curved at the base. This curve occurs as the competing stems grow out from the stump and upward. In subsequent growth years, many new shoots will emerge, and the value of the initial brush control operation will be lost. The end result is that hardwood stem density increases and the resprouted vegetation may be weaker and more prone to toppling under adverse conditions.

Further reducing the long term efficacy of management practices, the NCDOT's VM program has gone unchanged for virtually 13 years. New VM products have been approved by EPA and released into the marketplace over the last few years that can potentially improve program proficiency, reduce rights of way VM costs, and improve infrastructure health. These products have been examined through peer reviewed research and have been approved for label-specific utilization by the EPA and NCDA. The next logical step is to evaluate these products for inclusion in the department's VM program.

MATERIALS AND METHODS

Vegetation management under pines (vegetated areas adjacent to interchanges)

Field trials were initiated in a vegetated interchange area between the on ramp and divided highway, along US Highway 264 in eastern Wake County. The trial was designed to determine the appropriate herbicide or combination of herbicides to control unwanted vegetation and maintain a standing loblolly pine (*Pinus taeda*) canopy. Herbicides were applied late August 2013 using a CO^2 propelled single nozzle handgun (43 HC Handgun, Sprayer Systems Co., Glendale Heights, IL) with a D7 Stainless Steel Orifice Disc (T Jet Technologies, Springfield, IL). The equipment was calibrated to deliver 50 gallons total spray solution per acre. Plots were arranged in a randomized complete block design with three replicates of plots being 25 ft. X 50 ft. in size.

Herbicide and combinations included: fosamine (1.5% or 3% V/V, Bayer CropScience LP, Research Triangle Park, NC), glyphosate (2%, 4%, or 6% V/V, Dow AgroSciences LLC, Indianapolis, IN), triclopyr acid (3% or 4% V/V, Dow AgroSciences LLC, Indianapolis, IN) alone or in combination with metsulfulfuron methyl (4 or 8 oz/A, Bayer CropScience LP, Research Triangle Park, NC), imazapyr (0.5% or 1% V/V, BASF Corporation Research Triangle Park, NC) (Table 1). A nonionic surfactant was included as recommended on each herbicide label (0.25%, Loveland Products, Loveland, CO). An untreated check was also included in this trial for comparison.

Boomless Nozzle Spray Trial (general brush)

A field trial was initiated along US Highway 70 in Jones County. The area was cut, cleared and mulched during the previous fall. This trial was designed to evaluate various herbicides and combinations for control of unwanted vegetative regrowth in areas with comparable previous vegetation removal. The trial was treated in August 2013 with the majority of vegetation present consisting of resprouts from stumps resulting from the previous cutting operation. Herbicides were applied using a CO^2 propelled single XT024 Hypro Boom X-Tender Nozzle (Pentair, Hypro, England) calibrated to deliver approximately 20 gallons total solution per acre. Plots were arranged in a randomized complete block design with three replicates of plots being 15 ft. X 100 ft. in size.

Herbicide and combinations included: imazapyr (1 pt/A, BASF Corporation Research Triangle Park, NC) alone and in combination with glyphosate (1 or 2 Qts/A, Dow AgroSciences LLC, Indianapolis, IN), glyphosate (2 or 3 Qts/A), triclopyr acid (4 Qts/A, Dow AgroSciences LLC, Indianapolis, IN), triclopyr acid (1 or 2 Qts/A) in combination with metsulfulfuron methyl (1 or 2 oz/A, Bayer CropScience LP, Research Triangle Park, NC), aminopyralid (2, 4 or 6 oz/A, Dow AgroSciences LLC, Indianapolis, IN) in combination with triclopyr acid (1 to 2 Qts/A) (Table 1). A nonionic surfactant was included as recommended on each herbicide label (0.25%, Loveland Products, Loveland, CO). An untreated check was also included in this trial for comparison.

An additional component of this trial included retreating selected plots approximately 24 months after the original treatments. The vegetation consisted of combinations of additional resprouts and newly emerged seedlings in the mulched areas. Herbicides were applied using a CO^2 propelled single nozzle handgun (43 HC Handgun, Sprayer Systems Co., Glendale Heights, IL) with a D5 Stainless Steel Orifice Disc (T Jet Technologies, Springfield, IL). The equipment was calibrated to deliver 20 gallons total spray solution per acre.

Baccharis (*Baccharis halimifolia*) Control along Roadsides

Field trials were initiated in a vegetated interchange area between the on ramp and divided highway, along Aviation Parkway and I 540 in Wake County. The trial was designed to determine the appropriate herbicide or combination of herbicides to control Baccharis (*Baccharis halimifolia*) along roadsides while maintaining a grass cover for erosion prevention. Herbicides were applied August 2014 and July 2015 using a CO^2 propelled single nozzle handgun (43 HC Handgun, Sprayer Systems Co., Glendale Heights, IL) with a D7 Stainless Steel Orifice Disc (T Jet Technologies, Springfield, IL). The equipment was calibrated to deliver 40 gallons total spray solution per acre. Plots were arranged in a randomized complete block design with three replicates of plots being 12 ft. X 30 ft. in size.

Herbicide and combinations included: aminocyclopyrachlor (5.9, 7.5, or 9.1 Oz/A, Bayer CropScience LP, Research Triangle Park, NC) in combination with metsulfulfuron methyl (1.5, 2, 2.4 oz/A, Bayer CropScience LP, Research Triangle Park, NC), additionally both products in combination were applied along with fosamine (4% V/V, Bayer CropScience LP, Research Triangle Park, NC), or imazapyr (2% V/V, 5.5, 7 or 8.5 Oz/A, BASF Corporation Research Triangle Park, NC), triclopyr acid (3% or 4% V/V, Dow AgroSciences LLC, Indianapolis, IN) (Table 1). Methylated Seed Oil (MSO) (Southern Ag, Hendersonville, NC) was included at 1 % V/V. All herbicide applications were applied to minimize drift and application to non-target vegetation. An untreated check was also included in this trial for comparison.

Control of Pines

Field trials were initiated in May 2014 in Wake and Franklin Counties. Both locations contained dense loblolly pine (*Pinus taeda*) populations, with plants ranging from 4 to 6 feet in height. The trial was designed to evaluate various herbicides and combinations for control of unwanted pine regrowth in areas with limited mowing. Herbicides were applied using a CO^2 propelled single nozzle handgun (43 HC Handgun, Sprayer Systems Co., Glendale Heights, IL) with a D7 Stainless Steel Orifice Disc (T Jet Technologies, Springfield, IL). The equipment was calibrated to deliver 40 gallons total spray solution per acre. Plots were arranged in a randomized complete block design with three replicates of plots being 6 ft. X 15 ft. in size.

Herbicide and combinations included: aminocyclopyrachlor (15 or 18 Oz/A, Bayer CropScience LP, Research Triangle Park, NC) in combination with metsulfulfuron methyl (1.4 or 1.1 Oz/A, Bayer CropScience LP, Research Triangle Park, NC) and fosamine (1.5% or 3% V/V, Bayer CropScience LP, Research Triangle Park, NC), triclopyr acid (3 Gal/A, Dow AgroSciences LLC, Indianapolis, IN), glyphosate (2% V/V, Dow AgroSciences LLC, Indianapolis, IN), aminopyralid (7 oz/A, Dow AgroSciences LLC, Indianapolis, IN) (Table 1). A nonionic surfactant label (0.25%, Loveland Products, Loveland, CO) or Methylated Seed Oil (MSO) (Southern Ag, Hendersonville, NC) was included as recommended on each herbicide. An untreated check was also included in this trial for comparison.

Fosamine comparison with Triclopyr acid

Field trials were initiated in Stokes, Caswell, and Franklin Counties, NC. The trials were treated in October 2014. The Stokes and Caswell County locations contained Virginia pine (*Pinus virginiana*), yellow poplar (*Liriodendron tulipifera*) while the Franklin County site contained Sweet Gum (*Liquidambar styraciflua*) and Loblolly Pine (*Pinus taeda*). Herbicides were applied using a CO^2 propelled single XT024 Hypro Boom X-Tender Nozzle (Pentair, Hypro, England) calibrated to deliver approximately 45 gallons total solution per acre. Plots were arranged in a randomized complete block design with three replicates of plots being 15 ft. X 50 ft. in size.

Herbicide and combinations included: fosamine (1%, 2%, 3% or 4% V/V, Bayer CropScience LP, Research Triangle Park, NC), and triclopyr acid (4 Qts/A, Dow AgroSciences LLC, Indianapolis, IN) (Table 1). A nonionic surfactant was included as recommended on the Triclopyr label, (0.25%, Loveland Products, Loveland, CO). An untreated check was also included in this trial for comparison.

FINDINGS AND CONCLUSIONS

Where appropriate, statistical analysis occurred using RStudio 3.1.3 to conduct analysis of variance ($P = 0.05$) and means separation using agricolae and plyr packages (Wickham 2011; de Mendiburu 2015; R Core Team 2015). Factors used for comparing treatment-by-treatment effects included herbicide and herbicide rate, replication, year, location, and assessment intervals. Each separate experiment followed a randomized complete block design (RCBD). ANOVA normality assumptions were checked using Shapiro-Wilks test and Q-Q diagnostic plots. Mean separations occurred per Fisher's protected LSD ($P < 0.05$). Significance values were then used to quantify the association between herbicide treatment, and percent control or percent defoliation, of roadside vegetation on a species-by-species basis. In all cases of missing species or incomplete data, means are reported.

Vegetation management under pines (vegetated areas adjacent to interchanges)

Observed control of woody species with a single application of commonly used herbicides 12 MAT provided 5 to 95% control when compared to an untreated control (Table 2). Application of glyphosate, glyphosate in combination with triclopyr, and glyphosate in combination with imazapyr, provided an average control of 93.33 to 95%. The greatest control occurred with *Liquidambar* and *Acer spp*. using higher rates of glyphosate and the combinations of glyphosate with triclopyr or imazapyr. Control of *Quercus spp.* was highly variable with glyphosate or the combinations mentioned. However, the highest rate of glyphosate provided the best control at 90%.

A repeat application of the same herbicides 12 months after the initial application provided on average an increase in control in all species present. The second application provided an average increase in observed control among all species present. Application of glyphosate alone at 6% v/v, increased control to 100% for *Liquidambar* and *Quercus spp*. At 24 MAT, all herbicides except fosamine, provided 83.33 % control or greater in *Liquidambar* spp. and 72.5 % control or greater among *Quercus spp*. Control of *Acer spp*. remained variable, with 35 to 95 % observed control. Newly emerged seedlings accounted for the reduction in overall control, along with herbicides having minor soil activity (Table 3).

