# EFFECT OF DIRECTED-SPRAY GLYPHOSATE APPLICATIONS ON SURVIVAL AND GROWTH OF PLANTED OAKS AFTER THREE GROWING SEASONS

**Andrew B. Self, Andrew W. Ezell, Josh L. Moree, and Rory O. Thornton[1]**

**Abstract**—Thousands of acres of oak (*Quercus* spp.) plantations are established across the South annually. Survival and growth of these plantings have been less than desirable. Several techniques have been utilized in attempts to achieve improved success in these areas. One such technique that has been recommended is the application of directed-spray herbicide treatments. In this study, 3,240 bare-root Nuttall oak (*Q. nuttallii* Palmer) and white oak (*Q. alba* L.) seedlings were planted in February 2005 on Malmaison Wildlife Management Area near Carrollton, MS. One-third of the seedlings were subjected to a pre-emergent Oust® XP application in March 2005. One-third of the seedlings were treated with a pre-emergent Oust® XP application in March 2005 and directed-spray glyphosate applications throughout the 2005 growing season. One-third of the seedlings were subjected to pre-emergent Oust® XP applications in March of 2005, 2006, and 2007, and received directed-spray glyphosate applications once a month during the growing season each year. The effect of repeated directed-spray applications was evaluated, and significant differences were noted. Multiple examples of adverse seedling conditions were observed in the 3-year directed-spray plots. Seedling survival and total height were appreciably lower in 3-year directed-spray areas compared to nondirected-spray or 1-year directed-spray areas.

## INTRODUCTION

Thousands of acres are being converted to oak (*Quercus* spp.) plantations across the South annually. The performance of these plantings has been less than desirable in many attempts. Several factors are paramount in achieving the establishment of successful plantations in these areas. These factors include matching species to the site, proper handling of seedlings both on and off site prior to planting, and using proper planting techniques. Even when proper site-species relationships have been considered and seedlings of the proper species have been planted, vegetative competition is still a concern. Much of the acreage on which new hardwood plantations are being established is in the form of retired agricultural fields (Stanturf and others 2004). In these settings, herbaceous competition will often be intense, and the possibility of exotic or aggressive weed species is of serious concern. If these problematic species are present and not eliminated before planting, some form of postplant competition control may be necessary to establish satisfactory hardwood plantations. One such form is the application of directed-spray herbicide treatments.

If competing vegetation is not controlled with site preparation efforts, and aggressive weed species resistant to broad spectrum herbaceous chemical control are present, directed-spray herbicide applications are often prescribed. Typically, an application of a foliar active herbicide is applied to competing vegetation around the seedling. The seedling is either shielded, or herbicide is carefully applied immediately adjacent to the seedling without the use of shielding. In both cases, extreme caution is taken to avoid wind drift or vegetative drip of the herbicide onto the seedling. Most research involving the use of directed-spray herbicide applications has been at an experimental level with special precautions being given to precise application of herbicides. Under these settings, an extreme amount of time and effort is spent in an attempt to keep herbicide off of planted seedlings. If weather conditions are not optimal for application, the researcher may be able to delay spraying until more favorable conditions exist. This level of discretion and caution may not be possible in operational settings using migrant workers, contractors, or field personnel. Directed spraying in operational settings often takes place on a much more massive scale than most research efforts. Also, contractors performing operational directed-spray applications work under various time and expense constraints that the scientist does not have to consider.

Observing 25 seedlings each of green ash (*Fraxinus pennsylvanica* Marsh.) and sweetgum (*Liquidambar styraciflua* L.), Hopper and others (1992) found significantly greater 4-year survival in plots undergoing a directed application of Roundup® than in control plots (77 and 61 percent, respectively). Seedling growth was not affected by herbicide treatment. Moree and others (2010) indicated that white oak (*Q. alba* L.) survival was negatively impacted on a Delta site in Mississippi when repeated directed glyphosate applications came into contact with seedlings. This comparison was made while observing 1,080 seedlings in two different directed-spray regimes and 540 seedlings in control areas. Initial vegetation was high and some seedlings were affected by herbicidal drift and/or dripping from overhanging vegetation.

