PRELIMINARY COMPARISONS OF HERBICIDES AND APPLICATION PROCEDURES TO PROMOTE SIZE OF ADVANCED OAK AND YELLOW-POPLAR REPRODUCTION AFTER HARVEST

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Abstract—The repetitious use of diameter-limit harvesting in upland hardwoods has led to low-valued stands with heavy midstory and understory canopy layers containing mostly shade-tolerant species. Limited documentation is available on the means to successfully regenerate these impoverished areas into stands of more desirable, shade-intolerant species. The objective of this study is to evaluate the effectiveness of various herbicides and application methods to accelerate the growth (size) of small natural oak (*Quercus* spp.) and yellow-poplar (*Liriodendron tulipifera*) reproduction after harvest that otherwise would probably be outgrown by other undesirable species. The study area is in west-central Tennessee on the Western Highland Rim on nonindustrial forest land that has been cutover several times. Site index is 70 to 75 feet for upland oaks at 50 years, typical of many upland hardwood sites. Three 10-acre harvest blocks, each containing the following six treatments were established: banded foliar spray, banded foliar spray plus pre-emergent broadcast spray, radial release spray, radial release plus pre-emergent broadcast spray, pre-emergent broadcast spray only, and untreated control. Individual oak and poplar seedlings were measured after treatment applications in the fall of 2014 and again in January/February of 2017. Initial findings after two complete growing seasons indicate there was no difference in the natural reproduction growth response between treatments.

INTRODUCTION

Sustainable forestry requires that desirable timber species, typically shade-intolerant species, are successfully regenerated to form future stands. Mismanagement of forest land thru diameter-limit harvesting or high-grading leads to stand impoverishment when repetitiously implemented. Noss and others (1995) proposed that high-quality oak/hickory forests are on the decline in areas across the Central and Southern Appalachians. This degrade in quality is primarily attributed to species composition shifts resulting from diameter-limit harvesting. Trimble (1973) found that repeated single-tree selection and diameter-limit harvesting lead to a higher proportion of shade-tolerant species in the overall stand species composition along with a general reduction in species diversity. In such stands, foresters must take appropriate management actions to ensure the future stand will consist of higher proportions of shade-intolerant timber species. Establishment of adequate oak regeneration is also problematic in undisturbed and properly managed hardwood stands. Oaks (*Quercus* spp.) are some of the most difficult tree species to regenerate using common silvicultural practices and natural seed stock (Hannah 1987), even in favorably stocked stands. Oaks are a highly preferred species but have proven difficult to successfully establish in future stands after a disturbance. The primary reason that oak regeneration fails to form dominance in the future stand is usually attributed to a lack of adequate advanced regeneration or the slow growth yielding oak less competitive compared to other plants to capture available growing space. Various silvicultural practices are typically required to enable oak to develop into competitive size classes. Silvicultural regeneration practices have been scientifically studied in order to formulate methodology to routinely establish competitive oak reproduction. Loftis (1990) advocates the removal of subcanopy basal area by the shelterwood method or herbicide application to enable a greater establishment of oak in the understory. In ideal instances, advance oak regeneration would be established in oak-dominated stands prior to overstory removal in such fashion. The advance regeneration should be of adequate size as suggested by Sander (1971) whom advised that advance reproduction is an imperative for new oak sprout growth following clearcutting. His study shows that oak sprout growth was related to ground line diameter of the old stem in that larger stems resprouted and grew at faster rates. The most optimal size were stems between 0.5

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to 1 inch in diameter as these stems were able to attain a position in the dominant canopy and produced fewer sprouts per stem compared to regeneration >1 inch. For mismanaged stands that lack adequate parent oak stems to supply reproduction, managers must seek other options to successfully establish oak regeneration.