For overall control of woody vegetation with fosamine was statistically different ($P > 0.05$) from all other herbicide treatments at both the 12 and 24 MAT evaluations. All other herbicide treatments and combinations were not statistically differentiable ($P < 0.05$) treatment-by-treatment assessments for overall control. However, across all treatments, there was a recorded increase in control following the repeat application at 12 MAT (Table 4).

Research Implications

Follow-up applications of herbicides will be necessary to maintain control of woody species in these locations. Hand crews with portable equipment should be able to target unwanted vegetation and maintain the appearance desired. Growth of annual and perennial species was observed in plots where the herbicide treatments did not contain a soil active compound; these species generally included Japanese stiltgrass. (*Microstegium vimineum*), pokeweed (*Phytolacca americana*), and Virginia creeper (*Parthenocissus quinquefolia*).

Herbicide costs were estimated for each treatment based on current price information (labor and equipment cost not included) (Figure 1).

Boomless Nozzle Spray Trial (general brush)

Treatments were applied approximately 9 months after a cut and mulch operation, the majority of target species were resprouts from the cutting operation and have established root or rhizome systems. Initial treatments containing imazapyr (1 pt/A) alone or in combination with glyphosate (2 qt/A) provided 86 to 95% control on average of red maple (*Acer rubrum*) 12 MAT. Control of other species evaluated was mixed however, imazapyr and combinations containing glyphosate or triclopyr had the highest level of control for wax myrtle (*Morella cerifera*), gooseberry (Vaccinium stamineum), and magnolia (*Magnolia virginiana*). Oaks (*Quercus* spp.) however had better control with imazapyr alone at 37.5% (Table 5).

Results from evaluations 24 MAT provided an average increased level of control in most treatments regardless of species. The exception was with magnolia and hornbeam where control decreased regardless of herbicide (Table 6). When compared to overall plot evaluations, all treatments had an increase in control ratings with most increasing from 8 to 40%. However, few statistical differences were seen among treatments (Table 7).

Selected plots were resprayed 24 months after the initial treatment, and evaluated 12 MAT. The second application provided an average increase in observed control among all species present. Control of red maple remained high with an average of 81 to 96% across all herbicides and combinations. Wax myrtle and gooseberry control increased across all treatments to 68% or greater. Magnolia control increased across all treatments with triclopyr alone having the greatest control at 70%. Control of hornbeam and oaks was again variable, possibly due to emergence of seedlings. (Table 8.) Overall evaluations of all species showed a 3.33 to 20 % increase in control over the 36 month evaluation period. With little statistical differences among herbicides. (Table 9.)

Research Implications

Follow-up applications of herbicides will be necessary to maintain control of woody species in these locations. Hand crews with portable equipment should be able to target unwanted vegetation and maintain the desired results. Observations of additional species present in this location showed a rapid invasion of greenbrier (*Smilax L.*), and other native annual and perennial species approximately 24 months after the initial herbicide applications. Herbicide costs were estimated for each treatment based on current price information (labor and equipment cost not included) (Figure 2).

Baccharis (*Baccharis halimifolia*) Control along Roadsides

Baccharis has long been a nuisance species along many roadsides in the Coastal Plain and has recently spread into many areas of the Piedmont; covering guard rails and many back-slope areas. Herbicides selected and evaluated on baccharis control and other species commonly found in these areas. Mean percent control evaluations of baccharis at 6 MAT, indicated less than 50% control across all herbicides evaluated. However, no injury to grasses was observed (Table 10).

Observed control at 12 MAT indicated 78.33 to 100 % control with all combinations containing aminocyclopyachor. Triclopyr Acid alone provide less control at 63.33% due to regrowth of target plants. Lespedeza control of 66.67 to 100% across all treatments was observed however no injury to grass species occurred (Table 11).

Observed control 12 MAT was not statistically differentiable ($P < 0.05$) for any treatment containing aminocyclopyachor 80 to 100% control. Treatments of aminocyclopyachor and metsulfuron methyl were similar to triclopyr acid alone ($P < 0.05$) with 70 to 93% control (Table 12).

Research Implications

Regrowth from applications of triclopyr acid alone may result in undesirable long term control. Additional herbicide applications may be necessary for increased long term control. Thorough and precise spray coverage is necessary to control baccharis while avoiding unwanted non-target damage to desirable vegetation. Herbicide costs were estimated for each treatment based on current price information (labor and equipment cost not included) (Figure 3).

Vegetation management and control of pines.

Control estimates from a solitary application of regularly expended herbicides provided 66 to 100% control of *Pinus* spp., and 0 to 100% control among *Poaceae* spp. 12 MAT. Untreated controls offered a reference for means comparisons to denote percent control among all treatments. Herbicide applications of aminocyclopyrachlor in combination with metsulfuron methyl, aminocyclopyrachlor in combination with metsulfuron methyl and fosamine at both the low and high rates, triclopyr acid, and glyphosate provided an average control of 95 to 100% control among *Pinus* spp. 12 MAT. The fastest and greatest observed control of *Pinus* spp. occurred 1 MAT deploying aminocyclopyrachlor in combination with metsulfuron methyl and fosamine, and the triclopyr acid formulation. Control of *Poaceae spp.* using aminocyclopyrachlor in combination with metsulfuron methyl at both the low and high rate provide little to no control among all evaluations. However, the addition of fosamine to both the low and high rates of aminocyclopyrachlor in combination with metsulfuron methyl, provided 100% control at the 2, 3, and 12 MAT evaluations. Neither triclopyr acid nor aminopyralid provided *Poaceae* spp. control estimates > 11% after the 1 MAT. Glyphosate provided 100% control of *Poaceae* spp. at both the 1 and 2 MAT evaluations but was found to decrease in control performance at the 3 and 12 MAT evaluations; as observed control ranged from 3 to 23% using glyphosate. The trend of decreased control of *Poaceae* spp. over time using glyphosate, is likely due to regrowth after initial application (Table 13).

For general control of *Pinus* spp., all herbicide formulations were significantly different (P > 0.05) from the control at the 2, 3, and 12 MAT evaluations. However, aminocyclopyrachlor in combination with metsulfuron methyl, aminocyclopyrachlor in combination with metsulfuron methyl and fosamine at the low and high rates, triclopyr acid, and glyphosate provided > 95% control at the 12 MAT evaluation. A reduction of control was observed within applications of aminopyralid starting after the 2 MAT evaluation (Table 14).

Research Implications

Follow-up applications of herbicides will be necessary to maintain control of *Pinus* spp. in situations where aminopyralid is adopted. Hand crews with portable equipment should be able to effectively control undesirable *Pinus* spp. and maintain the appearance using glyphosate at 2% v/v, triclopyr at 3 gal/A, and either the low or high rate of aminocyclopyrachlor in combination with metsulfuron methyl, with or without fosamine, depending on the level of control desired.

Herbicide costs were estimated for each treatment based on current price information and application of 1 Acre/ 50 gallon total spray solution (labor and equipment cost not included) (Figure 4).

Treatment effects comparison between Fosamine and Triclopyr acid.

Observed responses of woody species from a single application of fosamine and triclopyr acid provided 8 to 100% defoliation 6 MAT among all test sites pooled for defoliation estimations among roadsides in Caswell, Stokes, and Franklin counties. Treatment evaluations 12 MAT indicate 0-100% defoliation among all herbicide treatments. Untreated controls provided a standard for mean defoliation comparisons to compare treatment results. No significant difference was noted 12 MAT among applications of fosamine at 3% v/v or 4% v/v, and triclopyr at 1% v/v. There was also no significant difference among the lowest rate of fosamine and the control 12 MAT. The most rapid defoliation treatment occurred 6 MAT using the highest rate of fosamine and triclopyr at 1% v/v formulation. Among the lowest rate of fosamine, defoliation percentages decreased 12 MAT; suggesting the lowest rate would be insufficient to detect any lasting treatment effects witnessed after 6 MAT (Table 15).

For general control of roadside vegetation, fosamine applications at the 1-3% v/v formulation were significantly different ($P > 0.05$) from the 4% v/v formulation of fosamine and the 1% v/v rate of triclopyr during the 6 MAT evaluation. However, the 3% rate of fosamine provided equally as sufficient defoliation as triclopyr and the highest rate of fosamine at the 12 MAT evaluation (Table 15).

Research Implications

Follow-up applications of herbicides will be necessary to maintain control of woody species in locations using fosamine formulations at the 1 or 2% v/v rate one year after initial application. To ensure defoliation of undesirable vegetation and maintain defoliation, hand crews with portable equipment should use the higher rates of fosamine or the 1% v/v triclopyr formulation.

Herbicide costs were estimated for each treatment based on current price information and application of 1 Acre/ 50 gallon total spray solution (labor and equipment cost not included) (Figure 5).

OVERALL CONCLUSIONS

Vegetation Management Under Pines

- Several herbicides are available that provide excellent control in this situation
- Glyphosate plus imazapyr would be the most cost effective long term option

General Brush Control Following Cut and Mulch Operations

- Timely treatment and retreatment of sprouts will reduce long term inputs
- Several herbicides applied alone or in combination will provide long term control
- Cost effective herbicide options can be selected based on species to be controlled

Baccharis Control

- Triclopyr alone did not provide adequate control
- Herbicide combinations with aminocyclopyrachlor did provide excellent control
- Baccharis may need to be spot treated on roadsides to limit management inputs
- Future research should evaluate metsulfuron mixtures with non-auxin herbicides

Control of Pines

- Triclopyr (3 gal/A) and glyphosate (2% v/v) provided excellent control of pines
- Glyphosate is the most cost effective treatment evaluated

Defoliation Comparison Between Fosamine and Triclopyr Acid

- Triclopyr (1% v/v) was as effective as fosamine (3 or 4% v/v) in defoliation of test species
- Utilization of triclopyr instead of fosamine would reduce input expenses

RECOMMENDATIONS AND IMPLEMENTATION

These research results cover a broad scope of woody vegetation management considerations, which should aid NCDOT in implementation of improved methods that reduce long term inputs while ensuring public safety. Since several different scenarios of woody vegetation control exist on NC roadsides, NCDOT should consider breaking scenarios down into clearly definable units with specific guidelines for each. For instance, vegetation management under pines can be readily achieved with glyphosate plus imazapyr with very little risk to non-target species. However, this option would less than ideal in areas where it is important to maintain turfgrass, such as woody vegetation encroachment into recovery zones. Additionally, the presence of difficult to control species, like Baccharis, may necessitate spot treatments rather than long distance applications. These difficult to control species may be managed more cost-effectively with spot applications. In these situations and others, managing early and keeping woody vegetation to minimal levels is more cost effective than expensive cut and mulch operations which provide excellent immediate control, but allow rapid resprouting.

