# EFFICACY AND NONTARGET IMPACT OF MIDSTORY INJECTION IN BOTTOMLAND HARDWOODS

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**ABSTRACT.—**Despite the well-documented need for midstory control in bottomland hardwood regeneration, little research has documented the efficacy of such efforts, or the potential negative effects on nontarget stems. More than 72,000 midstory stems located on 90 acres of northern Mississippi bottomland hardwood forest were injected with an imazapyr solution during August 2009. Crown reduction in injected stems was 96.8 percent at 1 year after treatment, with a range of 91.8 to 100 percent by species. Nontarget impact attributed to improper injection technique was observed in one location, but the minor foliar symptoms are not expected to result in long-term damage. No nontarget impacts were observed in other trees on the study site. Residual crop trees did not exhibit negative symptoms from the injection. Injection is effective for controlling midstory stems found in bottomland hardwoods and has a negligible effect on nontarget stems. Midstory injection is often a crucial component of regeneration in bottomland hardwoods and should continue to be used by land managers.

## INTRODUCTION

Bottomland hardwood sites are known to have some of the most productive forest soils, and species richness consequently tends to be higher on these sites than on more upland sites (Hodges and Switzer 1979). The high species richness and associated stand stratification often make competition control an essential part of bottomland hardwood regeneration efforts. Midstory injection has long been recognized as a viable and cost-effective method of controlling undesirable stems (Williston et al. 1976). Peairs et al. (2004) reported that midstory/understory control treatment generally increased desirable hardwood regeneration such as oaks (*Quercus* spp). Low light levels often observed in bottomland hardwood stands with dense midstory may not provide sufficient energy for adequate photosynthesis in oak seedlings (Hanson et al. 1987). Lockhart et al. (2000) reported that advanced cherrybark oak (*Q. pagoda* Raf.) seedlings released from midstory competition were 2.5 to 3.4 feet taller than seedlings that were not released.

A variety of chemicals can be used for midstory injection, but many managers use imazapyr (Arsenal® AC) (BASF Specialty Chemicals, Research Triangle Park, NC). Although injection effectiveness can vary by species, tree size, and season of application (Peevy 1971, Star 1973), imazapyr has been proven nearly 100 percent effective on a wide range of species such as black cherry (*Prunus serotina* Ehrh.), blackgum (*Nyssa sylvatica* Marsh.), red maple (*Acer rubrum* L.), American beech (*Fagus grandifolia* Ehrh.), and hickory (*Carya* spp.) (Miller 1993, Nelson et al. 1993).

Potential nontarget impact is a concern for some managers using herbicide treatments in hardwoods. A study in Ohio found that injecting tree-of-heaven (*Ailanthus altissima* Mill.) with a granular form

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of imazapyr (concentration of 83.5 percent) killed all injected trees; however, 17.5 percent of non-injected stems within 3 m were also killed (Lewis and McCarthy 2008). A similar study reported that untreated striped maples (*A. pensylvanicum* L.) were killed on sites where the midstory was injected with imazapyr (Kochenderfer and Kochenderfer 2008). Because interspecific root grafts are rare, Graham and Bormann (1966) concluded the herbicide was absorbed from the soil, which is in agreement with a study in West Virginia (Kochenderfer et al. 2001). The study found that midstory injection with imazapyr was more than 99 percent effective in controlling target midstory stems. Imazapyr treatments also damaged several crop trees, but a very high application rate with 7.5 percent imazapyr concentration may have contributed to the crop tree damage (Kochenderfer et al. 2001). It has been shown that imazapyr exhibits soil activity (Anderson 1996) and can be absorbed by roots of plants (U.S. Forest Service 1989). The half-life of imazapyr in soil ranges from 7 to 180 days in soil and is usually greater than 40 days (Michael and Neary 1991). Therefore, if sufficient quantities of imazapyr reach the soil, the herbicide could affect nontarget stems.

Although some studies have found midstory injection treatments using imazapyr can damage nontarget midstory stems, such as oaks, Ezell et al. (1999) reported that imazapyr had no effect on nontarget overstory stems on injected sites. In light of the conflicting results from previous studies on midstory injection of imazapyr, the objectives of this study were (1) to evaluate the efficacy of imazapyr treatment of midstory stems and (2) to determine if imazapyr affects nontarget midstory and overstory stems in southern bottomland hardwood stands.