Ware and Gardiner (2004) observed that 600 3-year-old Nuttall oak (*Q. nuttallii* Palmer) seedlings planted in a cutover were 44 percent more likely to be in a free-to-grow crown position when treated with directed-spray applications of Roundup® Ultra. While this treatment did not statistically impact survival or growth, the increase in free-to-grow

[1] Graduate Student, Professor, and Graduate Student, Mississippi State University, Department of Forestry, School of Forest Resources, Mississippi State, MS; and Wildlife Biologist, Mississippi Department of Wildlife, Fisheries, and Parks, Columbia, MS, respectively.

position could have significant impacts in later measurements. Zutter and others (1987) performed two studies in South Carolina which indicated that sweetgum seedlings undergoing a directed glyphosate application exhibited significantly greater 5-year height than seedlings in untreated control plots (12.0 and 7.9 feet, respectively). Diameter growth followed a similar pattern with directed-spray treated seedlings exhibiting 0.43 inches more growth compared to untreated seedlings, and seedlings in disked plots were significantly smaller than seedlings in directed-spray plots. There were no observed survival differences between disking, directed-spray application, and a combination of both. Directed-spray herbicide application appeared to increase seedling growth through competition reduction. Disking did not appear to be as beneficial since weed roots were not killed, resulting in continued competition with seedlings. Both studies utilized 40 trees or less per treatment.

Postplanting control of woody species in hardwood plantations is typically performed using directed-spray applications of glyphosate or triclopyr (Stanturf and others 2004). Use of these potentially damaging materials is dictated by the tolerance of woody species to chemical compounds typically used in herbaceous vegetation control. When using directed-spray application of herbicides the compound sprayed must not be soil active, thus foliar active products containing triclopyr, glyphosate, or 2, 4-DP have been recommended (Miller 1987).

## OBJECTIVES

The objectives of the study were:

1. To evaluate effects of directed-spray glyphosate applications on 3-year survival of oaks
2. To evaluate effects of directed-spray glyphosate applications on 3-year height growth of oaks

## MATERIALS AND METHODS

### Site Description

The tract selected for this study was formerly in row crop production and is located approximately 14 miles north of Greenwood, MS (90.0531° W, 33.6876° N) in Grenada County. The site was retired from row crop production sometime in the late 1990s. It has been maintained as an opening for wildlife through mowing and disking from agricultural retirement until the present. The study area encompasses approximately 7 1/2 acres on Waverly silt loam (coarse-silty, mixed, acid, thermic Cumulic Normaquept) and Falaya silt loam (coarse-silty, mixed, acid, thermic Aeric Cumulic Normaquept) soil series with slopes between zero and 2 percent. These soils are poorly drained and somewhat poorly drained, respectively. Average yearly temperature is 63.9 °F, and average yearly precipitation is 52.30 inches (Soil Conservation Service 1967). Soil tests indicate that the site has silt loam texture with pH ranging from 6.3 to 7.0.

There was a well-established herbaceous ground cover with a scattered woody component at the time of site selection. The dominant herbaceous species onsite included: Johnsongrass [*Sorghum halepense* (L.) Pers.], Bermudagrass [*Cynodon dactylon* (L.) Pers.], broomsedge bluestem (*Andropogon virginicus* L.), yellow nutsedge (*Cyperus esculentus* L.), blackberry (*Rubus argutus* Link), poison ivy [*Toxicodendron radicans* (L.) Kuntze], Brazilian vervain (*Verbena brasiliensis* Vell.), and Carolina horsenettle (*Solanum carolinense* L.). There were small scattered components of American sycamore (*Platanus occidentalis* L.), black willow (*Salix nigra* Marsh.), and boxelder (*Acer negundo* L.) across the entire site.