Timely application of herbicides is essential to reduce long-term woody management expenses. Small, young woody plants will be controlled more easily and with potentially lower herbicide inputs than taller, more mature plants. In addition, once woody vegetation exceeds spray height, costly cut and mulch operations are required in order to restore visibility and safety. Once cut and mulch operations are initiated, it is imperative that this investment be protected by scheduling follow up herbicide treatment in order to maintain the cleared areas. Appropriate treatment schedules should be maintained and scouting should also be conducted to be sure that problem areas are identified and managed in a timely fashion. Proper identification of species is also very important to target difficult to control species before they spread and become more costly to manage.

Additional research should be conducted to evaluate non-auxin herbicide control measures for Baccharis and other difficult to control woody species. While synthetic auxin herbicides can provide excellent control, improper use can result in off-target movement. The recent registration of dicamba tolerant crops will result in far greater dicamba use during cropping seasons and may result in additional inquiries to NCDOT about synthetic auxin applications along roadsides.

HERBICIDE RESISTANCE MANAGEMENT

Herbicide resistance has become an evolving issue and a serious problem in North Carolina and on a global scale. Though herbicide resistance in woody plants has shown uncommon, the principles encompassing resistance require great herbicide stewardship to promote and prolong chemically available options. Herbicide resistance has been seen in agronomic scenarios beginning in the 1970's, and since this period, herbicide chemistries demand constant development and management to ensure adequate control of weedy species.

Woody plant herbicide management plans do not allow for continual rotation of nuisance species. Therefore, the most important component of a resistance management strategy is rotation of herbicide modes of action and use of multiple herbicide modes of action within each target species. The herbicide mode of action relates to the physiological process whereby a herbicide kills susceptible plants. Table 16 lists mode of action along with the chemical family and active ingredients of herbicides likely used on woody plants in North Carolina. Note that each mode of action is assigned a unique identifier code for ease of use when determining herbicide management programs.

At least two modes of action should be used within each target species wherever possible to reduce the chance of herbicide resistance. This may be accomplished in numerous ways; pre-emergence herbicide applications followed by post-emergence applications and by tank mixtures of herbicides with two or more modes of action. Also, within a rotation, one should try to avoid dependence on herbicides with the same mode of action in all target species in the rotation (Table 16).

CITED REFERENCES

2017 N.C Agricultural Chemicals Manual. College of Agriculture and Life Sciences at North Carolina State University, December 1, 2016

Enloe, S., Loewenstein, N., Cain, D. 2010. Cut stump herbicide treatment for invasive plants in pastures, natural areas, and forests. Agronomy and Soils Series, Timely Information. Alabama Cooperative Extension System. Available Online: www.aces.edu/timelyinfo/AgSoil/2010/December/Dec_2010_D.pdf. Accessed 11 December 2010.

Felipe de Mendiburu (2015). agricolae: Statistical Procedures for Agricultural Research. R package version 1.2-3. http://CRAN.R-project.org/package=agricolae.

Hadley Wickham (2011). plyr: The Split-Apply-Combine Strategy for Data Analysis. Journal of Statistical Software, 40(1), 1-29. http://www.jstatsoft.org/v40/i01/.

Haymond, J.L., McNabb, K. 1994. Southern hardwood management. Southern Region Cooperative Extension Services Management Bulletin. pp 45-50.

Hurysz, P. and Crider, J. 2009. Technology advances vegetation management. Transmission and Distribution World; ROW Management. October: 48-54.

Jackson, D. and J. Finley. 2007. Herbicides and Forest Vegetation Management: Controlling Unwanted Trees, Brush and Other Competing Forest Vegetation. Penn State University, State College, PA. 18 pp.

Johnstone, R. 2008. Integrated vegetation management. Utility Arborist Association (UAA) Quarterly. Summer: 5-17.

McWhorter, M. Olsen, J.K., University of Florida, Potter, M.F., and Knapp, F.W. 2010. Mosquitoes. Urban integrated pest management in the southern region.

Minkel, J.R., 2008. The 2003 northeast blackout—five years later. Scientific America. Available Online: http://www.scientificamerican.com/article.cfm?id=2003-blackout-five-years-later. Accessed: 4 August 2011.

Nanita, S.C., Pentz A.M., Grant, J., Vogl, E., Devine, T.J., and Henze, R.M. 2009. Mass spectrometric assessment and analytical methods for quantitation of the new herbicide aminocyclopyrachlor and its methyl analogue in soil and water. Anal. Chem. 81: 797- 808.

Nickerson, N.H. 1992. “Impacts of Vegetation Management Techniques on Wetlands in Utility Rights-ofWay in Massachusetts.” Journal of Arboriculture, 18(2): 102-106.

Nowak, C.A., Abrahamson, L.P., Neuhauser, E.F. Forebank, C.G., Freed, H.D., Shaheen, S.B., and Stevens, C. H. 1992. Cost effective vegetation management on a recently cleared electric transmission line right-of-way. Weed Tech. 6: 828-837.

R Core Team (2015). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/.

Table 1. Herbicides referenced in report.

Active Ingredient	Common Name	Trade Name
6-amino-5-chloro-2-cyclopropylpyrimidine-4-carboxylic acid	Aminocyclopyrachlor	Method
4-amino-3,6-dichloro-2-pyridinecarboxylic acid	Aminopyralid	Milestone
Active Ingredient	Common Name	Trade Name
ethyl hydrogen (aminocarbonyl)phosphonate	Fosamine	Krenite
N-(phosphonomethyl)glycine	Glyphosate	Various
2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-pyridinecarboxylic acid	Imazapyr	Arsenal
methyl 2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]benzoate	Metsulfuron-methyl	Ally
3,5,6-trichloro-2-pyridyloxyacetic acid	Triclopyr acid	Various

PPDB: Pesticide Properties Database, 2017

Table 2. Vegetation management under pines (vegetated areas adjacent to interchanges). Means table for overall herbicide effectiveness based on species response 12 months after treatment (MAT).

		Mean Species % Control 12 MAT [b,c,d]		
Herbicide Formulation	Herbicide Rate[a]	*Liquidambar* spp.	*Acer* spp.	*Quercus* spp.
Fosamine	1.5% v/v	10	5	70
Fosamine	3% v/v	25	8	20
Glyphosate	2% v/v	88	35	-
Glyphosate	4% v/v	93	48	70
Glyphosate	6% v/v	93	72	90
Triclopyr	3% v/v	85	50	83
Triclopyr	4% v/v	72	83	-
Glyphosate + Triclopyr	3% v/v + 2% v/v	93	73	-
Glyphosate + Triclopyr	3% v/v + 3% v/v	93	77	50
Triclopyr + Metsulfuron Methyl	2% v/v + 4 oz/A (100 gal)	53	52	70
Triclopyr + Metsulfuron Methyl	2% v/v + 8 oz/A (100 gal)	90	63	33
Glyphosate + Imazapyr	2% v/v + 0.5% v/v	93	60	5
Glyphosate + Imazapyr	2% v/v + 1% v/v	95	85	-
Control	-	0	0	0

[a] All applications included a nonionic surfactant at 0.25% v/v.

[b] Control estimated on a 0 (no control) to 100 (complete control) ranking.

[c] Missing data, denoted (-), not present for control estimations; therefore, mean separations were not obtained.

[d] Due to uneven populations in treatment plots, means are reported based on species presence (n= 1-3).

Table 3. Vegetation management under pines (vegetated areas adjacent to interchanges). Means table for overall herbicide effectiveness based on species response 24 months after treatment (MAT).

		Mean Species % Control 24 MAT [b,c,d,e]		
Herbicide Formulation	Herbicide Rate[a]	*Liquidambar* spp.	*Acer* spp.	*Quercus* spp.
Fosamine	1.5% v/v	18	0	10
Fosamine	3% v/v	45	0	23
Glyphosate	2% v/v	97	35	-
Glyphosate	4% v/v	97	58	95
Glyphosate	6% v/v	100	68	100
Triclopyr	3% v/v	83	90	100
Triclopyr	4% v/v	95	50	-
Glyphosate + Triclopyr	3% v/v + 2% v/v	100	70	-
Glyphosate + Triclopyr	3% v/v + 3% v/v	90	58	100
Triclopyr + Metsulfuron Methyl	2% v/v + 4 oz/A (100 gal)	90	53	100
Triclopyr + Metsulfuron Methyl	2% v/v + 8 oz/A (100 gal)	90	95	73
Glyphosate + Imazapyr	2% v/v + 0.5% v/v	100	82	40
Glyphosate + Imazapyr	2% v/v + 1% v/v	100	80	-
Control	-	0	0	0

[a] All applications included a nonionic surfactant at 0.25% v/v.

[b] Control estimated on a 0 (no control) to 100 (complete control) ranking.

[c] Missing data, denoted (-), not present for control estimations; therefore, mean separations were not obtained.

[d] Due to uneven populations in treatment plots, means are reported based on species presence (n= 1-3).

[e] Means derived from observations 12 months after retreatment (24 months after initial treatment). Retreatment occurred at 12 MAT .

Table 4. Vegetation management under pines (vegetated areas adjacent to interchanges). Treatment-by-treatment effects for overall herbicide effectiveness based on species response 12 and 24 months after treatment (MAT).

		Pooled Species % Control[b,c,d]			
Herbicide Formulation	Herbicide Rate[a]	12 MAT		24 MAT [e]	
Fosamine	1.5% v/v	8	bc	13	c
Fosamine	3% v/v	30	b	33	b
Glyphosate	2% v/v	63	a	80	a
Glyphosate	4% v/v	70	a	90	a
Glyphosate	6% v/v	80	a	88	a
Triclopyr	3% v/v	68	a	85	a
Triclopyr	4% v/v	60	a	95	a
Glyphosate + Triclopyr	3% v/v + 2% v/v	73	a	85	a
Glyphosate + Triclopyr	3% v/v + 3% v/v	75	a	88	a
Triclopyr + Metsulfuron Methyl	2% v/v + 4 oz/A (100 gal)	68	a	90	a
Triclopyr + Metsulfuron Methyl	2% v/v + 8 oz/A (100 gal)	63	a	88	a
Glyphosate + Imazapyr	2% v/v + 0.5% v/v	80	a	98	a
Glyphosate + Imazapyr	2% v/v + 1% v/v	85	a	95	a
Control	-	0	c	0	c
$LSD_{0.05}$		29.48		68.68	
CV(%)		23.30		73.21	

[a] All applications included a nonionic surfactant at 0.25% v/v.