## STUDY AREA

### Location

Six 15-acre study sites typical of southern bottomland hardwood stands along river systems in Mississippi were used in the study. All six areas have similar site characteristics, including species composition, topography, and soil characteristics. The study areas have an overstory with a prominent oak component constituting 67.5 percent of stems. The current overstory contains trees of sawtimber size (diameter at breast height [d.b.h.] ≥11 inches), which account for 87.7 percent of stems. Overstory age distribution among sites ranges from 71 to 97 years, and the average age among sites is 83 years. The overstory basal area ranged from 92 to 122 $ft^2$ $acre^{-1}$. The midstory in these areas is dominated by shade-tolerant species of limited timber value. A combination of canopy closure and midstory occupancy limits ground cover. Each site predominantly contains soils from the Wilcox association, which are poorly drained soils made up of clay. Soil pH levels ranged between 4.5 and 5.2.

Sites 1 and 2 were located on the John W. Starr Memorial Forest, owned by Mississippi State University. The first of these study sites was located in section 34, T17N R13E in Winston County, Mississippi. The other study site was located in section 15, T17N R13E in Oktibbeha County, Mississippi.

Sites 3 and 4 were located on land owned and operated by C.A. Barge Timberlands LP. The first of these study sites was located in section 12, T15N R14E in Noxubee County, Mississippi. The other study site was located in sections 5 through 8, T15 R16E in Noxubee County.

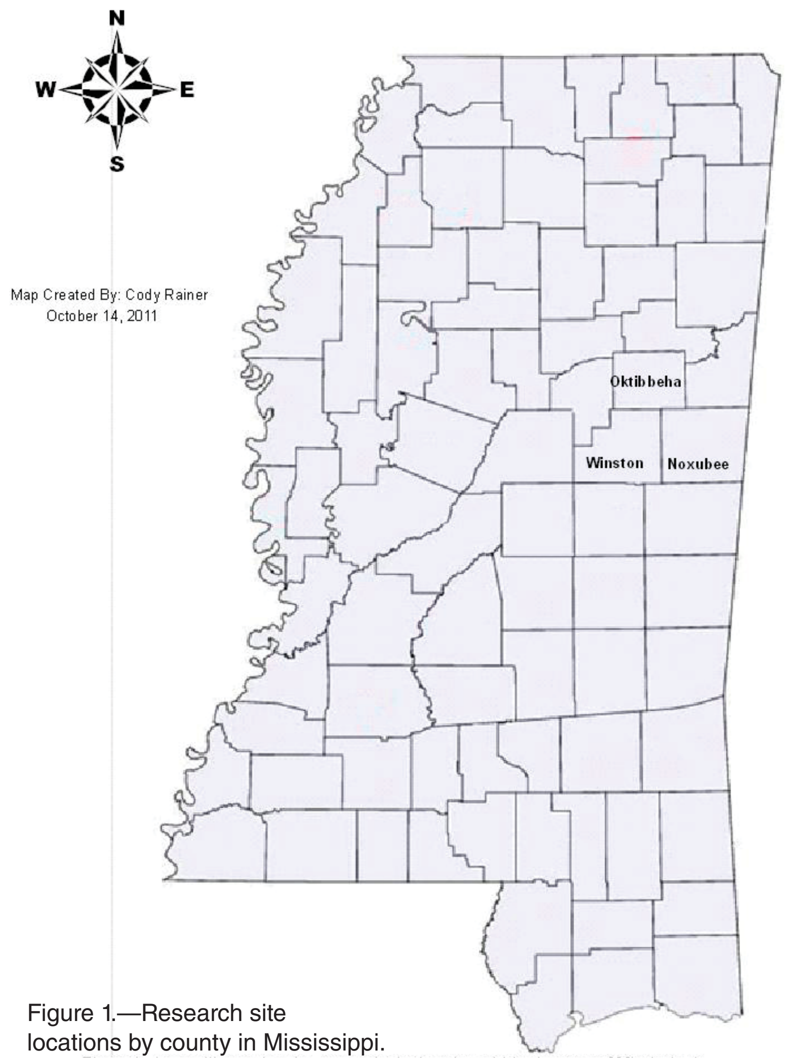

Figure 1.—Research site locations by county in Mississippi.