### Study Design and Plot Establishment

A three-split strip-plot in a randomized complete block design with subsampling was used in this experiment. Three replications consisting of one of each possible treatment combination were established. Several of these combinations were created for the study of factors not reported in this paper. Each replication consisted of 72 plots approximately 150 feet by 10 feet and contained 15 seedlings. A total of 216 treatment plots were established. Plots were marked at each end with 4-foot sections of 3/4-inch polyvinyl chloride (PVC) pipe. Individual seedling locations were determined and marked with 36-inch pin flags color specific to species. All boundary lines were delineated using a compass and a 100-foot surveyor's tape.

### Seedling Establishment

Nuttall oak and white oak seedlings were chosen for this study because they are two of the most commonly planted species in the South. Seedlings were purchased from Molpus Timberlands Nursery near Elberta, AL. On February 19, 2005, Mississippi State University personnel planted 1,620 1-0 bare-root seedlings of each species using a 10-feet by 10-feet spacing. Seedlings were transported to and stored onsite in a walk-in cooler until the time of planting.

### Treatments

Three competition control treatments were used in this study. These treatments included a pre-emergent application only, a control for one full growing season, and a total competition control treatment. The pre-emergent application only treatment consisted of one application of Oust® XP applied over the top of seedlings at a rate of 2 ounces per acre in March 2005. The one growing season and total herbicide control treatments were the same for the first growing season. These treatments also included a pre-emergent application of Oust® XP in March 2005. Additionally, the one growing season and total herbicide control treatments also consisted of directed-spray applications of glyphosate (1.5 percent v/v) once a month from June to October 2005 for control of forbs and other plants not controlled by the earlier applications. An herbicide regime identical to that used in year 1 in the one growing season and total herbicide control treatment areas was utilized in years 2 and 3 on plots in total herbicide control treatment areas.

### Field Data Collection

Initial seedling height measurements were taken April 15 to 25, 2005. Height was measured to the nearest tenth of a centimeter using a height stick. Seedling survival was based on ocular evaluation and was recorded at the end of the growing season in 2005, 2006, and 2007. All missing seedlings were considered dead. If a seedling was observed as a resprout in later observations, it was reinstated into earlier survival estimations. The cambium was checked on seedlings which appeared dead to ensure survival status.

### Statistical Analysis

Statistical analyses were performed using a mixed procedure in Statistical Analysis System (SAS) software version 9.1 and 9.1.3. Analyses were separated by species. A mixed model analyses of variance (ANOVA) was used to test for effects and interactions. Data were analyzed using least square means (LSMEANS). Survival percentages were arcsine square root transformed to normalize the data. However, actual means are presented for ease of data interpretation. Means were considered significant if $P < 0.05$.

## RESULTS

### Survival

Overall, survival was 78.1 percent for Nuttall oak and 57.8 percent for white oak. The 20.3 percent difference in overall survival was thought to result from the wet site conditions prevalent on this tract. The site was saturated for much of the winter and early growing season for all 3 years of the study. Inundation and/or soil saturation could have had negative impacts on white oak survival and growth. Survival of Nuttall oak was appreciably greater than survival observed in comparably treated white oak (table 1). These survival differences ranged between 5.8 and 30.6 percent among identical herbicide regimes.

The lowest seedling survival was observed in total herbicide control areas (table 1). Nuttall oak survival in this treatment (61.7 percent) was significantly lower compared to survival in the one growing season and pre-emergent only treatments (87.6 and 83.1 percent, respectively). White oak survival did not differ significantly among any of the three treatments. Treatment effects could have been masked due to much lower overall survival exhibited by white oak as a result of detrimental site conditions.

### Total Height

Average total height was 5.71 feet for Nuttall oak and 4.09 feet for white oak. Substantially greater total height was observed in Nuttall oak than in white oak treated comparably (table 2). Significantly lower total height was observed for both species in total herbicide control and one growing season treatment areas compared to pre-emergent only areas. Average tree heights of both species in the total herbicide control and one growing season treatment areas were not statistically different.

