Tree-of-heaven (*Ailanthus altissima*) control methods in broad-leaved forests of West Virginia

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History

Tree-of-heaven, also known as ailanthus, Chinese sumac, stinking sumac, copal tree, and varnish tree, is native to China and has a long cultural history. In China, it was considered a valuable species for medicinal purposes—the leaves, bark, and roots were all used in herbal medicine to treat mental illnesses, digestive problems, and skin conditions. Known as the 'spring tree' to communities in northern China, tree-of-heaven was the last to leaf-out following winter, indicating to they had survived the winter and that warmer weather was on its way. Although not a great source of fuel, this species was also used to cook and heat homes in northern China. Tree-of-heaven was also essential to feed the Cynthia moth (*Attacus cynthia*) to produce Shantung silk for the people of the Shantung peninsula.

Tree-of-heaven was transported out of China via several routes to America and other countries, but it was first brought into Philadelphia as an ornamental tree in 1784. It was an especially desirable tree in industrial cities and northeastern states due to the lack of needed care and its ability to withstand severe environmental conditions and high pollution that existed during this period. In the late 1880's, it was also used in afforestation projects in some states because of its rapid growth and tolerance for degraded sites. Its ability to out-compete native species and successfully reproduce via root/stump sprouting and wind-dispersed seed made tree-of-heaven very difficult to control, much less eliminate. Because of its aggressive nature, this species has been a concern to natural resources managers as early as the 1920's. Today, tree-of-heaven is considered an "invasive species" in 30 states across the nation.

Ecological Impact

Tree-of-heaven is a fast-growing species capable of spreading into both nearby and distant areas. A single female mature tree can produce over 300,000 seeds in one year; these seeds are equipped with a twisted wing that allows them to be carried by the wind for long distances. The root system has very aggressive rhizomes –which are buried horizontal stems–that grow their own roots and new shoots, essentially creating new plants. Tree-of-heaven has been reported to produce chemicals that are toxic to other plants. These features enable tree-of-heaven to form dense stands and out-compete most native vegetation. A common problem encountered by homeowners is that it has a weak branch structure that makes the species susceptible to storm damage which is a hazard near homes, buildings, and utility lines.

Identification

Tree-of-heaven is a deciduous tree that can grow up to 80 feet in height with a trunk diameter of 6 feet (in rare cases). As in its country of origin, it is one of the later species to leaf out in the spring. Its flowers bloom in July and early August.

The bark is light green to grayish-tan in color and covered with fissures, or linear cracks, as the tree matures. New growth and young branches are covered with lenticels, or tiny circular pores. Younger plants have stout, smooth, reddish-green stems.

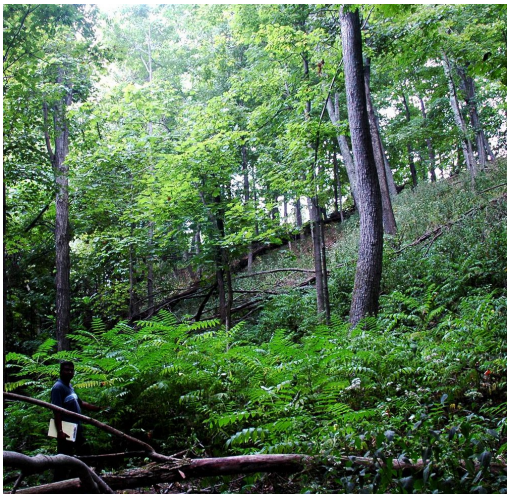

Photo: ***Dense patches of tree-of-heaven can develop in woodland understories***

Photo: ***A single leaf of tree-of-heaven.***

Tree-of-heaven has compound leaves similar to native sumac and walnut, although the margins of the leaflets lack the fine sawtooth (serrated) margins of these native species. Leaflets are arranged mostly opposite of each other and can be from one to two inches wide and four to seven inches in length. One leaf can consist of 10 to 41 leaflets and can be more than 4 feet long (see photo). One key trait that distinguishes its leaves from similar native species is 'glandular lobes' located near the base of the leaflets. Tree-of-heaven has large heart- to shield-shaped leaf scars, the mark that remains where a leaf stalk was once attached. Additionally, this species can be recognized by its unique, pungent odor of the crushed leaves, flowers, and other plant parts that some describe to be similar to rancid peanuts or cashews.