Early chemical release treatments have shown some potential to assist in improving oak regeneration success. A study by Thompson and Nix (1992) found that early crop tree release within a four year old clearcut using various herbicides significantly decreased herbaceous and woody plant competition. This reduction in competition resulted in increased seedling ground line diameters but did not improve height growth compared to control treatments. Nix (2004) remeasured the released natural oak in the clearcut ten years after the initial chemical release treatment. The follow up study found that four herbicide treatments significantly increased diameter growth of released oak seedlings. The researcher suggests that applying herbicide release treatments assists in enabling desirable oak to form dominance in the overstory canopy. This study investigates if herbicide applications applied during the initial growing season after a silvicultural clearcut applied to an impoverished stand can be implemented to enhance natural regeneration.

METHODS

Study site

The study site is located on former Mead-Westvaco land situated along the Humphreys and Houston County boundary line in west central Tennessee. One of the replicated blocks is located in Humphreys County, and the other two are in Houston County. All blocks are positioned on north and northeast facing aspects beginning near the top of the ridge and extended down to the midslope position. Soil types present in each block are Bodine cherty silt loams with estimated site index values of 70–75, base age 50 for upland oak species. The stand prior to the harvesting disturbance was considered as degraded due to multiple diameter-limit harvesting entries. Species composition primarily included white oak (*Q. alba*), hickory (*Carya* spp.), red oak (Q. rubra), blackgum (*Nyssa sylvatica*), yellow-poplar (Liriodendron tulipifera), chestnut oak (*Q. montana*), ash (*Fraxinus* spp.), sugar maple (*Acer saccharum*), and black cherry (*Prunus serotina*). A well-established understory and midstory of moderate to large saplings were present. Common species recorded during pre-harvest inventory in the larger size reproduction classes included eastern hophornbeam (*Ostrya virginiana*), yellow-poplar, blackgum, ash, hickory, American beech (*Fagus grandifolia*), and flowering dogwood (*Cornus florida*).

Study design

The study incorporates a randomized complete block sampling design. Three individual blocks were replicated on sites with uniform site productivity. These blocks received silvicultural clearcuts in early spring of 2014. Six individual treatment units approximately ¾-acre in size were implemented within each block:

1. Chemical seedling release treatments utilizing sulfometuron methyl (SFM 75® by Alligare LLC) only
2. Alternating banded strip treatment utilizing foliar sprays of glyphosate
3. Radial spray release utilizing foliar sprays of glyphosate
4. Alternating banded strips plus release using sulfometuron methyl
5. Radial sprays plus release using sulfometuron methyl
6. Untreated control

The three units that received sulfometuron methyl treatments were applied in May–June of 2014. Glyphosate applications were conducted between July–August of 2014. Banded sprays were approximately 4 feet in width and alternated treated (foliar sprayed) strips and untreated strips across the unit. Radial foliar sprays were implemented around individual oak and yellow-poplar seedlings using glyphosate only. Radial sprays treated vegetation in the surrounding area of approximately a 5-foot radius from the sample seedling. A stove pipe apparatus covered the seedling being released to protect foliage from incidental contract with herbicide solution. The banded and radial spray methods were also applied to two of the blocks that were previously sprayed with sulfometuron methyl. The final treatment unit did not receive any herbicide applications. These treatment units are labeled as SFM 75 only, radial, banded, radial plus SFM 75, banded plus SFM 75, and untreated control.

Approximately 150 naturally regenerated seedlings (approximately half of the population were oak species and half were yellow-poplar) for all treatment units over the three replicated blocks were measured in the fall of 2014 for ground line diameter and overall height. Ground line diameter was measured with digital calipers with accuracy to one-hundredth of an inch. Height measurements were taken with a standard retractable ruler to the nearest half an inch. All measurements were taken after completion of treatment applications during the dormant season. A total of 2,653 seedlings were measured on the site. Seedlings were measured again after two full growing seasons had elapsed in January/February of 2017. Only 1,563 seedlings were able to be relocated for measurement due to the robust response of warm-season grass vegetation. Measurement procedures were repeated in similar fashion as were performed during the initial measurements. The difference from the 2017 measurements minus the 2014 measurements was statistically analyzed for both diameter and height growth.

