

Field Guide for Managing Tree-of-heaven in the Southwest

Tree-of-heaven (*Ailanthus altissima* (Mill.) Swingle; synonyms: *A. glandulosa*, *Toxicodendron altissimu*) Quassia family (Simaroubaceae)

Tree-of-heaven is an invasive tree in southwestern states that has been listed as a noxious weed in New Mexico. This field guide serves as the U.S. Forest Service's recommendations for management of tree-of-heaven in forests, woodlands, and riparian areas associated with its Southwestern Region. The Southwestern Region covers Arizona and New Mexico, which together have 11 national forests. The Region also includes four national grasslands located in northeastern New Mexico, western Oklahoma, and the Texas panhandle.

Description

Tree-of-heaven (synonyms: ailanthus, Chinese sumac, stinking sumac, paradise tree, copal tree, Brooklyn palm) is a fast growing tree that was introduced as an ornamental into the United States from China. Its common name and scientific name both refer to its rather tall height (60 to 80 feet). It produces clusters of small, yellow-green flowers mostly in June and July in New Mexico, and April to May in Texas. Tree-of-heaven is dioecious with female trees producing clusters of persistent, one-seeded, winged fruit that resemble those found on maples. Male trees produce groups of staminate flowers that smell like burnt peanuts or cashews. Tree-of-heaven is a prolific seed producer (up to 300,000 seeds per tree in a year). The tree also regrows rapidly from the stump or lateral roots if cut or disturbed. In general, seeds are not long lived and usually do not persist in the seed bank for more than a year or 2.

Growth Characteristics

- Deciduous tree; 60 to 80 feet tall; 80 foot crown width; up to 3 foot trunk diameter.
- Perennial but generally a short-lived tree (30 to 50 years).
- Bark is light brown to pale grey when mature; smooth bark becomes more rough and fissured on trunk.
- Branches are grey, glossy and smooth with raised dots that become fissures with age. Twigs are reddishbrown and velvety.
- Wood is beige to light brown; soft, weak and coarsegrained; breaks easily.
- Pinnately compound leaf (1 to 4 feet long) with 10 to 41 leaflets (2 to 7 inches long).
- Dark green, broadly lanceolate leaflets; margins entire with teeth or lobes at the base; light green veins and whitish green underneath with glandular red dots near lobes.
- Dioecious; numerous, small, yellow-green flowers (8 to 16 inch panicles). Staminate flowers malodorous.
- Persistent propeller-like fruits (1.5-inch-long samaras); fruit turns pale green to tan to reddish as it matures. Fruits occur in dense clusters.

Ecology

Impacts/threats

Tree-of-heaven is an extremely competitive, fast-growing tree with young sprouts growing as much as 10 to 15 feet in a year. Once established, it can overrun native vegetation by developing dense thickets of cloned trees. It can dominate colonized sites indefinitely through resprouting and root suckering. Coupled with its size and structural weakness, the rapid rate of spread and growth of tree-of-heaven makes it an acute hazard along roadsides. In urban areas, tree-of-heaven roots can damage sewer lines and structures.

Location

The species is widespread across the United States (especially in eastern forests and woodlands), but populations tend to be more localized in the Southwest. It establishes readily along roadsides, railways, fencerows, woodland edges, forest openings, or in riparian zones. It is often found in waste areas or disturbed sites such as old fields and abandoned areas (e.g., mining communities). Tree-of-heaven is intolerant of flooding and deep shade; but it can occur in areas where trees normally do not grow such as cliff crevices or paved areas (parking lots, sidewalks, etc.).

Spread

Tree-of-heaven is a prolific seed producer; and its seed may be dispersed via wind, water, birds, and farm or road equipment. However, the majority of new plants within an area are usually from root sprouts. If the top is removed or the stump is cut, new sprouts from lateral roots may occur 50 to 90 feet from the parent tree.

Invasive Features

Tree-of-heaven is highly adaptable and can grow under limiting or harsh conditions such as soils that are saline, nutrient poor, or highly compacted. It will also grow in areas affected by heat, drought, or pollution. Allelopathic chemicals in leaves, bark, roots, and seed inhibit growth and germination of surrounding plants.

