VEGETATION CONTROL OPTIONS FOR IMPROVING AFFORESTATION OF A RETIRED SOD FARM IN CENTRAL ARKANSAS

Michael A. Blazier, Hal O. Liechty, and L. Michelle Moore

Abstract—To improve watershed quality, there was interest in converting a retired zoysiagrass (*Zoysia* spp.) sod farm in central Arkansas into hardwood forest. Six vegetation control options for glyphosate and sulfometuron methyl were tested for pre-planting vegetation control to foster water oak (*Quercus nigra* L.) and green ash (*Fraxinus pennsylvanica* Marshall) establishment while protecting water quality at the site. Including sulfometuron with glyphosate in a fall pre-planting application was the most effective for providing vegetation control through the first growing season after planting. A ryegrass (*Lolium* spp.) cover crop suppressed grass and broadleaf competing vegetation in the first growing season after planting, although not to the magnitude and duration as sulfometuron. Horseweed (*Erigeron canadensis* L.) was observed in plots receiving sulfometuron, which prompted an additional trial at this site on herbicides for horseweed control. Cloypyralid was most effective among herbicides tested for horseweed control without damaging the water oak and cherrybark oak (*Q. pagoda* Raf.) to which it was applied.

INTRODUCTION

Conversion of retired agricultural land to hardwood forests provides several ecosystem services, but one of the greatest impediments to successful establishment of hardwood seedlings is competition from grasses, non-crop broadleaf plants, vines, shrubs, and trees (Self and Ezell 2015, Stringer and others 2009, Von Althen 1991). Competing vegetation can reduce survival and growth of seedlings by reducing light, moisture, and nutrient availability for the crop species (Self and Ezell 2015, Stringer and others 2009). Suppressing competing vegetation is crucial for improving hardwood survival and growth, and herbicides applied prior to and/or soon after planting are effective at reducing non-crop vegetation (Self and Ezell 2015, Stringer and others 2009). For some site conditions, hardwood-compatible cover crops can be used for suppressing competing vegetation (Stringer and others 2009). Cover crops provide competition suppression by limiting the quantity of weed seeds that reach soil and germinate and by shading out potential weeds (Rentz 2005, Stringer and others 2009). Cover crops used for competition control for hardwood establishment are generally small grains or grasses that do not substantially compete with planted hardwoods for site resources (Stringer and others 2009).

Recent efforts to sustain and improve a watershed in central Arkansas included the conversion of a retired zoysiagrass sod farm into upland hardwood forest. Due to the management goal of improving water quality through this land use conversion, hardwood establishment protocols required a balance in hardwood establishment efficacy while minimizing erosion potential. The zoysiagrass had a relatively dense root mat that could suppress hardwood establishment, and field portions in which zoysiagrass had been removed and not replanted prior to the conversion project had an array of annual and perennial vegetation. Suppressing this vegetation with herbicides had the potential to foster hardwood establishment. However, broadcast application of soil-active herbicides with relatively long residual activity for competition suppression that could optimize hardwood establishment efficacy may have higher erosion potential due to longer duration of exposed soil. Application of herbicides in a band around each planting row could serve as an alternative to broadcast application that could maintain greater ground coverage of vegetation while providing competition control around seedlings. Other herbicide application factors that can affect the duration of exposed soil include application frequency and residual activity, with soil-active herbicides generally having longer residual suppression of competing vegetation than foliage-active herbicides. Cover crops could serve as an alternative to herbicides in order to maintain ground coverage while reducing competing vegetation; several cover crops have been shown to reduce soil erosion in the initial

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years of stand development in hardwood plantations (Malik and others 2000).

The objective of this study was to determine the effects of several competition suppression treatments on ground coverage trends in the initial years of hardwood forest planted on a retired zoysiagrass sod farm. While conducting this study, horseweed abundance increased within several herbicide-treated plots. This observation led to a second study with the objective of exploring the efficacy of herbicide treatments on horseweed suppression and hardwood tolerance of the herbicides.