[b] Overall control estimated on a 0 (no control) to 100 (complete control) ranking.

[c] Data among all species pooled for control estimations.

[d] Due to uneven populations in treatment plots, treatment differences are reported based on (n= 2 replications).

[e] Observations derived from a retreatment occurring 12 MAT (24 months after initial treatment).

Table 5. Boomless nozzle spray trial (general brush). Means table for overall herbicide effectiveness based on species response 12 months after treatment (MAT).

Herbicide Formulation	Herbicide Rate[a]	Mean Species % Control 12 MAT [b,c,d]					
		Acer rubrum	*Morella cerifera*	Vaccinium angustifolium	*Magnolia virginiana*	*Carpinus caroliniana*	*Quercus* spp.
Imazapyr	1 pt/A	87	60	70	5	10	38
Glyphosate	2 qt/A	32	10	43	5	85	0
Glyphosate	3 qt/A	30	23	43	50	30	-
Triclopyr	4 qt/A	32	8	40	80	25	-
Imazapyr + Glyphosate	1 pt/A + 2 qt/A	95	78	60	28	100	-
Imazapyr + Triclopyr	1 pt/A + 2 qt/A	68	85	15	0	45	10
Imazapyr + Triclopyr	2 pt/A + 4 qt/A	60	55	32	-	0	-
Imazapyr + Glyphosate	1 pt/A + 1 qt/A	38	43	0	-	30	-
Glyphosate + Triclopyr	1 qt/A + 2 qt/A	20	8	10	-	10	5
Glyphosate + Triclopyr	2 qt/A + 2 qt/A	25	10	28	-	70	8
Triclopyr + Metsulfuron Methyl	2 qt/A + 1 oz/A	37	8	50	-	70	5
Triclopyr + Metsulfuron Methyl	2 qt/A + 2 oz/A	13	0	0	-	95	15
Triclopyr + Aminopyralid	1 qt/A + 2 oz/A	33	23	5	-	48	13
Triclopyr + Aminopyralid	1 qt/A + 4 oz/A	22	3	3	0	90	10
Triclopyr + Aminopyralid	1 qt/A + 6 oz/A	32	10	25	-	38	15
Triclopyr + Aminopyralid	2 qt/A + 2 oz/A	37	0	40	-	70	-
Control	-	0	0	0	0	0	0

[a] All applications included a nonionic surfactant at 0.25% v/v.

[b] Control estimated on a 0 (no control) to 100 (complete control) ranking.

[c] Missing data, denoted (-), not present for control estimations; therefore, mean separations were not obtained.

[d] Due to uneven populations in treatment plots, means are reported based on species presence (n= 1-3).

Table 6. Boomless nozzle spray trial (general brush). Means table for overall herbicide effectiveness based on species response 24 months after treatment (MAT).

Herbicide Formulation	Herbicide Rate[a]	Mean Species % Control 24 MAT [b,c,d]					
		Acer rubrum	*Morella cerifera*	Vaccinium angustifolium	*Magnolia virginiana*	*Carpinus caroliniana*	*Quercus* spp.
Imazapyr	1 pt/A	83	5	20	0	5	30
Glyphosate	2 qt/A	45	5	28	0	60	5
Glyphosate	3 qt/A	50	13	35	10	40	-
Triclopyr	4 qt/A	47	10	20	10	15	-
Imazapyr + Glyphosate	1 pt/A + 2 qt/A	93	43	50	2	55	-
Imazapyr + Triclopyr	1 pt/A + 2 qt/A	85	58	28	0	30	5
Imazapyr + Triclopyr	2 pt/A + 4 qt/A	43	38	48	7	-	0
Imazapyr + Glyphosate	1 pt/A + 1 qt/A	55	35	32	0	-	40
Glyphosate + Triclopyr	1 qt/A + 2 qt/A	43	5	10	-	10	0
Glyphosate + Triclopyr	2 qt/A + 2 qt/A	47	20	15	-	40	0
Triclopyr + Metsulfuron Methyl	2 qt/A + 1 oz/A	50	15	30	-	35	5
Triclopyr + Metsulfuron Methyl	2 qt/A + 2 oz/A	25	0	0	-	35	20
Triclopyr + Aminopyralid	1 qt/A + 2 oz/A	50	25	10	-	20	15
Triclopyr + Aminopyralid	1 qt/A + 4 oz/A	38	15	10	0	50	0
Triclopyr + Aminopyralid	1 qt/A + 6 oz/A	60	30	23	-	18	0
Triclopyr + Aminopyralid	2 qt/A + 2 oz/A	63	0	15	-	30	-
Control	-	0	0	0	0	0	0

[a] All applications included a nonionic surfactant at 0.25% v/v.

[b] Control estimated on a 0 (no control) to 100 (complete control) ranking.

[c] Missing data, denoted (-), not present for control estimations; therefore, mean separations were not obtained.

[d] Due to uneven populations in treatment plots, means are reported based on species presence (n= 1-3).

Table 7. Boomless nozzle spray trial (general brush). Treatment-by-treatment effects for overall herbicide effectiveness based on species response 12 and 24 months after treatment (MAT).

		Pooled Species % Control[b,c]	
Herbicide Formulation	Herbicide Rate[a]	12 MAT	24 MAT
Imazapyr	1 pt/A	60 ab	78 abc
Glyphosate	2 qt/A	48 abc	63 abcd
Glyphosate	3 qt/A	33 bcd	73 abcd
Triclopyr	4 qt/A	47 abc	73 abcd
Imazapyr + Glyphosate	1 pt/A + 2 qt/A	78 a	85 a
Imazapyr + Triclopyr	1 pt/A + 2 qt/A	53 ab	82 ab
Imazapyr + Triclopyr	2 pt/A + 4 qt/A	43 abc	65 abcd
Imazapyr + Glyphosate	1 pt/A + 1 qt/A	52 ab	63 abcd
Glyphosate + Triclopyr	1 qt/A + 2 qt/A	40 abcd	48 d
Glyphosate + Triclopyr	2 qt/A + 2 qt/A	35 bcd	62 abcd
Triclopyr + Metsulfuron Methyl	2 qt/A + 1 oz/A	35 bcd	58 abcd
Triclopyr + Metsulfuron Methyl	2 qt/A + 2 oz/A	8 cd	52 cd
Triclopyr + Aminopyralid	1 qt/A + 2 oz/A	52 ab	57 bcd
Triclopyr + Aminopyralid	1 qt/A + 4 oz/A	25 bcd	52 cd
Triclopyr + Aminopyralid	1 qt/A + 6 oz/A	48 abc	72 abcd
Triclopyr + Aminopyralid	2 qt/A + 2 oz/A	32 bcd	73 abcd
Control	-	0 d	0 e
$LSD_{0.05}$		40.42	27.51
CV(%)		59.87	26.61

[a] All applications included a nonionic surfactant at 0.25% v/v.

[b] Overall control estimatd on a 0 (no control) to 100 (complete control) ranking.

[c] Data among all species pooled for control estimations.

Table 8. Boomless nozzle spray trial (general brush). Means table for overall herbicide effectiveness based on species response 36 months after treatment (MAT).

Herbicide Formulation	Herbicide Rate[a]	Mean Species % Control 36 MAT [b,c,d,e]					
		Acer rubrum	*Morella cerifera*	Vaccinium angustifolium	*Magnolia virginiana*	*Carpinus caroliniana*	*Quercus* spp.
Imazapyr	1 pt/A	95	85	65	35	35	65
Glyphosate	3 qt/A	82	83	68	35	20	-
Triclopyr	4 qt/A	90	88	55	70	35	-
Imazapyr + Glyphosate	1 pt/A + 2 qt/A	97	68	75	42	85	-
Imazapyr + Triclopyr	1 pt/A + 2 qt/A	97	95	68	-	50	35
Triclopyr + Aminopyralid	1 qt/A + 6 oz/A	82	85	53	-	40	65
Triclopyr + Aminopyralid	2 qt/A + 2 oz/A	88	80	68	-	60	-
Control	-	0	0	0	0	0	0

[a] All applications included a nonionic surfactant at 0.25% v/v.

[b] Control estimated on a 0 (no control) to 100 (complete control) ranking.

[c] Missing data, denoted (-), not present for control estimations; therefore, mean separations were not obtained.

[d] Due to uneven populations in treatment plots, means are reported based on species presence (n= 1-3).

[e] Means derived from observations 12 months after retreatment (36 months after innitial treatment). Retreatment occurred at 24 MAT .

Table 9. Boomless nozzle spray trial (general brush). Treatment-by-treatment effects for eight herbicide treatments based on species response 12, 24, and 36 months after treatment (MAT).

		Pooled Species % Control[b,c,d]			
Herbicide Formulation	Herbicide Rate[a]	12 MAT	24 MAT	36 MAT[d]	% Efficiency[e]
Imazapyr	1 pt/A	60 ab	78 a	85 ab	(+) 7
Glyphosate	3 qt/A	33 bc	73 a	83 ab	(+) 10
Triclopyr	4 qt/A	47 ab	73 a	87 ab	(+) 13
Imazapyr + Glyphosate	1 pt/A + 2 qt/A	78 a	85 a	90 a	(+) 5
Imazapyr + Triclopyr	1 pt/A + 2 qt/A	53 ab	82 a	90 a	(+) 8
Triclopyr + Aminopyralid	1 qt/A + 6 oz/A	48 ab	72 a	92 a	(+) 20
Triclopyr + Aminopyralid	2 qt/A + 2 oz/A	32 bc	73 a	77 b	(+) 3
Control	-	0 c	0 b	0 c	0
$LSD_{0.05}$		37.11	22.74	12.94	
CV(%)		48.20	19.36	9.80	

[a] All applications included a nonionic surfactant at 0.25% v/v.

[b] Overall control estimatd on a 0 (no control) to 100 (complete control) ranking.

[c] Data amoing all species pooled for control estimations.

[d] Observations derived from a retreatment occurring 24 MAT (36 months after initial treatment).

[e] Performance of comparing overall control difference from 24 MAT to the retreatment evaluation (36 months after initial treatment).

Table 10. Baccharis (*Baccharis halimifolia*) control along roadsides. Means table for overall herbicide effectiveness based on species response 6 months after treatment (MAT).

