TESTING THE EFFICACY OF TRICLOPYR AND IMAZAPYR USING TWO APPLICATION METHODS FOR CONTROLLING TREE-OF-HEAVEN ALONG A WEST VIRGINIA HIGHWAY

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Abstract—Tree-of-heaven (*Ailanthus altissima* [Mill.] Swingle) is a non-native invasive plant that is spreading throughout much of the U.S. In this study, efficacy of the herbicides triclopyr and imazapyr was tested using injection and basal bark treatment methods. No treatment was 100 percent effective. Only triclopyr injection was significantly different from other treatments, providing the least control. Both injection and basal spray treatments with imazapyr affected untreated neighbor stems, probably through root connections and/or root leaking.

INTRODUCTION

Originating in Southeast Asia, tree-of-heaven is now found on all continents except Antarctica (Udvardy 1998). In the Americas, tree-of-heaven can now be found from Massachusetts to Oregon and from Toronto to Argentina (Hu 1979). In some locations, it is so common that it appears to be a part of the native flora (Little 1979). It has been present in urban and agricultural settings for quite some time, often growing where no other tree would, but is now spreading into our forests, displacing more desirable native trees.

Possible control methods for tree-of-heaven include manual (hand pulling, digging, girdling), mechanical (chopping, cutting, mowing), burning, grazing, biocontrol, and chemical control (Hoshovsky 1988). Successful control methods for tree-of-heaven will kill both the stems and roots while allowing for the reestablishment of native vegetation on the site (Burch and Zedaker 2003).

Chemical treatments are often performed on tree-of-heaven with differing levels of success. Foliar broadcast applications are effective in defoliating this species. Basal bark application may be used on trees up to six inches in diameter. For larger stems, cut stump treatments, treating fresh-cut stem surfaces with herbicide, may be effective (Randall and Martinelli 1996). A study of chemical control by Burch and Zedaker (2003) was successful in removing existing trees, in preventing resprouting, and allowing for reestablishment of native vegetation on the site. Basal bark treatments with an herbicide combination including picloram (at least 5 percent of the product Tordon K) proved most successful. Treatments of triclopyr ester, imazapyr, and a combination of the two herbicides all controlled *A. altissima* better than cutting alone, but were not as effective as treatments containing picloram.

The quandary is that the label for Tordon K (picloram) reads, "Picloram is a chemical which can travel (seep or leach) through soil and under certain conditions has the potential to contaminate groundwater which may be used for irrigation and drinking purposes." Because of the potential negative impacts on water and on adjacent trees in high-valued broadleaved stands, it may be advisable to formulate prescriptions that do not include picloram.

With the overall purpose of finding an herbicide treatment that can be used on the invasive tree-of-heaven growing in broadleaved stands in the central Appalachians, we established a study to investigate the efficacy of two commonly used herbicides in combination with two herbicide application methods. The objective of this study was to test the efficacy of triclopyr or imazapyr applied by basal bark treatment or

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stem injection. Our secondary objective was to observe damage to non-target stems that may occur by means of root connections and seepage.

METHODS

Study Site

The study was established in a 0.44 mile long plot centered on the Mile 150 marker along the northbound lane of I-79 in Morgantown, West Virginia. Several benches of shale and sandstone are present along most of this study site. Exposed bedrock-derived soils grade into forest soils on the north end of the site. Tree of heaven is a clonal species, but most of this stand was contiguous and there were no discernable isolated clones.

Herbicides and Application Methods

Imazapyr and triclopyr were the herbicides selected for use in this experiment. These are commonly-used forestry herbicides in many areas of North America, particularly in pine plantations of the Southeastern United States.

Imazapyr inhibits the production of three chain amino acids necessary for plant growth and protein synthesis (Tu and others 2001). Mortality of treated plants is largely dependent on the amount of amino acids they have stored. Roots begin to die soon after application followed by aboveground growth cessation; mortality generally occurs one month after treatment (Cox 1996). Imazapyr is reported to be most effective during axillary budding (post-emergent) (Hanlon and Langeland 2000).

Triclopyr behaves like a synthetic auxin, imitating natural plant hormones (e.g. indoleacetic acid) and causing the growing tips of the plant to elongate, distort, wither, and die (Ware 2000). Triclopyr herbicide symptoms are likely caused by disorganized cell division that leads to vascular damage (WSSA 1994).