Statistical Analyses

Statistical analyses were performed for analysis of variance (ANOVA) using mixed models (SAS Institute Inc., Cary, NC version 9.4). Data tests indicated satisfactory normality and equal variances. No transformations were utilized in the analyses. Tukey's significant difference test was incorporated to separate the least squares means. The significance level was set at $\alpha = 0.05$. All sampled seedlings, regardless of species, were combined by treatment for analysis to compare treatment means.

RESULTS

Ground line diameter growth means (combined oak and yellow-poplar seedlings) following two growing seasons for individual herbicide treatments were as follows: 0.360 inches for banded, 0.318 inches for banded plus sulfometuron methyl, 0.310 inches for control, 0.355 inches for sulfometuron methyl only, 0.303 inches for radial release, and 0.339 inches for radial plus sulfometuron methyl. No significance difference was revealed for change in diameter growth between treatments ($p = 0.74$) (table 1).

Height growth means for the banded, banded plus sulfometuron methyl, untreated control, sulfometuron methyl only, radial release, and radial plus sulfometuron methyl were 24.4, 21.5, 23.5, 27.1, 17.2, and 21.7 inches, respectively. Findings show a non-significant difference between treatments ($p = 0.058$) (table 2).

Competing plant competition was substantial after two complete growing seasons (table 3). Ocular estimations revealed that all but three out of eighteen treatment units had 50 percent or greater coverage by broomsedge bluestem (*Andropogon virginicus*) and Nepalese browntop (*Microstegium vimineum*). All treatments displayed high levels of grass establishment on at least one of the three replications. Banded glyphosate with sulfometuron methyl applications received the greatest amount of herbicide active ingredient but had the highest rates of grass coverage.

DISCUSSION

Results indicate that initially there was no apparent response between herbicide treatments and the untreated control after two growing seasons. The lack of response may be attributed to below average precipitation over the course of active plant growth since herbicide applications were completed. Seven of the 12 months (April–September) showed below average rainfall for the 2015 and 2016 growing seasons according to National Oceanic and Atmospheric Administration (NOAA) data. Of particular interest is the period during April and May of the 2016 growing season. Monthly rainfall for these months was 4.05 inches and 3.16 inches below the average (dating back to the year 2000). This season of the year is when tree diameter growth or the early wood should be growing at optimal levels. The reduction in moisture available for uptake by trees probably affected plant growth. If these spring months had a normal or above average rainfall, seedling growth response may likely have been different amongst treatments.

Another plausible explanation may be increased competition from grasses following the harvest disturbance. The high establishment rate of grasses suggests that the reduction of forbs through herbicide applications essentially released grasses from suppression. The tremendous emergence of warm season grasses, primarily broomsedge and Nepalese browntop likely hindered tree seedling development. Grasses have dense, fibrous root systems which compete for space in the same soil horizon as new tree seedlings. Available soil moisture is likely intercepted by the fibrous grass roots limiting growth potential for tree seedlings. The ability for a given tree to expand its root system is also impacted by the abundance of grass roots. The result of this competition by grass is a reduction in above ground height growth with growth instead allocated more towards root biomass (Collet and others 2006, Harmer and Robertson 2003). The study also suggests that total root length and the number of root tips decrease with increasing competition. High-density assemblages of grass root contributed to nutrient and water depletion. The diminution of resources directly leads to condensed seedling root growth (Collet and others 2006). Thus, seedling growth may have been directly influenced by the dense establishment of grasses on the study site. Treatments that received higher intensity herbicide applications using both sulfometuron methyl and glyphosate had a higher percentage of coverage by grasses based on ocular estimations. A secondary treatment during the growing season of 2015 to control the emerging grass may be beneficial to enhance seedling growth. Additional treatments however may prove unfavorable economically to private landowners although sufficient control of broomsedge can be achieved by applying bromacil, diuron, tebuthuron, buthidazole (Griffin and others 1988), and glyphosate (Butler and others 2002). Perhaps delaying applications until after a full growing season may yield a contradictory outcome as revealed by this study. The probability is high however that grass would re-emerge from seed stock even with a change