		Mean Species % Control 6 MAT [b,c]		
Herbicide Formulation	Herbicide Rate[a]	*Baccharis* spp.	*Poaceae* spp.	*Lespedeza* spp.
Aminocyclopyrachlor + Metsulfuron Methyl	7.5 oz/A + 2 oz wt/A	12	0	10
Aminocyclopyrachlor + Metsulfuron Methyl	9.1 oz/A + 2.4 oz wt/A	13	0	13
Aminocyclopyrachlor + Metsulfuron Methyl + Fosamine	7.5 oz/A + 2 oz wt/A + 4% v/v	50	0	38
Aminocyclopyrachlor + Metsulfuron Methyl + Imazapyr	5.9 oz/A + 1.5 oz wt/A + 2 gal A/100 gal	3	0	18
Aminocyclopyrachlor + Metsulfuron Methyl + Imazapyr	7.5 oz/A + 2 oz wt/A + 7 oz wt/A	7	0	23
Aminocyclopyrachlor + Metsulfuron Methyl + Imazapyr	9.1 oz/A + 2.4 lb A/100 gal + 8.5 oz wt/A	12	0	28
Aminocyclopyrachlor + Metsulfuron Methyl + Imazapyr + Fosamine	5.9 oz/A + 1.5 oz wt/A + 5.5 oz wt/A + 4% v/v	10	0	23
Triclopyr Acid	2% v/v	5	0	20
Control	-	0	0	0

[a] All applications included a methylated seed oil (MSO) surfactant at 1% v/v.
[b] Control estimated on a 0 (no control) to 100 (complete control) ranking.
[c] Due to uneven populations in treatment plots, means are reported based on species presence (n= 1-3). Therefore, mean separations were not obtained.

Table 11. Baccharis (*Baccharis halimifolia*) control along roadsides. Means table for overall herbicide effectiveness based on species response 12 months after treatment (MAT).

		Mean Species % Control 12 MAT [b,c]		
Herbicide Formulation	Herbicide Rate[a]	*Baccharis* spp.	*Poaceae* spp.	*Lespedeza* spp.
Aminocyclopyrachlor + Metsulfuron Methyl	7.5 oz/A + 2 oz wt/A	93	0	87
Aminocyclopyrachlor + Metsulfuron Methyl	9.1 oz/A + 2.4 oz wt/A	78	0	67
Aminocyclopyrachlor + Metsulfuron Methyl + Fosamine	7.5 oz/A + 2 oz wt/A + 4% v/v	97	0	100
Aminocyclopyrachlor + Metsulfuron Methyl + Imazapyr	5.9 oz/A + 1.5 oz wt/A + 2 gal A/100 gal	97	0	100
Aminocyclopyrachlor + Metsulfuron Methyl + Imazapyr	7.5 oz/A + 2 oz wt/A + 7 oz wt/A	99	0	100
Aminocyclopyrachlor + Metsulfuron Methyl + Imazapyr	9.1 oz/A + 2.4 lb A/100 gal + 8.5 oz wt/A	100	0	100
Aminocyclopyrachlor + Metsulfuron Methyl + Imazapyr + Fosamine	5.9 oz/A + 1.5 oz wt/A + 5.5 oz wt/A + 4% v/v	100	0	100
Triclopyr Acid	2% v/v	63	0	100
Control	-	0	0	0

[a] All applications included a methylated seed oil (MSO) surfactant at 1% v/v.

[b] Control estimated on a 0 (no control) to 100 (complete control) ranking.

[c] Due to uneven populations in treatment plots, means are reported based on species presence (n= 1-3). Therefore, mean separations were not obtained.

Table 12. Baccharis (Baccharis halimifolia) control along roadsides. Treatment-by-treatment effects for overall herbicide effectiveness based on species response 6 and 12 months after treatment (MAT).

		Pooled Species % Control[b]	
Herbicide Formulation	Herbicide Rate[a]	6 MAT	12 MAT
Aminocyclopyrachlor + Metsulfuron Methyl	7.5 oz/A + 2 oz wt/A	8 bc	93 ab
Aminocyclopyrachlor + Metsulfuron Methyl	9.1 oz/A + 2.4 oz wt/A	12 b	80 ab
Aminocyclopyrachlor + Metsulfuron Methyl + Fosamine	7.5 oz/A + 2 oz wt/A + 4% v/v	43 a	98 a
Aminocyclopyrachlor + Metsulfuron Methyl + Imazapyr	5.9 oz/A + 1.5 oz wt/A + 2 gal A/100 gal	10 b	98 a
Aminocyclopyrachlor + Metsulfuron Methyl + Imazapyr	7.5 oz/A + 2 oz wt/A + 7 oz wt/A	13 b	98 a
Aminocyclopyrachlor + Metsulfuron Methyl + Imazapyr	9.1 oz/A + 2.4 lb A/100 gal + 8.5 oz wt/A	10 b	100 a
Aminocyclopyrachlor + Metsulfuron Methyl + Imazapyr + Fosamine	5.9 oz/A + 1.5 oz wt/A + 5.5 oz wt/A + 4% v/v	12 b	100 a
Triclopyr Acid	2% v/v	8 bc	70 b
Control	-	0 c	0 c
$LSD_{0.05}$		9.71	23.41
CV(%)		43.28	16.48

[a] All applications included a methylated seed oil (MSO) surfactant at 1% v/v.

[b] Overall control estimated on a 0 (no control) to 100 (complete control) ranking.

Table 13. Control of pines. Means table for overall herbicide effectiveness based on species response 1, 2, 3, and 12 months after treatment (MAT).

		Mean Species % Control [b,c]							
		1 MAT		2 MAT		3 MAT		12 MAT	
Herbicide Formulation	Herbicide Rate[a]	*Pinus* spp.	*Poaceae* spp.	*Pinus* spp.	*Poaceae* spp.	*Pinus* spp.	*Poaceae* spp.	*Pinus* spp.	*Poaceae* spp.
Aminocyclopyrachlor + Metsulfuron Methyl	15 oz/A + 1.175 oz wt/A	13	7	87	0	100	0	100	0
Aminocyclopyrachlor + Metsulfuron Methyl	18 oz/A + 1.425 oz wt/A	15	5	70	3	70	0	68	0
Aminocyclopyrachlor + Metsulfuron Methyl + Fosamine	15 oz/A + 1.175 oz wt/A + 4% v/v	92	32	100	100	100	100	95	100
Aminocyclopyrachlor + Metsulfuron Methyl + Fosamine	18 oz/A + 1.425 oz wt/A + 4% v/v	82	77	100	100	100	100	100	100
Triclopyr Acid	3 gal/A	92	12	95	3	98	0	99	0
Glyphosate	2% v/v	60	100	78	100	100	23	100	3
Aminopyralid	7% v/v	8	0	100	5	85	0	67	0
Control	-	0	0	0	0	0	0	0	0

[a] All applications included a methylated seed oil (MSO) surfactant at 1% v/v; except for Aminopyralid which received a nonionic surfactant at 1 % v/v.

[b] Control estimated on a 0 (no control) to 100 (complete control) ranking.

[c] Due to uneven populations in treatment plots, means are reported based on species presence (n= 1-3). Therefore, mean separations were not obtained.

Table 14. Control of pines. Treatment-by-treatment effects for overall herbicide effectiveness based on species response 1, 2, 3, and 12 months after treatment (MAT).

Herbicide Formulation	Herbicide Rate[a]	*Pinus* spp. % Control[b]			
		1 MAT	2 MAT	3 MAT	12 MAT
Aminocyclopyrachlor + Metsulfuron Methyl	15 oz/A + 1.175 oz wt/A	13 d	87 a	100 a	100 a
Aminocyclopyrachlor + Metsulfuron Methyl	18 oz/A + 1.425 oz wt/A	15 d	70 a	70 a	68 a
Aminocyclopyrachlor + Metsulfuron Methyl + Fosamine	15 oz/A + 1.175 oz wt/A + 4% v/v	92 a	100 a	100 a	95 a
Aminocyclopyrachlor + Metsulfuron Methyl + Fosamine	18 oz/A + 1.425 oz wt/A + 4% v/v	82 b	100 a	100 a	100 a
Triclopyr Acid	3 gal/A	92 a	95 a	98 a	99 a
Glyphosate	2% v/v	60 c	78 a	100 a	100 a
Aminopyralid	7% v/v	8 de	100 a	85 a	67 a
Control	-	0 e	0 b	0 b	0 b
$LSD_{0.05}$		9.65	34.82	34.08	37.81
CV(%)		12.19	25.25	23.83	27.45

[a] All applications included a methylated seed oil (MSO) surfactant at 1% v/v; except for aminopyralid which received a nonionic surfactant at 1 % v/v.

[b] Overall control estimated on a 0 (no control) to 100 (complete control) ranking.

Table 15. Fosamine comparison with triclopyr acid. Treatment-by-treatment effects for overall herbicide effectiveness based on defoliation 6 and 12 months after treatment (MAT).

		Pooled Sites % Defoliation[b,c,d]	
Herbicide Formulation	Herbicide Rate[a]	6 MAT	12 MAT[e]
Fosamine	1% v/v	9 d	0 c
Fosamine	2% v/v	43 c	59 b
Fosamine	3% v/v	87 b	100 a
Fosamine	4% v/v	99 a	100 a
Triclopyr	1% v/v	100 a	99 a
Control	-	0 d	0 c
$LSD_{0.05}$		9.57	9.42
CV(%)		17.92	16.63

[a] Triclopyr included a nonionic surfactant at 0.25% v/v.

[b] Overall defoliation estimatd on a 0 (no defoliation) to 100 (complete defoliation) scale.

[c] Data among all test sites pooled for % defoliation estimations among roadsides in Caswell, Stokes, and Franklin counties; respectively.

[d] Treatment differences are reported based on (n= 3 replications per location).

Table 16. Herbicide Modes of Action

Active Ingredient(s)	Chemical Family	Group	Mode of Action	Known Resistance[1]
2,4-D	phenoxy-carboxylic acid	4	Synthetic auxin	Yes
2,4-D + triclopyr	phenoxy-carboxylic acid + pyridine carboxylic acid	4 + 4	Synthetic auxin + Synthetic auxin	Yes
aminopyralid	pyridine carboxylic acid	4	Synthetic auxin	No
aminopyralid + triclopyr	pyridine carboxylic acid + pyridine carboxylic acid	4 + 4	Synthetic auxin + Synthetic auxin	No
bromacil	uracil	5	Photosystem II inhibition; different binding behavior than groups 6 & 7	No
dicamba	benzoic acid	4	Synthetic auxin	Yes
fosamine	other	27	Growth regulator	Yes
glyphosate	glycine	9	EPSP synthase inhibition	No
hexazinone	triazinone	5	Photosystem II inhibition; different binding behavior than groups 6 & 7	No
imazapyr	imidazolinone	2	ALS inhibition	No
metsulfuron methyl	sulfonylurea	2	ALS inhibition	No
tebuthiuron	urea	7	Photosystem II inhibition; different binding behavior than groups 5 & 6	No
triclopyr	pyridine carboxylic acid	4	Synthetic auxin	Yes
triclopyr + fluroxypyr	pyridine carboxylic acid + pyridine carboxylic acid	4 + 4	Synthetic auxin + Synthetic auxin	No

[1]Refernce the 2017 N.C Agricultural Chemicals Manual or Table 1. for a detailed guide of known resistance based on treatment parameters.