MATERIALS AND METHODS

Study Site

A study site was established at a retired sod farm in central Arkansas in February 2013 near the town of Perryville (32° 52' 15.45" N, 92° 43' 47.59" W). Soils for the fields selected for the study were alluvial silt loam soils mapped as Rexor (fine-silty, siliceous, active, thermic Oxyquic Hapludalf), Amy (fine-silty, siliceous, semiactive, thermic Typic Endoaquult), and Sallisaw (fine-silty, siliceous, superactive, thermic Typic Paleudalf) series (USDA SCS 1982). Long-term average annual temperature and precipitation for the region of the study site is 16 °C and 132 cm, respectively (SCIPP 2017).

Treatments and Experimental Design

Primary study—Eight competition control treatments were conducted in 2013; treatments included broadcast and band application of herbicides, single and multiple pre-plant herbicide applications, and a ryegrass cover crop (table 1). Treatments were applied to 0.06-ha plots established in two fields at the sod farm. There were four replications of each treatment in each field applied in a completely randomized design. All herbicides were applied with a tractor-drawn sprayer with shielding to foster application accuracy by reducing drift potential. For treatments that had banded herbicide application, the sprayer was outfitted with a boom that applied herbicide in a band 1.8 m in width along each planting row. In all treatments that included glyphosate, glyphosate was applied at 11.7 L ha^{-1} as Accord® XRT (Dow AgroSciences, LLC, Indianapolis, IN). Sulfometuron methyl (hereafter referred to as "sulfometuron") was applied at 209.7 g ha^{-1} as Oust® XP (Bayer CropScience LP, Research Triangle Park, NC) in all treatments in which it was included. In August 2013, plots receiving the RYEGRASS treatment were treated with 2241 to 3921 kg ha^{-1} of lime based on liming recommendations for ryegrass within soil tests performed for each plot. Ryegrass was planted for the RYEGRASS treatment in September 2013 by broadcast seeding 33.6 kg ha^{-1} of pure live seed.

Plots were planted by hand with water oak and green ash in February 2014. The site was subsoiled to a 51-cm depth in November 2013. Seedlings were planted at 1074 trees ha^{-1} at a spacing of 3.0 m × 3.0 m. The treatment structure of this study was a split-plot structure, with tree species as sub-plot factor and herbicide treatment as a whole-plot factor.

Horseweed study—In all treatments in the primary study that included sulfometuron, horseweed was observed as the primary vegetation that emerged after the herbicide was applied. To determine whether horseweed could be controlled by either adding an extra herbicide with sulfometuron methyl or using an alternative to sulfometuron, several treatments were conducted. Treatments included: (1) untreated control, (2) sulfometuron as Oust® XP (OUST), (3) sulfometuron as Oust® XP and sulfosulfuron as Outrider® (Valent BioSciences LLC, Libertyville, IL) (OUSTOUT), (4) clopyralid as Transline® (Dow AgroSciences, LLC, Indianapolis, IN) (TRAN), and (5) a pre-mixed granular blend of sulfometuron and metsulfuron methyl (OustExtra®, Bayer CropScience LP, Research Triangle Park, NC) (OUSTX).

Table 1—Pre-planting vegetation control treatments conducted for establishment of green ash and water oak at a retired zoysiagrass sod farm in central Arkansas

Treatment	Herbicide applied April 2013	Herbicide applied September 2013
CONTROL		
RYEGRASS	Broadcast glyphosate	Broadcast glyphosate
BrG	Broadcast glyphosate	
BaG+BaG	Banded glyphosate	Banded glyphosate
BaG+BaGS	Banded glyphosate	Banded glyphosate and sulfometuron methyl
BrG+BaG	Broadcast glyphosate	Banded glyphosate
BrG+BaGS	Broadcast glyphosate	Banded glyphosate and sulfometuron methyl
BrG+BrGS	Broadcast glyphosate	Broadcast glyphosate and sulfometuron methyl

In two fields at the sod farm, 0.02-ha plots were established in September 2014. Soil of one field was mapped as a Sallisaw series gravelly silt loam, and soil in the other field was mapped as a Leadville silt loam (loamy-skeletal, mixed, superactive Ustic Glossocryalf). Treatments were replicated three times in each field. Herbicides applied for all treatments were applied using a tractor-drawn sprayer with shielding to minimize drift. For the OUST and OUSTOUT treatments, sulfometuron was applied in October 2014 at 209.7 g ha^{-1}. Herbicide for the OUSTX treatment was also applied in October 2014 at 279.6 g ha^{-1}. In April 2015, sulfosulfuron was applied for the OUSTOUT treatment and clopryralid was applied for the TRAN treatment at 90.9 g ha^{-1} and 0.7 L ha^{-1}, respectively.