Control Methods

As is the case for most undesirable plants, there are different ways to control tree-of-heaven. The effectiveness of treatments used varies with the size of the plants, their location, and the time of the year. Control treatments can generally be classified as either:

1. Mechanical, where plants are pulled or cut,
2. Chemical, using herbicides to kill the plant, or
3. Biological, where other life forms are used to consume or otherwise hamper the development of the plant.

In this paper, mechanical and chemical control treatments are discussed for eliminating tree-of-heaven in mixed-broadleaved woodlands in West Virginia.

Mechanical Control Treatments

Mechanical control treatments are most effective when used in combination with herbicides, but sometimes successful control can be achieved by cutting or pulling tree-of-heaven stems without using herbicides. Success in eliminating tree-of-heaven is usually achieved when a landowner or caretaker has a small number of plants to control and plenty of time for follow-up treatments.

When tree-of-heaven is a small seedling, it can be easily picked by hand. For smaller populations and individual trees that have not fully established their root systems, hand pulling or digging up the entire plant can be effective as long as all parts of the roots are removed. As the tree grows into a sapling that is over 6 feet tall, it takes a lot of effort to pull the roots out; roots must be removed because if left in the soil, they will frequently re-sprout.

As the tree grows larger, loppers, brush saws or chainsaws are needed to cut the stems. Cutting is not recommended for larger trees and dense stands unless the property owner or land manager plans follow-up treatments to eliminate root suckers that will begin to emerge shortly after cutting. Burning and grazing have proved somewhat effective control methods, however, they only weaken the root system and are not a long-term solution for controlling tree-of-heaven.

Chemical Control methods

Herbicides are chemicals that are used to kill unwanted plants. Herbicides are more effective to control tree-of-heaven when used in combination with mechanical treatments since the latter facilitates better "uptake" of the chemical into the target plant tissues. In many cases, one herbicide application is insufficient to completely eliminate tree-of-heaven from a forested site. Follow-up treatments are needed to eliminate this problem species from areas where it has established. Persistence and monitoring are key to effective control of any invasive species.

Herbicide labels specify the legal and safe use of the herbicide. Labels are usually found attached to the herbicide containers, but are also available on the CDMS Agro-chemical database website (www.cdms.net). Currently there are 17 labels on this website that specifically list either "Tree-of-Heaven" or "Ailanthus" as a plant that can be treated.

Careful attention to the label's directions of use is crucial as several of these herbicides are likely to damage adjacent trees if applied in forest settings. Some are labeled to be used to eliminate all vegetation on a site as in forestry "site preparation" treatments where new

seedlings will be planted. Still others are labeled for use in close association with various crops, in right-of-ways, and along roadsides where damage to associated vegetation is not a critical issue. Many other herbicide labels contain generic terms that designate a given herbicide for controlling "unwanted trees and brush"; unless specifically stated in the label, an herbicide that can control woody trees can be used to treat tree-of-heaven as long as all other application, chemical hygiene, crop and food safety, and environmental restrictions are followed. As with all chemical use, environmental factors such as soil depth and texture, proximity to water sources, and surrounding vegetation should be considered prior to selecting an herbicide. Be sure to read all instructions on the label and follow safety and state requirements when using herbicides.

The use of personal protective equipment is essential in safely using herbicides to treat tree of heaven. Each herbicide has a list of the type of clothing that should be worn and equipment that should be used to assure a safe and effective application of the product.

Herbicides used to kill tree-of-heaven are delivered to the target plant using one of four application methods: foliar, stem injection, cut-stump, and basal bark applications. In general, it is not difficult to kill tree-heaven with any one of these application/herbicide combinations. One of the biggest challenges is controlling the sprouts that may arise from the roots and stump, even after an herbicide treatment. Some common herbicide products are listed by active ingredient in table 1. Careful monitoring and follow-up of treated tree-of-heaven patches and individual stems will assure more effective control of the species.

Foliar applications

Foliar applications are treatments in which herbicides are sprayed directly on leaves, or "foliage". This application type is limited to periods when the leaves are fully expanded. These treatments are remarkably effective for tree-of-heaven, although because of the species' rapid growth, the leaves are within easy reach of a hand-held sprayer for only a couple of years. More powerful sprayers can be used to spray the leaves of taller saplings and mature trees but doing so may damage non-target plants. So in most cases on private farms and woodlands, foliar applications are best suited for the smaller trees with leaves that can be reached by a hand-held spray nozzle.