Table 17. Chemical Control of Woody Plants				
Herbicide and Formulation	**Amount of Formulation**	**Use Option**	**Resistance**	**Precautions and Remarks**
Foliar Treatment				
2,4-D amine 4 SL, MOA 4	2 gallons in 100 gallons water	Most woody species	Rhododendron resistant; ash, red maple, and persimmon generally resistant.	To reduce vapor drift hazard, use amine formulations along with low spraying pressure to prevent spray drift. Wet foliage and stems thoroughly. Most effective results obtained by spraying within 6 weeks after plants have reached full-leaf stage. This treatment used primarily on trees or brush less than 6 feet tall. Only certain trade formulations of 2,4-D can be used on ditch banks or near other bodies of water; check labels.
2,4-D low volatile ester or oil-soluble amine	varies			Use as invert emulsion to reduce drift hazards See

				remarks for 2,4-D amine.
2,4-D + triclopyr EC	1 to 1.5 gallons in 100 gallons water *(handgun application)*			Spray to wet all leaves and green stems to drip point. Use low spraying pressure to prevent drift. For best results, apply when plants are actively growing after full leaf in spring to early summer. This treatment is used primarily on trees and brush less than 6 feet tall. For application via boom or other broadcast spray equipment. For aerial application (helicopter only), use Nalcotrol to prevent drift. See label for specific information. Warning: Restrictions on grazing or harvesting of green forage: Do not graze lactating dairy animals or
2.0 + 1.0 pound/gallon, MOA4	1.5 to 4 gallons in water to deliver 15 to 30 gallons total spray/acre			

				harvest green forage for 14 days following treatment with 2 gallons per acre or less; with treatment rates greater than 2 gallons per acre, do not graze or harvest green forage until the following growing season. For other livestock, no grazing restrictions apply at rates under 2 gallons per acre. Above 2 gallons per acre, do not graze or harvest green forage from treated areas for 14 days after treatment. Restrictions on haying (harvesting of dried forage): For lactating dairy animals, do not harvest hay until the next growing season. For other livestock, do not harvest hay for 7 days

				after treatment at rates under 2 gallons per acre. Above 2 gallons per acre, do not harvest hay for 14 days after treatment. *Slaughter restrictions: Withdraw livestock from grazing treated grass or treated hay at lest 3 days before slaughter. This restriction applies to grazing during the season following treatment or hay harvested during the season following treatment.*
fosamine 4 SL	1.5 to 3 gallons in 100 gallons water			Apply to foliage during the 2-month period prior to fall leaf coloration. Thoroughly and uniformly cover plants without drenching. Add surfactant WK at the rate of 1 quart per 100 gallons of

				spray. Surfactant WK is not needed with Krenite S. Rate and gallonage depend on plant size and species to be controlled. Check label. Use in noncropland, fence lines, etc.
dicamba 4 SL	1 gallon in 100 gallons			Apply when leaves are fully developed. Spray with a handgun to completely wet foliage, and allow spray to run down the stem. Add a nonionic surfactant at the rate of 2 quarts per 100 gallons of finished spray solution to improve wetting. Retreatment may be required, but do not exceed 2 gallons per treated acre during one growing season. Keep spray off desired plants. Do not

				spray in rooting zone of desired plants.
triclopyr 3 SL	2 to 3 gallons in 100 gallons water			Spray to thoroughly wet leaves, stems, and root collars. Can be mixed with other woody plant herbicides. See label. Avoid drift.
triclopyr 4.4 EC	1 to 3 gallons in 100 gallons water			
2,4-D amine 3.8 SL, MOA 4	2 to 8 pints/acre	Woody brush and trees	-	Apply when weeds are small and actively growing before bud stage. Bienennial and perennial species are best controlled in seedling to rosette stage before flower stalks appear.
dicamba 4 SL, MOA 4	0.5 to 4 pints in 25 to 200 gallons water			For low volume applications, apply 3 to 5% v/v rate. Check product label for tank mix partners for woody brush and vines.
glyphosate 5.4 SL, MOA 9	5 to 8% solution			If brush has been mowed or trees cut, wait until regrowth

				reaches recommended stage before treating. Apply as a low volume directed spray on at least 50% of the targeted foliage using a lateral zigzag motion from top to bottom. Spray to wet, not runoff. Add NIS at 2 quarts per 100 gallons of spray solution.
metsulfuron methyl 60 DF, MOA 2	0.33 to 4 ounces/acre in 10 to 50 gallons water			For industrial, noncrop sites on young, actively growing weeds and brush. High volume ground application: mix 0.5 to 3 ounces per 100 gallons spray solution, and apply at 100 to 400 gallons per acre. Low volume and ultra-low volume ground applications: mix 4 to 8 ounces per 100 gallons spray solution,

				and apply at 10 to 50 gallons per acre.
triclopyr 4 EC, MOA 4	2 pints in 10 gallons water/acre			Treat after rapid growth period in spring when leaf tissue is fully expanded and terminal growth has slowed. During drought or for hard-to-control weeds, add 2 to 3 quarts of 2,4-D low volatile ester to spray solution.
triclopyr + fluroxypyr 2 EC 1.5 + 0.5 pounds/gallon, MOA 4	3 to 8 pints/acre			Broadcast applications: treat in late spring through summer when leaves are fully expanded and terminal growth has slowed. If brush has been mowed, allow 9 to 12 months of regrowth before treating. NIS or liquid fertilizer at 1 to 2 quarts per 100

				gallons of spray solution may improve control. High volume foliar treatment of individual plants: apply 1 to 2 gallons of PastureGard plus 1 quart NIS per 100 gallons of spray solution.
aminopyralid 2 SL, MOA 4	4 to 7 fluid ounces/acre	Black locust, honey locust, mimosa, redbud, and wisteria	-	Treat when weeds are actively growing. Include a non-ionic surfactant. Avoid mowing for 14 days after application.
aminopyralid + triclopyr 1.1 SL, MOA 4	6 to 9 pints/acre	Numerous woody species	-	Treat when weeds are actively growing. Include a non-ionic surfactant.
imazapyr 2 SL, MOA 2	0.5 to 5% v/v 0.6 to 6.4 fluid ounces/gallon	Most vegetation	-	Most effective with 1% methylated seed oil.
Basal Stem Treatment				
2,4-D low volatile ester 4 SL, MOA 4	2 gallons in 100 gallons high quality mineral oil	Most woody species	Black locust resistant	Spray lower 12 inches of stem or trunk and let some solution run into ground. May be used any time of year, but is
triclopyr 4.4 EC, MOA 4	1 to 3 gallons in 100 gallons high quality mineral oil			

				much more effective during dormant season. One growing season required before plants die completely. This treatment used primarily on plants less than 6 inches in diameter. Root suckering species may be resistant. Both dormant stem and basal treatments useful to farmers and landowners because during winter there is less hazard to crops and more labor probably available. Do not use around the home or ditch banks.
2,4-D + triclopyr EC 2.0 + 1.0 pound/gallon, MOA 4	4 gallons in high quality mineral oil to make 100 gallons spray			Spray basal portions of trees or brush to a height of 15 to 20 inches from the ground. Thoroughly

				wet all basal bark areas, including crown and ground sprouts and ground area at base of stems or trunk. For trees larger than 6 to 8 inches diameter, use stump treatment. Winter and early spring treatments give best results. See warning for livestock and haying usage for Crossbow listed above under "Most Woody Species."
imazapyr 2 SL, MOA 2	8 to 12 fluid ounces in 1 gallon high quality mineral oil		-	Treat lower 18 inches of stem. May be used on stems up to 4 inches DBH. Do not apply to point of dripping or puddling.
2,4-D amine 3.8 SL, MOA 4	8 qt in 100 gal water or 2.6 fl oz in 1 gal water	Woody brush and trees	-	Thoroughly wet the base and root collar of all stems until the spray accumulates around the root collar at the ground

				line. Wetting the stems will aid in control.
triclopyr 4 EC, MOA 4	2 gallons in 98 gallons high quality mineral oil			Spray basal 15 to 20 inches of plant to point of runoff at soil surface.
triclopyr + fluroxypyr 2 EC 1.5 + 0.5 pounds/gallon, MOA 4	50% product + 50% high quality mineral oil			Apply at any time to stems less than 6 inches in diameter except when snow or water prevents spraying to ground line. Use solid cone or flat fan nozzles at low pressure. Spray to wet but not runoff.
Dormant Stem Treatment				
2,4-D + triclopyr EC 2.0 + 1.0 lb/gal, MOA 4	1 to 4 gallons in high quality mineral oil to make 100 gallons spray	Most woody species	-	Thoroughly wet upper and lower stems, including root collar and any ground sprouts. Treat when brush is dormant and the bark is dry, but not when snow or water prevents spraying to ground line. Best results occur with late-winter to

				early spring applications. Brush over 8 feet in height is difficult to control with this method. See warning for livestock and haying usage for Crossbow listed above under "Most Woody Species."
triclopyr 4 EC, MOA 4	3 to 6 quarts in high quality mineral oil to make 100 gallons spray	Woody brush and trees	-	Treat any time brush is dormant and most foliage has dropped. Use 20 to 40 psi with knapsack or power spraying equipment. Do not apply if snow or water prevents spraying to ground line. Wet stems to point of runoff and ground below the plant for root suckering species, such as sumac, sassafras, or locust.
Stump Treatment To Prevent Regrowth				
2,4-D low volatile ester 4 SL, MOA 4	3 gallons in 100 gallons high quality mineral oil	Most woody species	-	Soak freshly cut stumps with spray

				solution to prevent sprouting, or use AMS crystals on stump. Hasten decay of stump by covering with layers of soil and a nitrogen fertilizer. Keep moist.
2,4-D + triclopyr EC 2.0 + 1.0 lb/gal, MOA 4	4 gallons in high quality mineral oil to make 100 gallons spray			Cut down trees and treat stumps, including the freshly cut surface, bark, crown, and ground sprouts. Winter and early spring treatments (before growth begins) give best results.
dicamba 4 SL, MOA 4	16.5 gal in 100 gal water			Spray or paint freshly cut surface with the solution. Area adjacent to bark should be thoroughly wet.
2,4-D amine 3.8 SL, MOA 4	8 qt in 100 gal water or 2.6 fl oz in 1 gal water	Woody brush and trees	-	Apply as soon as possible after cutting trees. Thoroughly soak entire stump including cut surface, bark, and exposed roots.