In January 2015, water oak and cherrybark oak were hand-planted for the study. Cherrybark oak was planted instead of green ash in this trial because in 2014 the emerald ash borer (*Agrilus planipennis* Fairmaire) was discovered in central Arkansas, and the recommended forest management practice to curtail ash borer infestation was to avoid planting green ash. Both tree species were planted in each plot as a sub-plot treatment factor.

Measurements

Primary study—In May 2014, September 2014, and June 2015, ground coverage assessments were performed. A 1 m × 1 m quadrat subdivided into 25 equally-sized cells was used to visually determine the percentage of ground covered by total, grass/sedge (hereafter referred to as “grass”), broadleaf forb, and woody vegetation. These measurements were taken at six subsample points per plot along a zigzag pattern within the center of the plot. Data for the subsample points were averaged for each plot for statistical analysis.

Horseweed study—In July 2015, ground coverage measurement was performed with a quadrat as conducted in the primary study. In this trial, horseweed coverage and total number of horseweed plants per quadrat were assessed at each sample point in addition to the same parameters as in the primary study. Horseweed plants per quadrat were also assessed in September 2015. In June 2015 and August 2016, tree damage was measured for each tree by visually assessing each tree and assigning a numerical damage score (table 2).

Statistical Analysis

Analysis of variance (ANOVA) was performed for all parameters in both studies using PROC GLIMMIX of the SAS System 9.4 (SAS Institute, Inc., Cary NC) at a significance level of $p = 0.05$. For coverage variables of the primary study, a repeated measures model with an autoregressive correlation structure that included field, herbicide treatment, sampling date, and all possible interactions between the variables as fixed effects was used. Tree species was not considered for these analyses because the ground coverage component of this study was measured for the entire plot rather than the subplot.

Table 2—Score system used to evaluate condition of cherrybark oak and water oak seedings in response to herbicides applied to suppress horseweed at a retired zoysiagrass sod farm in central Arkansas

Tree condition	Tree condition score
No effect, vigorously growing	1
Chlorotic leaves	2
Dead leaves, upper stem	3
Dead leaves, lower stem	4
Dieback at top	5
Dieback to bottom, re-sprouting	6
Dieback to bottom, no re-sprouting	7
Chlorotic leaves, dieback at top	8
Dead	9

For the horseweed study, ANOVA for total horseweed plants m^{-2} was performed using the same model as used for the variables of the primary study. For ground coverage, grass coverage, broadleaf coverage, and horseweed coverage, the model used for ANOVA included field, treatment, and their interaction as fixed effects. The ANOVA model for tree damage scores was a repeated measures model with an autoregressive correlation structure that included field, date, species, treatment, and their interactions as fixed effects. The interaction of treatment and species was identified as an error term in the model to account for the split-plot treatment structure.

Means separations were performed for all variables when significant effects were determined by ANOVA. When significant main effects were determined, the LINES option of the LSMEANS statement was used to perform F-protected least significant difference (LSD) means separation. When significant interactions were determined, the SLICEBY and LINES options of the SLICE statement were used to perform F-protected LSD means separation of effects within the interaction.

RESULTS AND DISCUSSION

There were significant date × treatment effects in the analyses of total, grass, and broadleaf coverage in the primary study (figs. 1–3). There were no significant treatment × field effects in the analyses of these parameters in the primary study, so data presented and discussed are averaged for both fields. No vine vegetation was observed in the study. Generally, treatments that included sulfometuron methyl had lower vegetation (total, grass, broadleaf) coverage for a longer time. No treatments affected vegetation coverage by June 2015, which was 19 or 25 months after the vegetation control treatments were conducted.