In the low volume basal bark treatments used in this study, the lower ten inches of selected tree-of-heaven stems were sprayed until thoroughly wet, including the root collar area, but not to the point of runoff. Garlon 4 (triclopyr ester) and Stalker (imazapyr) were used for each of the two low volume basal bark treatments. Because of the low volume of herbicide that was needed for this study, herbicide was applied with one liter spray bottles. These bottles were calibrated in the lab so that the volume of herbicide mixture used to treat each tree could be estimated.

Stem injections were applied using the EZject® lance. The EZject inserts .22 caliber shells containing solid herbicide through the bark and into the cambium. Injections are applied to the lower ten inches of treated stems. Herbicides used in this method included imazapyr capsules (same active ingredient as Stalker) and triclopyr amine capsules (same active ingredient as Garlon 3A). Triclopyr capsules contain 0.24g active ingredient (0.27g total), and imazapyr contain 0.18g active ingredient (0.24g total). Label recommendations for injection rates are related to the size of the stem to be injected; one capsule per four inches (dbh) of circumference. The number of capsules to be injected was calculated prior to treatment to assure that each stem was injected with the recommended number of capsules.

Treatments and Assessment

During the summer of 2004, 150 tree-of-heaven stems were identified, mapped, and measured for use in this study. Diameter and height measurements were taken to assess treatment differences in efficacy of treatments by size class.

Thirty trees were randomly assigned to each of the four herbicide/application treatments. All treatments were applied on August 4-5, 2004. Treatments included:

1. Low volume basal bark — 20 percent Garlon 4 (61.6 percent triclopyr ester) in Aqumix (BB-T)

2. Low volume basal bark — 8.25 percent Stalker (27.6 percent imazapyr) in Aqumix (BB-I)

3. EZject — triclopyr (44.4 percent triethylamine salt) capsule injection (I-T)

4. EZject — imazapyr (83.5 percent imazapyr) capsule injection (I-I)

Thirty untreated control trees were also randomly chosen. A 2.25m radius buffer was established around each subject tree to diminish the possibility of herbicide translocation between adjacent treatment trees. The two nearest living neighbor trees to each treated stem were marked, regardless of species, to monitor for herbicide translocation.

Treatment stems were revisited in August 2005 (12 months after treatment) and were assigned a four-category efficacy score using the following qualitative ratings:

1. Tree was treated, but with no apparent negative effect on growth or health of the tree

2. Treatment effects evident with partial defoliation or retardation of foliage development

3. Defoliation complete, suckering or sprouting present

4. Defoliation complete, no evidence of suckering

Numerical Methods

All analyses were performed using SAS (SAS 2003). Fisher's LSD and Dunnett's t-test were used as mean separation procedures at the alpha=0.05 significance level. Qualitative ratings of treatment efficacy are ordinal. Although they are used in many disciplines, parametric methods such as ANOVA are inappropriate for analyzing data on an ordinal scale (Munzel and Bandelow 1998). Hence, efficacy ratings for treatment stems were rank-transformed and ranks used as the dependent variable in a single factor analysis of variance (e.g., Iman 1982).

RESULTS AND DISCUSSION

No treatment provided 100 percent control (i.e, both top-kill and no sprouting). A Dunnett test shows that all treatments were significantly different in efficacy from the untreated controls. Table 1 shows the differences between the treatments. LSD failed to show a significant difference between efficacy of basal bark treatment of triclopyr (BB-T) and capsule injections of imazapyr (I-I). These treatments provided the highest level of control. Triclopyr injection (I-T) provided the least control, with treated trees showing little or no effect of herbicide treatment.

Table 1—Differences in level of control between treatments based on mean rank of ratings

Treatment	N	Mean rank of rating
I–I	30	68.3 A
BB–T	30	62.4 BA
BB–I	30	52.7 B
I–T	30	19.3 C

Means with the same letter are not significantly different based on Fisher's LSD.

While imazapyr injections and both basal bark treatments resulted in total defoliation of at least 80 percent of treated stems (table 2), basal bark treatments with imazapyr had a higher proportion of treated stems with root suckering than the others (fig. 1), explaining why it is significantly less effective. A Dunnett test shows that only this treatment had a higher number of sprouts per stem than the untreated control.