Management

Control efforts for tree-of-heaven should focus first on preventing establishment in new areas. Next, small infestations should be treated; mature female trees located on otherwise healthy sites should especially be targeted to help reduce the seed available for germination. Finally, large infestations should be removed or at least controlled. Management efforts should focus on treatments that stress the root system and lead to a reduction in seed production. For example, a treatment regime can be started early in the summer when root reserves are at their lowest and repeated as necessary to keep root reserves low. Since tree-of-heaven is relatively shade intolerant, establishment of desirable competing trees and shrubs should be encouraged following control efforts.

Complete control for tree-of-heaven will likely require 1 to 5 years of continuous planning and integrated management. Consider the following actions when planning a management approach:

- Maintain healthy plant communities to limit tree-of-heaven establishment. Minimize disturbance and/or promptly revegetate disturbed or bare ground areas with desirable native species.
- Conduct surveys, map known infestations, and monitor for tree-of-heaven, especially on roadsides, fence lines, trails, waterways, parking lots, etc. Keep annual records of reported infestations.
- Combine mechanical, cultural, and chemical methods for most effective control of tree-of-heaven.
- Implement a monitoring and followup treatment plan in areas where control practices have been made to further suppress root sprouts and seedlings.

Table 1 summarizes management options for controlling tree-of-heaven under various situations. Choice of individual control method(s) for tree-of-heaven depends on the density and degree of the infestation, current land use, and site conditions (accessibility, terrain, microclimate, other flora and fauna present, etc.). Other important considerations include treatment effectiveness, overall cost, and number of years needed to achieve control. More than one control method may be needed for a particular site.

Physical Control

Tree-of-heaven is very difficult to control by simple cutting or by other mechanical means. Not only do trees resprout with tremendous vigor, but massive root suckering also occurs, which in some cases results in many more new stems spreading over a wider area. There are several practical techniques that can help make physical control of tree-of-heaven more effective. These include: (1) cutting trees before they become too large; (2) cutting trees in early summer when root reserves are lowest; (3) cutting regrowth repeatedly and frequently, and applying herbicide to cut surfaces; and (4) providing shade from competitive native plants after control efforts.

Table 1. Management options*

Site	Physical Methods	Cultural Methods	Biological Methods	Chemical Methods
Roadsides, fence lines, rights-of-way, and noncrop areas	Cut larger top growth to ground level in spring or early summer; use mowing as a followup treatment at regular intervals throughout the growing season. Tools for cutting include loppers,	Educate road crews to identify and report infestations along roads. Coordinate control efforts with other land managers.	Consider using goats in combination with herbicide spraying. Useful classical biological control agents	Methods include foliar application, basal bark spray, cut-stump; injection, application of herbicide to cut areas. Use targeted application with a

	<p>machetes, brush cutters, and power saws. A cutting method is more effective as a treatment if followed up with chemical treatment.</p>		<p>are currently being researched.</p>	<p>systemic herbicide.</p>
<p>Pasture, rangeland, or riparian corridors</p>	<p>Hand pull or dig out very young seedlings. Older seedlings/saplings need to be root grubbed or girdled at the base.</p> <p>Physical methods alone are generally not recommended as they often result in significant basal and root sprouting. If used, follow up with a chemical treatment.</p>	<p>After removal of treeof-heaven, monitor for root sprouts and seedlings; then cut, pull, or spray them. Bag and dispose of seed in a landfill or by burning.</p> <p>Place signs near trailheads or road corridors; educate public to identify and report infestations.</p>	<p>Same as above.</p>	<p>Methods include foliar application, basal bark spray, cut stump, stem injection. In aquatic or riparian areas, use herbicides approved for use in these areas.</p> <p>For mature trees, apply herbicide in cuts made in the bark by a girdling or drilling method. Grooves in the bark should be made all around the trunk, and the cut should be deep enough to go through the cambial layer down into nonliving layers. Girdle or drill in June and early July.</p>
<p>Forest openings, fields, and/or extensive, dense infestations</p>			<p>Same as above.</p>	<p>Apply herbicide via aerial or broadcast foliar spray, basal bark spray, cut stump, or injection</p>

				method. Avoid desirable tree species, if present.
Wilderness, other natural areas, and/ or small infestations			Same as above.	Individual plant treatment (IPT) methods including foliar application, basal bark spray, cut stump, or stem injection. Leave treated plants in place so they can easily be monitored later for regrowth.

* Choice of a particular management option must be in compliance with existing regulations for land resource.