Only the three treatments that included sulfometuron methyl had lower coverage than the CONTROL treatment in the May 2014 assessment (fig. 1). By the September 2014 assessment, only the BrG+BaGS treatment had lower total coverage than the CONTROL treatment. These results suggest that the greatest overall vegetation control at this site was achieved by broadcast application of glyphosate in the spring prior to planting and including sulfometuron in the herbicide application conducted in the fall prior to planting. Ezell (2002) similarly determined that inclusion of sulfometuron in fall herbicide applications was effective at suppressing vegetation in the following growing season.

There was greater differentiation among treatments in grass coverage than for total coverage (fig. 2). In May 2014, only the RYEGRASS treatment had similar grass coverage relative to the CONTROL. Although similar in coverage, the grass in the RYEGRASS treatment was overwhelmingly ryegrass, whereas the CONTROL treatment had a mixture of grass species. In the May 2014 assessment, the two treatments (BrG+BaGS, BrG+BrGS) that consisted of a spring broadcast application of glyphosate followed by fall application of sulfometuron and glyphosate had the lowest grass coverage. The BaG+BaGS treatment had greater grass coverage than the BrG+BaGS and BrG+BrGS treatments but lower coverage than all other treatments. This finding suggests that although the inclusion of sulfometuron in the fall banded herbicide application provided greater grass control than treatments that included only glyphosate, grass re-encroachment occurred sooner without being preceded by a spring broadcast application of glyphosate. All vegetation control treatments that consisted of only glyphosate had lower grass coverage than the CONTROL treatment in May 2014, but grass coverage of these treatments was greater than all treatments that included sulfometuron. These results illustrate the value of including sulfometuron in the fall pre-planting herbicide application for providing longer-term grass suppression in the year after planting.

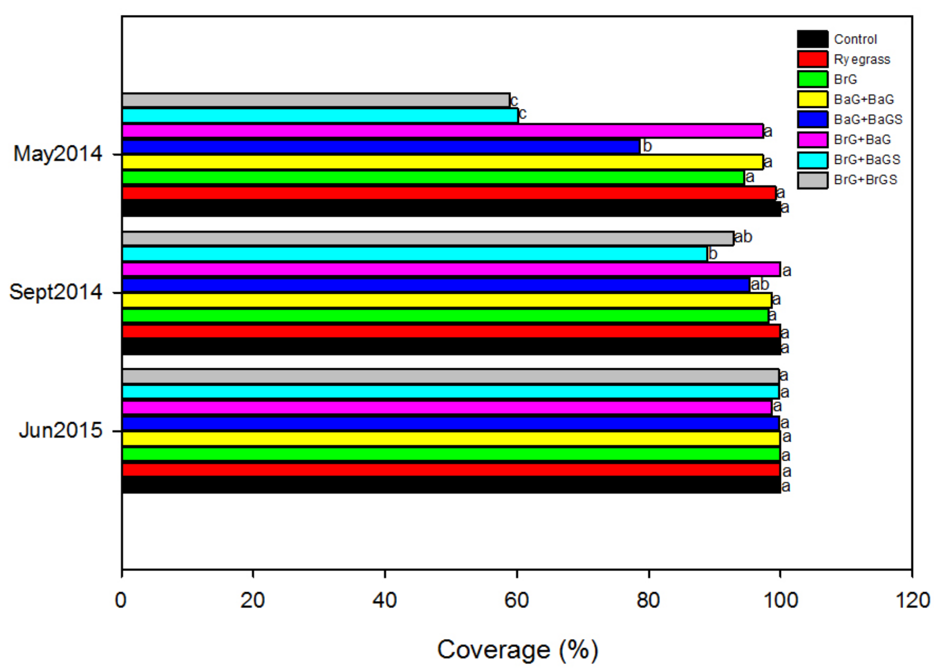

Figure 1—Total ground coverage by vegetation in response to vegetation control treatments in response to herbicide treatments applied prior to planting of green ash and water oak at a retired zoysiagrass sod farm in central Arkansas. For each date, bars followed by a different letter are significantly different at *p* <0.05.