Table 1. Example product names containing glyphosate, triclopyr, and imazapyr and are labeled for use in forest settings. Percent active ingredient for each herbicide is shown in parentheses.

Active ingredient	Example product names
glyphosate:	Roundup Pro Concentrate (50%), Accord Concentrate (54%), Credit Extra (34%), Rattler (41%), Rodeo (54%), Razor Pro (41%), Touchdown Pro (28%)
triclopyr (amine):	Garlon 3A (44%), Tahoe 3A (44%),
triclopyr (ester):	Garlon 4 (62%), Element 4 (62%)
imazapyr:	Arsenal (53%), Chopper (28%), Habitat (29%)

The most common herbicides for directed foliar applications contain the active ingredient "glyphosate" (pronounced gly-fo-sate). This ingredient is absorbed into the leaf and inhibits an internal plant process that manufactures amino acids. Hence, the glyphosate stops the production of crucial amino acids and the plant can no longer survive. A big advantage of this herbicide is that it binds with soil particles which render it inactive, a situation that helps to minimize incidental plant damage. Recommended foliar applications of glyphosate herbicides are found on the labels that are required to be sold on the herbicide container.

Generally, a 1-2 percent mixture of herbicide with water is the recommended rate for foliar applications (table 2a). When spraying the herbicide be sure to completely wet the leaves but avoid any drips. If herbicide drips from the leaves, this is too much. To decrease the amount of herbicide falling from the leaves, move the spray nozzle farther away from the leaves or move the wand more quickly. There is some degree if incidental damage that can occur to other plants when applying foliar applications. Careful attention to adjacent plants should be taken to minimize damage.

Stem injection

As the name implies, stem injection involves delivering herbicide directly into the stem through the bark of the tree. This treatment is recommended for periods when the leaves are fully expanded and the trees are actively growing. There are several methods for doing this, but the most common and least costly is the "hack-and-squirt" method. A lightweight hatchet is used to cut an opening through the bark and into the vascular (fluid conducting) tissue of the tree. A quick downward strike to the stem of the tree results in a small notch that penetrates the bark. Herbicide is then squirted from a hand-held spray bottle into the notch. Many herbicide labels recommend the number of "hacks" to make around each tree in relation to the diameter of the tree, for example, "one hack per 2 to 3 inches of tree diameter." A simple rule of thumb is to leave about a thumb width (3/4") between hacks. The amount applied to each squirt is generally ½ to 1 milliliter. A single squirt from most spray bottles is between 1-2 ml. To determine how much is emitted from a given spray bottle, count the number of squirts it takes to fill a graduated cylinder or other liquid measuring device to a known value then divide the total volume by the number of squirts. Herbicides used in hack and squirt treatment are shown in table 2a.

Cut-stump application

Herbicides can also be effective when applied to a freshly cut stump. For stumps less than 3 inches in diameter, the entire

stump surface should be sprayed immediately after cutting the stem. Herbicide should be applied to the sapwood area, which is just the inside the bark of freshly cut stumps. The active vascular tissue is just inside the bark and in the cut stump application this tissue will transport herbicide into the roots.

For the most part, herbicides that are used in ailanthus stem injection treatments can be used in cut stump treatments. See table 2b for general recommended application rates.

Basal bark application

Basal bark applications are treatments where herbicide is applied to the tree bark near ground level. These herbicides are developed in a way they can be mixed with oil, either a bark oil or diesel oil. The herbicide enters the sap stream as it is absorbed through the bark. Applying herbicide to the bark of the stem has some big advantages. It is relatively easy to walk around and spray the trees if the terrain is favorable, there is no need to cut the tree in any way (added work), and the treatment can be very effective. Basal bark treatments can be applied any time during the year as long as snow or water do not prevent the applicator from spraying the root crown. The disadvantage is that once the tree gets too big, the bark gets too thick and this treatment loses some of its effectiveness. When the basal part of the tree trunk is greater than 6 inches in diameter (about 18 inches in circumference), it is better to use a stem injection method to assure better control. Table 2b lists some general basal bark treatment rates.

Table 2a. Various herbicides that can be used on tree-of-heaven in mixed broadleaved forests of West Virginia.