## SUMMARY AND DISCUSSION

Nuttall oak exhibited greater survival and height compared to white oak in each herbicide regime. Nuttall oak survival was significantly greater for seedlings in the one growing season and pre-emergent only treatments compared to seedlings in the total herbicide control treatment. No notable difference between treatments was observed for white oak. While white oak can survive as well as Nuttall oak under more suitable site conditions, lack of statistical difference between treatments was probably the result of the low overall survival of white oak due to wet site conditions. The significantly lower survival in total herbicide control areas indicates a negative effect of repeated glyphosate applications.

Total height was significantly greater for both species in the pre-emergent only areas compared to the other two treatments. Multiple examples of adverse treatment effects on seedlings were observed in the total herbicide control and one growing season plots. Repeated herbicidal contact of the seedlings resulted in lower overall height growth of trees in these areas. There were also some discrepancies between calculated height averages and realistic evaluations of overall treatment effect due to “end tree” influence. “End trees” were located at plot ends and often included the first and sometimes the second tree from either plot end. “End trees” occurred in more intensive treatments and were created through individual trees receiving comparatively little glyphosate contact with respect to other trees in the plot. These trees had substantial influence on height averages and statistical comparisons, effectively serving as outliers pulling height averages upwards.

**Table 1—Survival by herbicide regime combination**

| Herbicide regime | White oak | Nuttall oak |
|---|---|---|
| | -------------- *percent* -------------- | |
| Pre-emergent only | 61.5 a | 83.1 a |
| One growing season | 57.0 a | 87.6 a |
| Total herbicide control | 55.9 a | 61.7 b |

Values within a column followed by different letters are significantly different at $\alpha = 0.05$ according to Duncan’s Multiple Range Test.

**Table 2—Total height by herbicide regime combination**

| Herbicide regime | White oak | Nuttall oak |
|---|---|---|
| | -------------- *feet* -------------- | |
| Pre-emergent only | 4.60 a | 6.20 a |
| One growing season | 3.99 a | 5.55 a |
| Total herbicide control | 3.85 a | 5.53 b |

Values within a column followed by different letters are significantly different at $\alpha = 0.05$ according to Duncan’s Multiple Range Test.

## CONCLUSIONS

Overall, best survival and growth results were observed in areas not undergoing or undergoing less directed-spray applications. Precautions were taken to ensure that seedlings were not accidentally contacted through either wind drift or vegetative drip. However, when performing 5 to 6 applications per year (15 to 18 applications over 3 years) contact inevitably occurs. While herbicidal contact might have only a slight effect if contact occurs once or twice, repeated monthly contact over several years has a substantial cumulative impact. This is of paramount concern when using migrant workers, contractors, or field personnel to perform directed spraying. Nonresearch oriented personnel may or may not have the expertise and/or knowledge to perform this technique satisfactorily. Directed spraying on an operational scale usually occurs on considerably more area at once than most research efforts. Contractors performing directed spraying under various time and expense constraints may not be able to postpone applications until ideal field conditions are present before spraying.

While plausible in research settings, directed spray applications may not be biologically or economically feasible for large-scale operations on retired agricultural areas across the South. Studies testing seedling survival and growth in areas treated with pre-emergent applications of broad spectrum herbicides before the first growing season have shown excellent results (Ezell 1999, Ezell and Catchot 1997, Ezell and Hodges 2002, Ezell and others 2007, Russell and others 1997). The costs of each treatment used in this study are as follows: pre-emergent only = $33.80 per acre, one growing season = $267.55 per acre, and total herbicide control = $802.65 per acre (at year 3). Economically, directed glyphosate applications are very cost prohibitive compared to a pre-emergent application of a broad spectrum herbicide, and their usage at this regime's intensity would not be possible for most landowners.

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