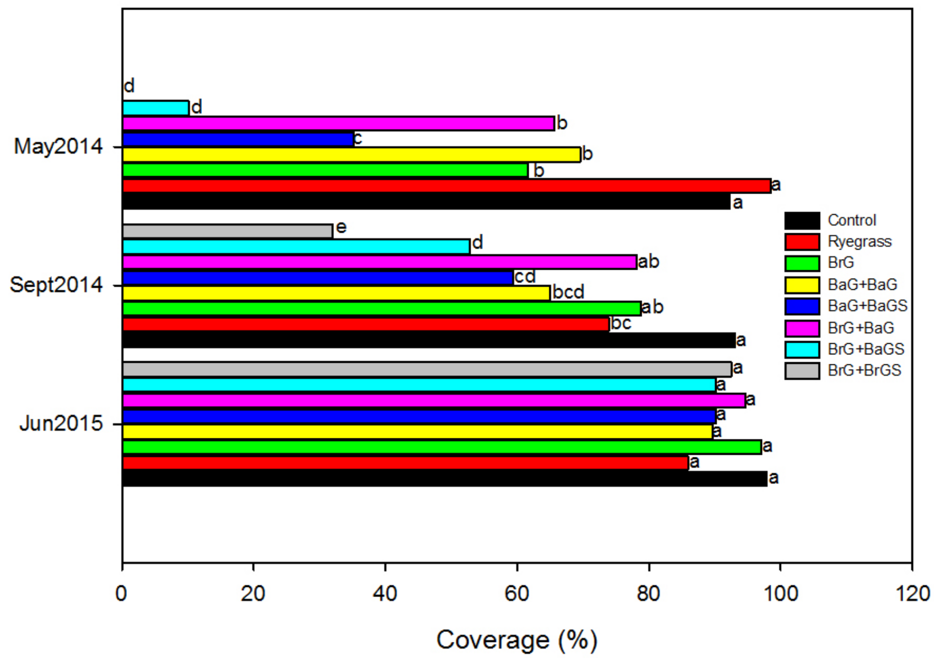

Figure 2—Ground coverage by grass vegetation in response to vegetation control treatments in response to herbicide treatments applied prior to planting of green ash and water oak at a retired zoysiagrass sod farm in central Arkansas. For each date, bars followed by a different letter are significantly different at *p* <0.05.

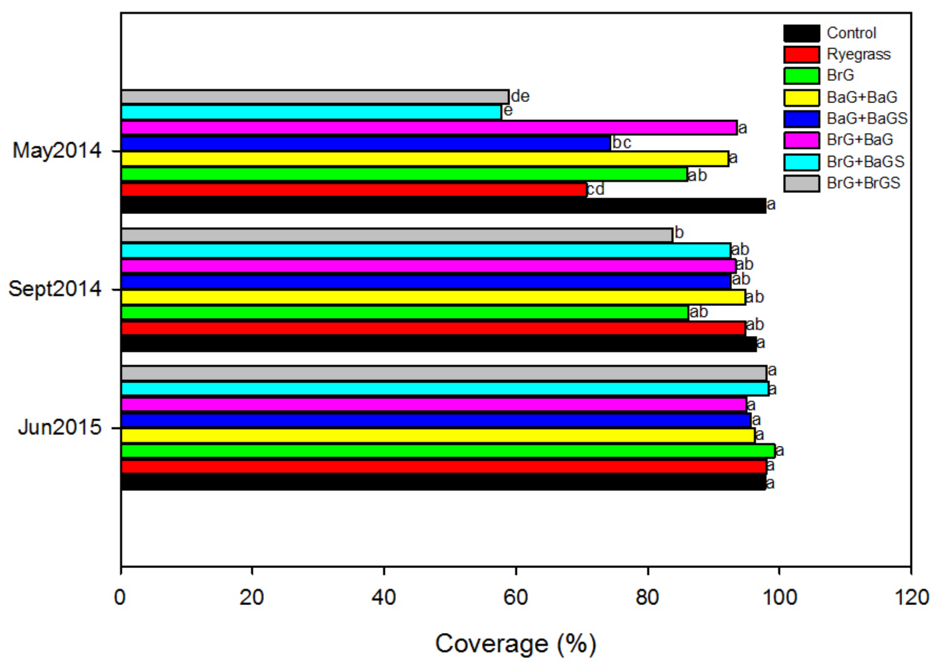

Figure 3—Ground coverage by broadleaf vegetation in response to vegetation control treatments in response to herbicide treatments applied prior to planting of green ash and water oak at a retired zoysiagrass sod farm in central Arkansas. For each date, bars followed by a different letter are significantly different at *p* <0.05.