Application Type	Herbicide Active Ingredient	Comments
Foliar	glyphosate	For most concentrated herbicides (greater than 40% glyphosate) mix a 2% solution (vol/vol with water). For herbicides without a surfactant, a non-ionic surfactant (generally 1%) should be added.
	triclopyr (amine)	Mix 2% in water. Special attention to eye protection and chemical resistant gloves required. Surfactant is recommended to improve spray coverage.
	triclopyr (ester)	Follow directions on label to blend oil/surfactant/herbicide mixture with water; continuous agitation recommended.
Stem injection (hack and squirt)	glyphosate	Mix a 25-100% solution with water. Apply about 3/4 squirt[a] to each frill (small pocket made with a downward stroke of hatchet). Frills should be spaced evenly around the stem at about 4 feet on the stem. Leave ¾ inch between frills.
	triclopyr (amine)	Mix a 50-100% solution with water. Apply about 3/4 squirt to each frill for 100% solution and half as much for 50% solution. Space frills evenly around tree with about 3/4 inch between frills.
	imazapyr	Using an imazapyr-based herbicide with greater than 40% active ingredient (e.g., Arsenal), mix a 25-100% solution with water. Apply about 3/4 squirt to each frill. Dilute solutions (5% herbicide/95% water, i.e., 6oz herbicide per gallon water) can also be used but frills should be "thoroughly wet". Note: imazapyr-based herbicides have shown a relatively higher degree of damage to non-target broadleaved trees, likely caused by transfer of herbicide through root grafts.

[a] Spray bottles vary by the amount of liquid emitted for each squirt. Most, however, emit 1-2 milliliters, depending on the nozzle aperture setting and the viscosity of the herbicide.

Photo:
Early season damage on tree-of-heaven resulting from a basal bark application of 20% Garlon 4 in bark oil.

Table 2b. Various herbicides that can be used on tree-of-heaven in mixed broadleaved forests of West Virginia.

Application Type	Herbicide Active Ingredient	Comments
Cut stump	glyphosate	Spray 50-100% solution (in water) to freshly cut stump.
	triclopyr (amine)	Spray or brush undiluted herbicide to freshly cut stump.
	triclopyr (ester)	Spray a solution of 20-30% vol/vol with bark oil or diesel oil to top of stump (especially just inside bark area), sides of the stump and root collar. This treatment can be made any time during the year including winter, as long as snow and water conditions allow spraying to the root collar.
	imazapyr	Using an imazapyr-based herbicide with greater than 40% active ingredient (e.g. Arsenal), spray or brush dilute solution (5% in water) on stump 1-2 inches from inside bark ("cambium area"). If using an oil soluble product (e.g., Chopper), mix 8-12 ounces per gallon oil and apply to surface of cut stump.
Basal bark	triclopyr (ester):	20% vol/vol with bark oil or diesel oil; this is the "low volume" basal bark treatment that is applied to the lower 12-15 inches of stems less than 6 inches in diameter; completely coat the stem but not to the point of runoff. A 1-5% vol/vol (with oil) can also be used in the same way although enough should be applied to begin to run off the stem.
	imazapyr	Mix 8-12 ounces of oil soluble imazapyr product (e.g., Chopper) with oil and apply to lower 12-18 inches of stems less than 4 inches diameter at breast height. Spray stem to include root collar.

Table 3. Recommended application types by season and diameter at breast height (DBH). DBH refers to the average size of plants being treated.

	----------Season----------				------DBH (in.)------		
Application type	Winter	Spring	Summer	Fall	0.1 to 1	1 to 5	5+
Foliar			X		X		
Stem injection			X			X	X
Cut stump: water carrier			X			X	X
Cut stump: oil carrier	X	X	X	X		X	X
Basal bark	X	X	X	X		X	

Summary

Tree-of-heaven can be safely and effectively controlled in broadleaved forests mechanically and/or chemically. Importantly, the effectiveness of these methods varies by the season of the year and size of the plant. Table 3 provides a general overview of recommended herbicide applications by season and the size of tree-of-heaven. In any effort to control tree-of-heaven, monitoring and follow-up treatments are essential to assure effective control. Finally, when using herbicides, always follow instructions on the label.

Photo:
Tree-of-heaven seeds (samaras) are wind distributed. Female trees can produce thousands of seeds each year.

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