dicamba 4 SL, MOA 4	1 gal in 1 to 3 gal water			NIS or oil may be added to enhance control. Make application within 30 minutes of cutting. Area adjacent to the bark should be thoroughly wet.
triclopyr 4 EC, MOA 4	20 to 30 gallons in high quality mineral oil to make 100 gallons spray			Treat with a backpack or knapsack sprayer using low pressure and a solid cone or flat fan nozzle. Spray stump sides and outer portion of cut surface but not to point of runoff. Apply anytime except when snow or water prevent spraying to ground line.
triclopyr + fluroxypyr 2 EC 1.5 + 0.5 lb/gal, MOA 4	50% product + 50% high quality mineral oil			Apply to freshly cut stumps using solid cone or flat fan nozzles at low pressure. Wet stump sides, root collar, and outer portion of cut surface but not to point of runoff. Apply

				anytime except when snow or water prevent spraying to ground line.
glyphosate 5.4 SL, MOA 9	50 to 100% solution	Woody species; dogwood, hickory, maple, oak, poplar, sweet gum, sycamore, and willow	-	Treat freshly cut stumps or resprouts. Apply to freshly cut stumps immediately after cutting or reduced performance may occur.
Stump Treatment				
aminopyralid + triclopyr 1.1 SL, MOA 4	apply undiluted	Numerous wood species	-	Apply as soon as possible after cutting stems.
imazapyr 2 SL, MOA 2	8 to 16 ounces in 1 gallon high quality mineral oil	Most woody species	-	Apply as soon as possible after cutting stems.
Soil Treatment Beneath Woody Plants				
hexazinone 2 SL, MOA 5	2 to 4 gallons in 100 gallons water	Most woody species	-	Apply as a coarse spray, using a handgun applicator. Direct spray beneath plants to be controlled. Apply during the period between late winter and early summer. Do not apply in vicinity of desirable plants.

bromacil 2 SL, MOA 5	varies			Apply as a coarse spray, using a handgun applicator. Use at least 200 gallons of spray per acre. Direct spray beneath plants to be controlled just before or during the period of active growth. Do not apply in vicinity of desirable plants. Rates depend on species to be controlled. Check label.
tebuthiuron 20 P, MOA 7	5 to 30 pounds/acre			Rates depend on species to be controlled. Check label for specific rates. Apply when ground is not frozen. Do not apply to the root zone of desirable trees or shrubs or where runoff can carry the herbicide to desired plants.

*Formulations, treatments options, resistance information, and remarks all directly derived from the 2017 N.C Agricultural Chemicals Manual. Please consult this manual for additional herbicide information or concerns. *This edition was prepared by the College of Agriculture and Life Sciences at North Carolina State University and by an editorial committee consisting of Joseph C. Neal, Horticultural Science, Chair; Alan York, Crop and Soil Sciences; Carl R. Crozier, Crop and Soil Sciences; Barbara Shew, Entomology and Plant Pathology; Hannah J. Burrack, Entomology and Plant Pathology; Travis Gannon, Crop and Soil Sciences; Christopher S. DePerno, Forestry and Environmental Resources; Gary T. Roberson, Biological and Agricultural Engineering; Wayne G. Buhler, Department Head Representative; Thomas A. Melton, Administrative Advisor; and James W Burnette Jr., Structural Pest Control & Pesticide Division, North Carolina Department of Agriculture & Consumer Services.*

Figure 1.

Vegetation Management Under Pines
(vegetated areas adjacent to interchanges)

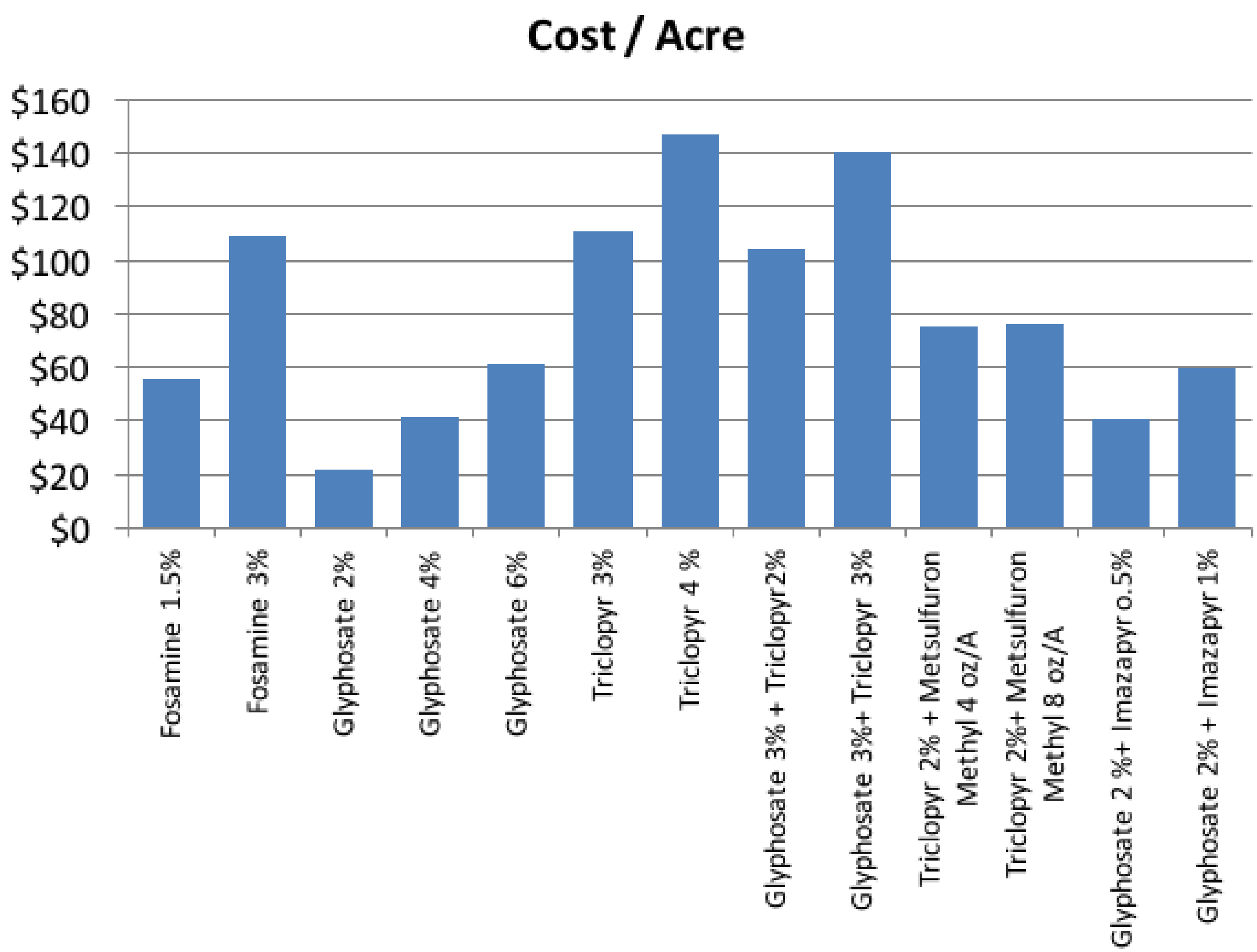

Figure 2.

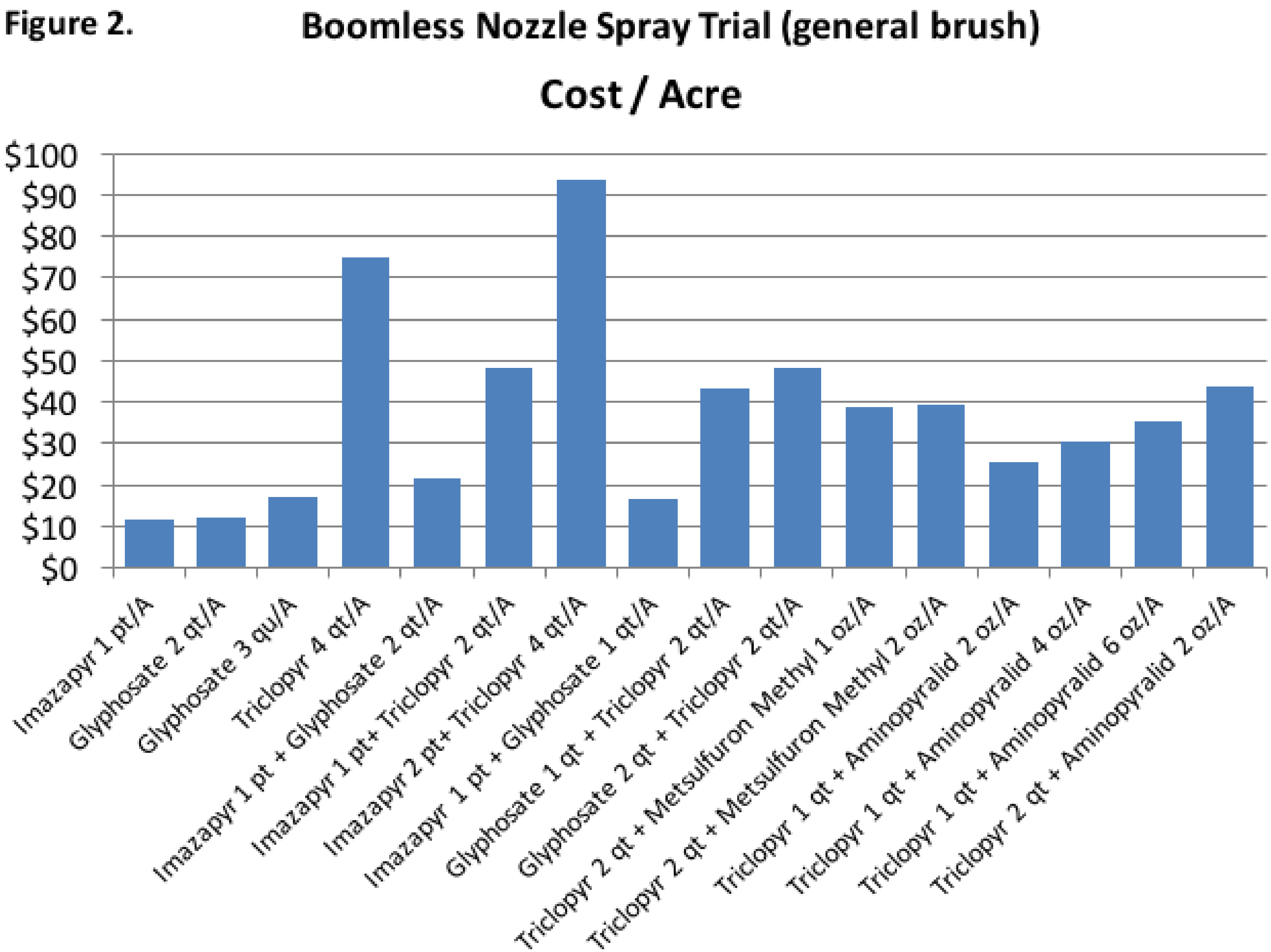
Boomless Nozzle Spray Trial (general brush)
Cost / Acre
$100
$90
$80
$70
$60
$50
$40
$30
$20
$10
$0
Imazapyr 1 pt/A
Glyphosate 2 qt/A
Glyphosate 3 qu/A
Triclopyr 4 qt/A
Imazapyr 1 pt + Glyphosate 2 qt/A
Imazapyr 1 pt+ Triclopyr 2 qt/A
Imazapyr 2 pt+ Triclopyr 4 qt/A
Imazapyr 1 pt + Glyphosate 1 qt/A
Glyphosate 1 qt + Triclopyr 2 qt/A
Glyphosate 2 qt + Triclopyr 2 qt/A
Triclopyr 2 qt + Metsulfuron Methyl 1 oz/A
Triclopyr 2 qt + Metsulfuron Methyl 2 oz/A
Triclopyr 1 qt + Aminopyralid 2 oz/A
Triclopyr 1 qt + Aminopyralid 4 oz/A
Triclopyr 1 qt + Aminopyralid 6 oz/A
Triclopyr 2 qt + Aminopyralid 2 oz/A