By September 2014, the BrG+BrGS treatment had lower grass coverage than all other treatments (fig. 2). Grass coverage of the BrG+BaGS treatment had become higher than that of the BrG+BrGS treatment, although it remained lower than that of the CONTROL, RYEGRASS, BrG, and BrG+BaG treatments. These results suggest that broadcast application of sulfometuron within the fall herbicide application led to the longest-lasting grass suppression throughout the first year following planting. Among the treatments that included only glyphosate, their similarity in grass coverage in all assessments suggests that there was no added benefit to the fall glyphosate application in terms of grass suppression in the year after planting. The RYEGRASS treatment had lower grass coverage then the CONTROL in September 2014. By September the ryegrass had died in this treatment, so this result suggests that it suppressed the establishment of other grasses during the first growing season after planting.

Broadleaf coverage differed among treatments through September 2014, but differences among treatments were not as marked as for grass coverage (fig. 3). In May 2014, similar to grass coverage results, the lowest broadleaf coverage was observed in the two treatments (BrG+BaGS, BrG+BrGS) that consisted of a spring broadcast application of glyphosate followed by a fall herbicide application that included sulfometuron. Also similar to grass coverage results, by September 2014 the BrG+BrGS treatment had lower broadleaf coverage than all other treatments. These results demonstrate that the highest efficacy for non-crop broadleaf suppression was achieved by pre-planting broadcast applications of glyphosate in the spring followed by a broadcast application that included sulfometuron in the fall. The RYEGRASS treatment had lower broadleaf coverage than the CONTROL and all treatments that included only glyphosate. This result illustrates the efficacy of the ryegrass cover crop for suppressing non-crop broadleaf vegetation, although broadcast applications of glyphosate preceded planting of ryegrass to foster its establishment. The treatments that included only glyphosate proved ineffective for non-crop broadleaf vegetation suppression; broadleaf coverage of all these treatments was similar to the CONTROL in all observations.

In the horseweed study, there were significant field × treatment effects in the analyses of total ground coverage, grass coverage, horseweed coverage, and horseweed plants m^{-2} (table 3). A substantial factor contributing to the different treatment rankings by field in this study was likely flooding of the field located on Sallisaw soil. In May 2015, the region received 33 cm of precipitation, with 11 cm occurring in a strong storm on May 11, 2015 (NOAA 2015). The field located on Sallisaw soil (referred to hereafter "Sallisaw field") was located approximately 130 m from a creek that expanded and submerged the field for days after the May 11, 2015 storm. This inundation may have reduced herbicide activity in the Sallisaw field relative to the field on Leadville soil (henceforth referred to as "Leadville field"), which did not experience flooding.

Table 3—Vegetation coverage (percent) and crop tree condition score (1–9 scale) in response to herbicide treatments applied prior to planting of cherrybark oak and water oak to suppress horseweed at a retired zoysiagrass sod farm in central Arkansas

	Control	TRAN	OUST	OUSTOUT	OUSTX
Sallisaw field					
Total ground coverage	14.6 *ab*	22.5 *a*	6.2 *b*	13.6 *b*	14.4 *ab*
Grass coverage	13.7 *ab*	19.8 *a*	5.9 *a*	12.9 *ab*	14.2 *a*
Broadleaf coverage	2.4 *a*	3.8 *a*	1.3 *a*	0.2 *a*	0.1 *a*
Horseweed coverage	0.3 *a*	0.0 *a*	0.1 *a*	0.1 *a*	0.0 *a*
Tree condition score	2.9 *d*	3.3 *cd*	4.7 *ab*	3.9 *bc*	5.0 *a*
Leadville field					
Total ground coverage	24.0 *a*	22.2 *a*	2.2 *b*	3.0 *b*	2.0 *b*
Grass coverage	22.8 *a*	22.2 *a*	1.8 *b*	0.5 *b*	1.4 *b*
Broadleaf coverage	7.7 *a*	3.1 *a*	0.4 *a*	2.4 *a*	0.6 *a*
Horseweed coverage	1.3 *ab*	0.2 *b*	0.1 *b*	1.6 *a*	0.2 *b*
Tree condition score	1.9 *b*	2.1 *b*	2.4 *b*	2.6 *b*	4.5 *a*

For each row, numbers followed by a different letter are significantly different at $p < 0.05$.