Sites 5 and 6 were located on the Noxubee National Wildlife Refuge, owned and operated by the U.S. Fish and Wildlife Service. The first of these study sites was located in section 35, T17N R14E in Oktibbeha County. The other study site was located in section 2, T16N, R15E in Noxubee County (Fig. 1).

## Stand Composition

Oaks present in the overstory were cherrybark, southern red (*Q. falcata* Michx.), Nuttall (*Q. texana Buckl.*), white (*Q. alba* L.), Shumard (*Q. shumardii* Buckl.), post (*Q. stellata* Wangenh.), water (*Q. nigra* L.), swamp chestnut (*Q. michauxii* Nutt.), overcup (*Q. lyrata* Walt.), and willow (*Q. phellos* L.). There was also a small component of sweetgum (*Liquidambar styraciflua* L.), American beech (*Fagus grandifolia* Ehrh.), black gum, yellow-poplar (*Liriodendron tulipifera* L.), sycamore (*Platanus occidentallis* L.), loblolly pine (*Pinus taeda* L.), baldcypress (*Taxodium distichum var. distichum* [L.] Rich), and hickory (*Carya* spp.) in the overstory of the sites. The midstory contained species such as American hornbeam (*Carpinus caroliniana* Walt.), pawpaw (*Asimina triloba* [L.] Dunal), American holly (*Ilex opaca* Ait.), slippery elm (*Ulmus rubra* Muhl.), red mulberry (*Morus rubra* L.), red maple, sugarberry (*Celtis* l*aevigata* Willd.), eastern hophornbean (*Ostrya virginiana* Mill.), and winged elm (*Ulmus alata* Michx.). This composition is consistent with cover types 91 through 93 documented by the Society of American Foresters.

## METHODS

On the six study sites, approximately 72,000 midstory stems were injected by using hatchets and adjustable spray bottles in the "hack and squirt" method. Each non-oak stem in the midstory ≥1 inch in d.b.h. received one hack per 3 inches of d.b.h. with 1 ml of a 20 percent volume-to-volume Arsenal® AC aqueous solution applied per hack. Stems between 1 and 3 inches in diameter received one hack. Midstory injection took place during August and September 2009.

Ninety 0.025-acre plots were evaluated in August 2010 to evaluate the efficacy of the injection. The plots were placed on a systematic grid across each site with 312 feet between each plot. Each midstory stem within a plot was identified by species and diameter and recorded as injected or non-injected. Crown reduction was recorded for all stems using ocular estimation. Evaluation could range from 0 to 100 percent reduction. One individual was responsible for determining crown reduction to maintain consistency throughout the evaluation. Crown reduction as a percentage was also recorded for all overstory stems on the plots. In addition, any damage such as necrosis or chlorosis noted on nontarget stems across the study sites outside the measurement plots was recorded and reported. Recorded data on trees outside measurement plots also included crown reduction, diameter, and species. A 5-acre control was established at each study site to monitor the natural processes of crown reduction in the midstory during the study. Thirty 0.025-acre plots were evaluated within each control.

## RESULTS

All sites were uniform in the response to treatments, so we report the results for species and d.b.h. for all sites combined. However, crown reduction was analyzed and is presented individually by site. Overall crown reduction for injected midstory stems on the sample plots was 96.8 percent. Table 1 indicates that injected stems were effectively controlled across all six sites 1 year after treatment. Crown size was reduced by at least 91 percent for all species on all sites (Table 2).