Table 1—Tukey mean separation results amongst combined treatments for seedling ground line diameter growth

Treatment	Observations	Mean diameter (inches)	Standard error	Letter group
Banded	265	0.360	0.015	A
Banded + SFM 75	263	0.318	0.015	A
Control	294	0.310	0.014	A
SFM 75 only	271	0.355	0.014	A
Radial	248	0.303	0.015	A
Radial + SFM 75	222	0.339	0.015	A

Table 2—Tukey mean separation results amongst combined treatments for seedling height growth

Treatment	Observations	Mean height (inches)	Standard error	Letter group
Banded	265	24.4	1.042	A
Banded + SFM 75	263	21.5	1.048	AB
Control	294	23.5	0.996	A
SFM 75 only	271	27.1	1.073	A
Radial	248	17.2	0.889	B
Radial + SFM 75	222	21.7	0.936	AB

in application timing. Given this conclusion, it may be best to accept the coexistence of both vegetation types. Eventually, the released oak and yellow-poplar will develop and create shaded environments that diminish the presence of the grasses. The projected enhanced rate of growth after two growing seasons did not occur based on current findings.

CONCLUSION

This study initially suggests that an early precommercial thinning to newly established reproduction after two growing seasons may be unnecessary to ensure successful establishment of desirable oak and yellow-poplar seedlings in the future overstory. The initial herbicide treatments did assist in controlling the establishment of shade-tolerant species regeneration, but the consequence was promotion of thick grasses rather than increased growth of oak and yellow-poplar seedlings. However, in subsequent years, we hypothesize that these early silvicultural release treatments to promote oak and yellow-poplar through the use of herbicides may create a greater abundance of these species in the overstory at crown closure. The abundant shade-tolerant species with the potential to become part of the overstory or influence the development of more desirable, shade-intolerant species were controlled by these herbicide treatments, even though these treatments did promote the proliferation of grasses. This result will be attributed to the increased amount of growing space available for crown development created from the early thinning. In addition, should adequate or surplus rainfall occur over the next couple of growing seasons, a difference may be noticeable between the treatments. Future data to support or renounce these theories will be acquired in upcoming years.

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Table 3—Ocular estimates of vegetative ground cover percentages by individual treatment units

		Vegetative cover type				
Block	Treatment	Broomsedge	Microstegium	*Rubus* sp.	Leaf litter/ saplings	Herbaceous/ sparse grass
A	Control	***	40%	60%	***	***
B	Control	95%	***	5%	***	***
C	Control	80%	***	5%	***	15%
A	Control + SFM 75	40%	10%	50%	***	***
B	Control + SFM 75	60%	***	25%	***	15%
C	Control + SFM 75	95%	***	***	***	5%
A	Radial	10%	40%	30%	20%	***
B	Radial	15%	***	85%	***	***
C	Radial	90%	***	10%	***	***
A	Radial + SFM 75	60%	***	***	20%	20%
B	Radial + SFM 75	50%	***	5%	45%	***
C	Radial + SFM 75	85%	***	15%	***	***
A	Banded	10%	75%	15%	***	***
B	Banded	15%	***	70%	15%	***
C	Banded	85%	***	15%	***	***
A	Banded + SFM 75	95%	***	5%	***	***
B	Banded + SFM 75	95%	***	5%	***	***
C	Banded + SFM 75	70%	***	***	***	30%

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ERRATA

The author found a significant difference among treatments after submission of this article. These findings will be made known to the scientific community at a later date.