Total ground coverage was generally lower with the addition of sulfometuron in the horseweed study (table 3). In the Leadville field, all treatments that included sulfometuron had lower ground coverage than the control and TRAN treatments. In the Sallisaw field, the OUST and OUSTOUT treatments had lower total coverage than the TRAN treatment. The higher total coverage of the TRAN treatment than that of the treatments that included sulfometuron is likely due to lower array of species suppressed by clopyralid relative to sulfometuron. Clopyralid was included in this trial because it is labeled to control horseweed, but clopyralid only suppresses broadleaf and woody brush species whereas sulfometuron can control broadleaf and grass species (Dow AgroSciences 2016, DuPont 2002). This tendency of the TRAN treatment to control only broadleaf vegetation was seen in the grass coverage results (table 3). The TRAN treatment had greater grass coverage than all treatments except the control in the Leadville field and greater grass coverage than the OUST treatment in the Sallisaw field. Clopyralid was not more effective than sulfometuron-containing herbicides at controlling broadleaf vegetation; all treatments had similar broadleaf vegetation.

There were no differences in horseweed coverage among treatments in the Sallisaw field (table 3). In the Leadville field, the OUSTOUT treatment had greater horseweed coverage than the OUSTX, TRAN, and OUST treatments (table 3). These horseweed coverage results are counter-intuitive because the sulfosulfuron component of the OUSTOUT treatment is labeled for horseweed suppression (Monsanto 2006) and horseweed was observed in relative abundance in the primary study that inspired the horseweed trial.

Horseweed coverage was generally low in all treatments, ranging from 0.11 to 1.6 percent. The short time between the heavy rainfall of May 2015 and the July 2015 coverage assessment and the small plot size of the horseweed trial were likely contributors to these results. Horseweed did not establish abundantly in any plots by the time of the coverage assessment. In the horseweed count assessment that was conducted in July and September 2015, there was a significant treatment effect (fig. 4). Across both fields and observation periods, the TRAN and OUSTX treatments had lower horseweed plants m^{-2} than the control treatment. These results suggest that clopyralid and a mixture of sulfometuron and metsulfuron methyl worked best at controlling horseweed at this site.

Despite its efficacy at suppressing horseweed, the OUSTX treatment was most damaging to the tree species tested (table 3). There was a significant date × treatment × field effect in the analysis of tree condition scores, with significant treatment × field effects observed in the June 2015 assessment. In the Leadville field, the OUSTX treatment had higher tree condition scores (higher scores indicate greater damage) than all other treatments. In the Sallisaw field, the OUSTX treatment had higher condition scores than all treatments except the OUST treatment. OustExtra® is not labeled for site preparation applications of water oak and cherrybark oak; its inclusion in this trial was to determine whether it could be used to suppress horseweed without damaging these species. The tree damage and horseweed plants m^{-2} results of this study suggest that clopyralid is a better herbicide for suppressing horseweed than OustExtra®. However, the inability of clopyralid to control grasses makes it less effective as a site preparation

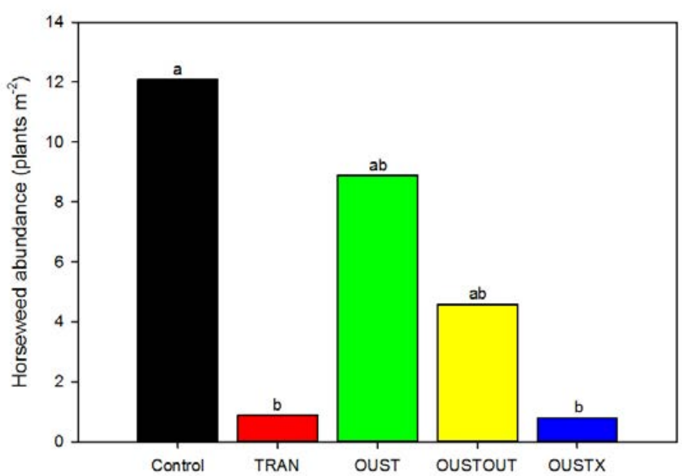

Figure 4—Horseweed abundance in response to vegetation control treatments in response to herbicide treatments applied prior to planting of cherrybark oak and water oak at a retired zoysiagrass sod farm in central Arkansas. Columns headed by a different letter are significantly different at $p < 0.05$.