Figure 3. Baccharis (*Baccharis halimifolia*) Control along Roadsides

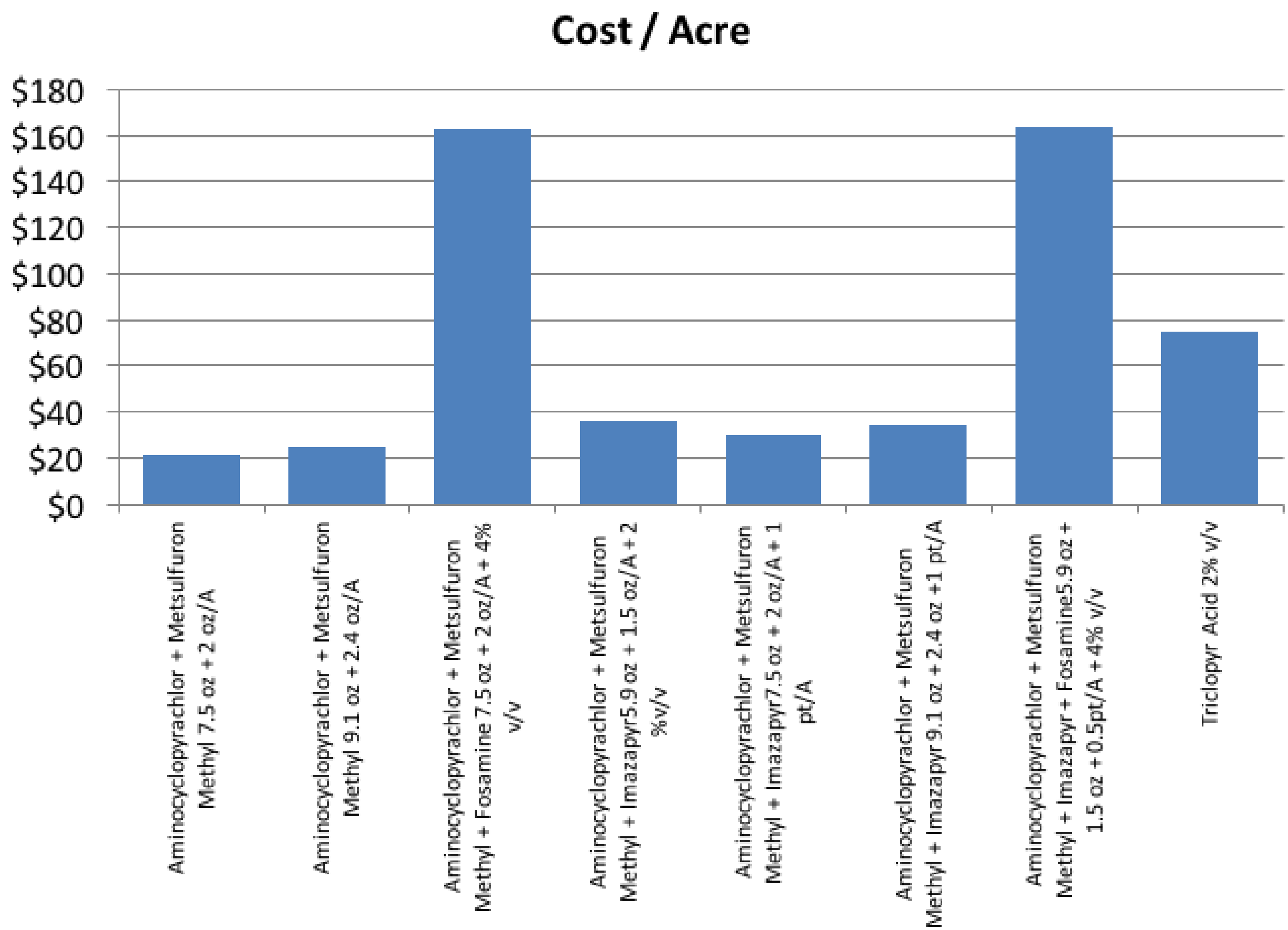

Figure 4.

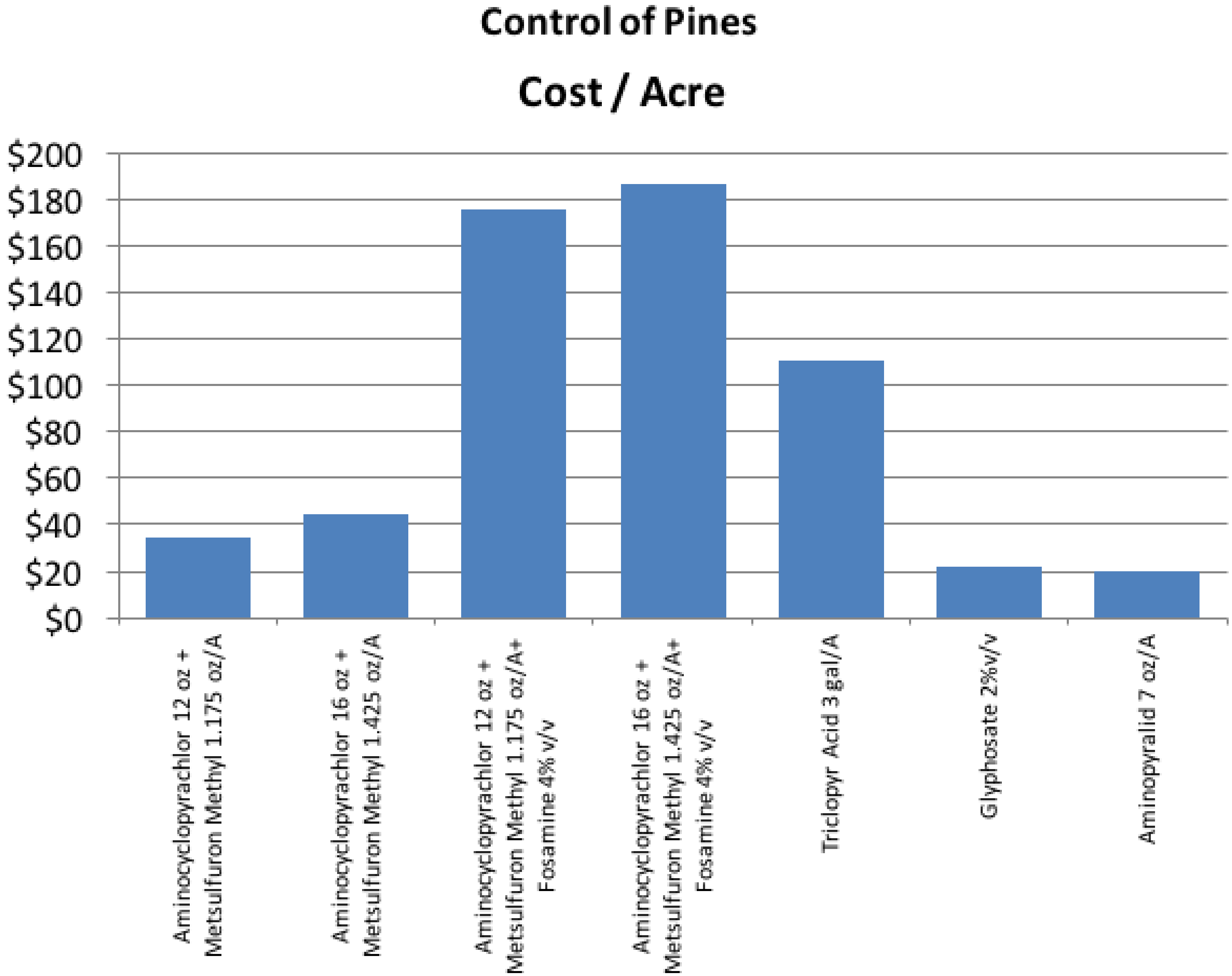
Control of Pines
Cost / Acre
$200
$180
$160
$140
$120
$100
$80
$60
$40
$20
$0
Aminocyclopyrachlor 12 oz + Metsulfuron Methyl 1.175 oz/A
Aminocyclopyrachlor 16 oz + Metsulfuron Methyl 1.425 oz/A
Aminocyclopyrachlor 12 oz + Metsulfuron Methyl 1.175 oz/A+ Fosamine 4% v/v
Aminocyclopyrachlor 16 oz + Metsulfuron Methyl 1.425 oz/A+ Fosamine 4% v/v
Triclopyr Acid 3 gal/A
Glyphosate 2%v/v
Aminopyralid 7 oz/A

Figure 5.

Fosamine Comparison with Triclopyr Acid