Grubbing – For saplings or young trees, hand grubbing or mechanical extraction of roots may be effective. However, grubbing is usually not practical for mature trees or dense stands. Removal of the entire root is necessary for control of individual trees.

Mechanical Methods

Mowing – After larger trees have been cut to ground level, resprouting wood is soft enough to be mowed at regular intervals which can stress root reserves and lead to fewer root suckers. However, an infrequent mowing cycle may allow the sprouts to spread and become too tall to mow. Mowing is more effective when followed up with a chemical treatment.

Prescribed Fire

Controlled burning is likely to favor further spread of tree-of-heaven since prolific root and stump sprouting occurs in response to fire stress. Scorching or heat girdling individual plants by using a blowtorch or flamethrower may be an option, but monitoring and treatment of root and stump sprouts as a followup will be required.

Cultural Control

Early detection and plant removal are critical for preventing establishment of tree-of-heaven. Coordination efforts should be made between land managers, the local public, and road crews, etc., on identification of tree-of-heaven so suspected infestations can be reported. Vehicles, humans, and livestock should be discouraged from traveling through infested areas;

and a program to check and remove seeds from vehicles and livestock after going through infested areas should be considered to help stop seed dispersal.

Biological Control

Grazing Tree-of-heaven usually has low palatability for grazers; however, livestock (cattle, sheep, and goats) and deer will consume it during certain times of the year under specific circumstances. Goats will eat leaves and bark. Deer will browse leaves during the summer—especially in shady, forested areas. Under heavy grazing pressure, livestock will remove new suckers and sprouts. Use of grazing in combination with herbicide spraying may be effective in certain situations.

Classical Biological Control

A variety of insects and diseases affect tree-of-heaven with varying success; however, there are no biological control agents currently approved for use in the United States. Table 2 summarizes biological agents currently being researched, which includes three fungal pathogens, two weevils, and a moth. Approval for one of the weevil species, *Euchryptorrhynchus brandti*, is anticipated in the near future. Agents used for biological control in southwestern states should be adaptable to arid environments and local conditions. Public, tribal, and private land managers may obtain biological control agents for release directly from local offices of the USDA Animal and Plant Health Inspection Service (APHIS) when the agents are available. Other sources of biocontrol agents include private companies or locally developed insectaries. A permit must be obtained from APHIS before biological control agents can be transported across state boundaries. Regulations and permit applications (PPQ 526 permit forms) pertaining to interstate shipment of biological control agents can be found on APHIS website at <http://www.aphis.usda.gov/ppq/permits/>. Although biological control agents may be collected and released within a given state without a permit from APHIS, the state's Department of Agriculture or Agricultural Extension Service should be consulted for any regulations relating to movement of these agents inside the state.

Chemical Control

Herbicides are usually the most effective way to kill the root system of mature tree-of-heaven and to control regrowth from cut trees that occurs as sprouts or root suckers. There are several registered products that can be applied in a variety of ways including: (1) foliage application, (2) topical application to cut stems and stumps, (3) injection into the trunk, and (4) basal spraying. Although aboveground portions of tree-of-heaven are relatively easy to suppress or kill with herbicide treatment, it is also important to control the root system. Therefore, special attention should be paid to selection of the correct herbicide, optimal application rate, and appropriate time to get good results. Care should always be taken when spraying any herbicide near nontarget plants. It is important to read and carefully follow all instructions and warnings provided on the herbicide label.

Herbicide

Control Methods Foliar spraying may be used to control younger trees or low growing tree-of-heaven infestations that can easily be covered with a spray solution. Apply herbicide to fully-expanded leaves using individual plant treatment (IPT) with a backpack sprayer or treat clusters of trees using a tractor- or truck-mounted sprayer (broadcast application). Thoroughly wet all green leaves and shoots, especially near the top of the tree.