herbicide. A future study should be devoted to tank mixtures of clopyralid with sulfometuron on cherrybark oak and water oak to determine whether such mixtures will best control an array of vegetation, including horseweed, without damaging these species. Current labeling for Transline® mentions Oust® as a compatible tank mixture, but water oak is not identified as tolerant tree species (Dow AgroSciences 2016).

CONCLUSIONS

Inclusion of sulfometuron in a fall glyphosate application prior to planting had the greatest and longest-lasting vegetation control in the first year after planting the hardwood species at this sod farm. The ryegrass cover crop was a viable option for maintaining organic matter on the soil surface while providing suppression of broadleaf and grass vegetation, although its efficacy for control of both vegetation types was lower than the fall application of sulfometuron. Management decisions between these options would be driven by compromises between competition control efficacy and continual maintenance of organic matter for water quality purposes. Both competition control options had at least 94 percent of the surface covered in living vegetation by May of the first growing season after planting. If relying solely on glyphosate for competition control with these site conditions, a single application in the spring prior to planting was as effective as applying glyphosate in the spring and fall prior to planting. Horseweed was resistant to sulfometuron, but clopyralid appeared effective as controlling horseweed without significantly damaging water oak and cherrybark oak planted at this site. Clopyralid tank mixed with sulfometuron might be an option for controlling horseweed in addition to the species suppressed by sulfometuron, but further testing is necessary to determine effects of this mixture on water oak and cherrybark oak.

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LITERATURE CITED

Dow AgroSciences. 2016. Transline® specimen label. Dow AgroSciences, LLC, Indianapolis, IN. 7 p.

DuPont. 2002. Oust XP® herbicide. Specimen Label H-64342. E.I. DuPont de Nemours and Company, Wilmington, DE. 11p.

Ezell, A. 2002. Addition of sulfometuron methyl to fall site preparation tank mixes improves herbaceous weed control. In: Outkalt, K.W., ed. Proceedings of the eleventh biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-48. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 251–253.

Malik, R.K.; Green, T.H.; Brown, G.F.; Mays, D. 2000. Use of cover crops in short rotation hardwood plantations to control erosion. Biomass and Bioenergy. 18(6): 479–487.

Monsanto. 2006. Outrider® herbicide. Specimen Label 71014E3-14. Monsanto Technology LLC. 5p.

National Centers for Environmental Information [NOAA]. 2015. Daily station summary, Perryville 2.3 SSW, AR, US. Daily Station Summaries. https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:US1ARPY0004/detail. [Date accessed: May 29, 2017].

Rentz, R. 2005. Use of cover crops in hardwood production. In: Dumroese, R.K.; Riley, L.E.; Landis, T.D., eds. National proceedings: Forest and Conservation Nursery Associations—2004. RMRS-P-35. Fort Collins, CO: U.S. Department of Agriculture Forest Service, Rocky Mountain Research Station: 28.

Self, A.B.; Ezell, A.W. 2015. Herbicide options for hardwood management. Extension Publication POD-01-015. Starkville, MS: Mississippi State University Extension Service. 7 p.

Southern Climate Impacts Planning Program [SCIPP]. 2017. Climate trends, Arkansas, Climate Division 5, Annual. http://charts.srcc.lsu.edu/trends/. [Date accessed: May 17, 2017].

Stringer, J.W.; Clatterbuck, W.; Seifert, J. 2009. Site preparation and competition control guiedlines for hardwood tree plantings. Extension Publication SREF-FM-014, PB1783, FOR-107. Knoxville, TN: University of Tennessee, Institute of Agriculture. 35 p.

U.S. Department of Agriculture Soil Conservation Service [USDA SCS]. 1982. Soil survey of Perry County Arkansas. Washington, DC: U.S. Government Printing Office. 114 p.

Von Althen, F.W. 1991. Afforestation of former farmland with high-value hardwoods. The Forestry Chronicle. 67(3): 209–212.