**Table 1.—Mean crown reduction of injected stems at each site in Mississippi 1 year after treatment**

| Site | Mean crown reduction of injected stems (%) |
|---|---|
| 1 | 94.9 |
| 2 | 96.5 |
| 3 | 96.4 |
| 4 | 96.7 |
| 5 | 96.1 |
| 6 | 97.3 |
| Overall | 96.3 |

Results demonstrated that injection efficacy was excellent on stems with a d.b.h. ≤ 6 inches. Because of the lack of larger-diameter trees in the midstory, sample size for trees with diameters 7 to 11 inches was very low (6, 1, 1, 0, and 1, respectively). We found that the herbicide will control a 1-inch stem or an 11-inch stem as long as a consistent dosage (ml per inch of d.b.h.) is applied. Nontarget midstory stem impact from the injection proved to be minor. Injected midstory stems exhibited 96.8 percent crown reduction, whereas non-injected stems averaged only 0.7 percent crown reduction. Midstory stems in control (untreated) areas had crown reduction similar to non-injected stems in the treatment area.

**Table 2.—Mean crown reduction by species of injected stems across all six study sites in Mississippi, 1 year after treatment**

| Species | Reduction (%) | N† |
|---|---|---|
| American hornbeam | 100.0 | 302 |
| Blackgum | 99.8 | 21‡ |
| Deciduous holly | 98.0 | 61 |
| Green ash | 97.3 | 64 |
| Hickory | 95.2 | 470 |
| Pawpaw | 99.8 | 45 |
| Persimmon | 97.5 | 2‡ |
| Red maple | 92.3 | 108 |
| Sweetgum | 98.5 | 94 |
| Winged elm | 91.8 | 214 |

† Number of stems in sample plots
‡ Insufficient number of stems for valid evaluation

## DISCUSSION

Nontarget overstory stems evaluated on all sites exhibited little effect from the chemical injection. Only three overstory stems on the 90 acres injected were observed to be adversely affected. All three stems were sweetgum, which are highly susceptible to imazapyr and reproduce by root suckers. The three stems all exhibited minor symptoms and are expected to have no lasting effects. The adverse impact on the nontarget overstory stems likely can be attributed to the inexperience of one member of the injection crew. The damage occurred in an area where that individual was repeatedly cautioned about poor injection technique.

It is also possible that these sweetgum trees shared a common root system with injected stems. Root suckering is rare in southern hardwood species, and none of the more valuable and highly desirable species exhibit this trait. Sweetgum and American beech are the species most often associated with this feature, but it is important to note that the high density of midstory stems where the damaged trees were located also characterized numerous other areas in the study. Yet in all the areas examined during the sampling and in a more extensive survey to check for nontarget impact, we did not find similar damage.

We think the lack of consistent nontarget impact considered in conjunction with the poor injection work of one crew member is appreciable evidence that the symptoms were attributable to "operator error" and not to chemical movement through the root systems. Based on these observations, we can surmise that chemical root transfer is minimal to nonexistent and the crown reduction observed and recorded was due to the natural senescence or dieback common in midstory and understory stems. Any nontarget stem herbicide impact in this study (if any occurred) likely resulted from failure to properly apply the herbicide solution and keep it in the injection frill, which could allow imazapyr to reach the soil and cause nontarget impacts.

## CONCLUSIONS

Midstory injection of an imazapyr solution is very effective in controlling target stems. Injected stems in this study were reduced by more than 96 percent. Even though 100 percent crown reduction was not achieved for all injected trees 1 year after treatment, trees with crowns severely damaged by herbicide died by the next growing season. Nontarget impact of injection was almost nonexistent and was represented by only minor symptoms. The lack of consistent nontarget impact suggests that root grafting was not a principal factor in any chemical movements. Nontarget stems negatively affected may be attributed to an inexperienced injection crew.

Imazapyr is not the only herbicide used for injection which exhibits soil activity. Although this study is the first one in which we have formally evaluated plots for nontarget impact, we have injected hundreds of acres of hardwoods with imazapyr solutions and have never found any nontarget impact to our desirable crop trees. In this study, there were many midstory sweetgum stems in dense areas which were missed during injection. These stems were the best candidates to exhibit symptoms resulting from root graft transfer, yet none did. Conducted properly, injection with imazapyr requires substantially less labor than conventional injection (most trees receive only one hack) and is a very cost-effective tool for controlling undesirable stems in southern bottomland hardwoods.

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