Although the control trees were not treated with herbicide, five of them had new suckers. This is not surprising, as clonal growth in tree-of-heaven is often a response to injury or stress to the parent plant (Kowarick 1995). The hot, dry shale slopes of the highway cut on which this study is located, likely provide enough stress to cause some suckering, even in untreated stems. In fact, this site had many stems showing severe basal damage due to downslope soil and rock movement with significant bark and woody tissue damage on the uphill sides of these stems.

Several non-target hardwood stems adjacent to imazapyr treated trees (basal bark and injection treatments) showed obvious signs of herbicide damage, including wilting, prolific axillary budding, and chlorosis and necrosis of foliage. This effect was most common in tree-of-heaven stems (up to 15 feet from the treatment stem), but was also observed in black locust (*Robinia pseudoacacia* L.) and white ash (*Fraxinus americana* L.) up to 48 inches from the treated stem. This is likely the result of root leakage, or root grafting between treated stems and those adjacent. No herbicide damage was observed in stems neighboring triclopyr treated stems.

Table 2—Attributes of treated stems prior to and 12 months following herbicide treatments

Treatment	D.b.h.	Root suckers per acre	D.b.h.	Capsules per stem	Topkill	Stems w/ root suckers
	inches	*number*	*ml/inch*		*- - - - - percent*	*- - - - -*
Controls	2.97	1,276			0	16.7
BB–T	3.05	4,359	2.76		90	13.3
BB–I	2.95	9,143	3.13		80	40
I–T	3.35	1,063		2.63	3.3	10
T–T	3.13	1,488		2.47	93.3	6.7

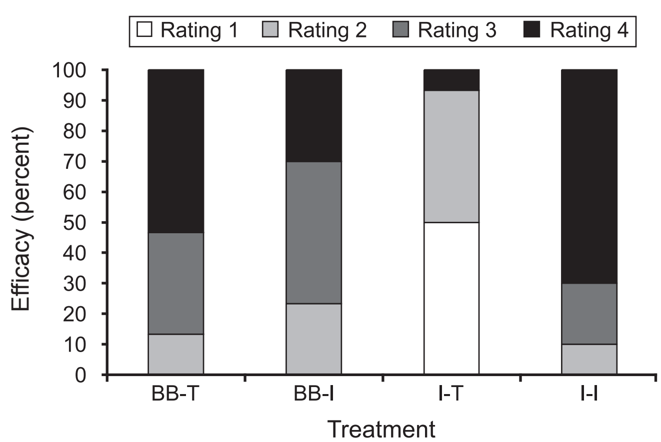

Figure 1—Proportions of trees at each level of control for all treatments.

Damage to untreated trees was not unexpected. In fact, the label for Stalker warns against possible damage to nontarget stems through root uptake. Imazapyr exhibits soil activity (Anderson 1996) and is known to be absorbed through the roots of plants outside of treated areas (USDA 1989). A study by Kochenderfer and others (2001) showed that in a hardwood crop tree release in central West Virginia, imazapyr treatments applied to competing trees adversely affected several crop trees. On one site, 66 percent of the crop trees were killed by imazapyr treatments applied to competing non-crop trees. As in our study, they observed no nontarget herbicide damage in the triclopyr treatments. Herbicide damage to untreated trees caused by imazapyr is of importance as tree-of-heaven is becoming increasingly common in woodlots and forest gaps where incidental damage to other more valuable hardwood trees is undesirable.

While damage to adjacent trees was not unexpected, the spatial extent of damage was, and only two nearest neighbor trees were marked for observation. No design for collecting and quantifying damage to unmarked trees was in place, so results of imazapyr damage are purely observational. More research needs to be conducted on damage to nontarget stems when using imazapyr.

Management Implications

No treatment in this study provided 100 percent control of tree-of-heaven stems by killing both the aboveground and belowground portions of the tree. We recommend against the use of triclopyr injection since this treatment was the least effective. Imazapyr injection was not significantly more effective in control than basal bark treatments with triclopyr. In areas with valuable crop trees or in mixed species stands, it is not advisable to use imazapyr treatments based on this and other studies; in these situations, basal bark treatments with triclopyr should be used. In tree-of-heaven stands where a monoculture has formed, use of imazapyr treatments may be a useful strategy in achieving greater control.

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