Table 2. Classical biological control agents

Species	Type of Agent	Site of Attack	Impact on Host	Use/Considerations for Release
<i>Verticillium dahliae</i>	fungal pathogen	roots; xylem	Invades xylem and root system; plant responds by stopping flow of water and nutrients to infected areas. May result in death of all or part of tree.	Fungus persists in soil for 10+ years without host. Currently being researched but not yet approved for use.
<i>Verticillium albo-atrum</i>	fungal pathogen	roots; xylem	Similar to <i>Verticillium dahliae</i> above.	Currently being researched.
<i>Fusarium oxysporum</i>	fungal pathogen	leaves	Fungus causes leaves to turn yellow and drop earlier than normal, followed by the death of branches or whole tree.	Same as above.
<i>Atteva punctella</i>	Ailanthus webworm	leaves	Selectively feeds on male tree-of-heaven plants.	Same as above.
<i>Euchryptorrhynchus brandti</i>	beetle/ weevil	lower trunk; phloem	Eggs laid in phloem under bark.	Release studies nearly complete; approval anticipated for 2011. Studying whether weevil can be used as a vector for <i>V. albo-atrum</i>
<i>Euchryptorrhynchus chinensis</i>	beetle/ weevil	lower trunk; phloem	Eggs are laid in phloem; life cycle completed under the bark which results in death of tree	Currently being researched.

Table 3 provides herbicide recommendations for foliar spraying. The two most common herbicides used on tree-of-heaven with the foliar spray approach are glyphosate and triclopyr. These systemic herbicides are absorbed through leaves and stems and then transported to the root

system. They have low soil activity so they pose little risk to groundwater if applied properly. However, these products can harm other desirable plants and care should be taken not to spray those nearby. When using a backpack sprayer, a 2 percent solution of either glyphosate (e.g., Roundup®) or imazapyr (e.g., Habitat®) is effective on healthy trees that are fully leafed out. Another new herbicide option that has not been widely tested for foliar application is Viewpoint®. This product is a combination of aminocyclopyrachlor, imazapyr, and metsulfuron. Consult the label closely when mixing or applying any herbicide solution. Use of a nonionic surfactant (0.5 percent or as per label) is often recommended to ensure even coverage and, thus, greater herbicide uptake into the leaves. However, some herbicides come premixed with a surfactant; and the label should always be checked for mixing directions.

Basal bark spraying is an effective control method that does not require cutting. This method is optimally used when tree-of-heaven is fully leafed but before it begins to show fall color. However, basal bark spraying can be labor intensive and is most appropriate for treating small infestations or isolated trees, especially those with trunk diameters between 4 and 8 inches. For trunks less than 6 inches in diameter, a continuous 12-inch wide band should be sprayed around the tree base. For trunks greater than 6 inches, apply a 24-inch band. Add a dye to the solution to aid in determining coverage. Consult the herbicide label for mixing and application directions.

The most commonly recommended herbicide for lowvolume basal bark spraying is triclopyr mixed as a 20 percent herbicide:80 percent crop oil solution. Mixing picloram with triclopyr and crop oil as a 20 percent:20 percent:60 percent mixture can improve the effectiveness of control; however, a certified applicator must be used since picloram is a restricted use product. Stalker® (imazapyr) has also been shown to be effective for basal bark control. It can be used alone or in combination with Garlon 4® (triclopyr) at a concentration of 15 percent Garlon 4® and 5 percent Stalker® in 80 percent oil diluent. Complete coverage by wetting around the entire trunk is necessary for good control.

A backpack sprayer fitted with an adjustable cone nozzle can be used for basal bark spraying. Apply herbicide using approximately 30 psi and spray until the bark is wet, but not running off (approximately 3/4 teaspoon of mixture per inch of stem diameter). Leave treated trees standing in place so they can be revisited the next year and, if necessary, new foliage can be spot sprayed.

IPT cut stump treatment is often used in areas where mechanical treatments or foliar applied herbicide spraying are restricted due to logistical considerations or when there is a need to be highly selective for protection of nontarget vegetation. The treatment involves hand cutting or chain sawing a tree as close to the ground surface as reasonable. Herbicide is then applied with a paintbrush, hand-held spray bottle, or backpack sprayer. The cut surface should be horizontal to the ground to minimize runoff, and any residual sawdust over the cut surface should be removed prior to herbicide application. **Herbicide must be applied to the cut surface within 5 minutes after cutting to ensure uptake of the chemical before the plant can seal off the cut area.** For

cut stumps larger than 4 inches in diameter, herbicide should be applied to the cambial layer lying just inside the bark ring. The top, sides, and exposed roots of smaller cut stumps (including those occurring in clumps) should be thoroughly wetted with herbicide. Cut trunks, limbs, and other top growth should then be disposed of in an acceptable manner (e.g., stack piles or chipped).

For cut stump treatments, a solution of triclopyr ester or imazapyr should be used in a mixture with bark oil or crop oil. The herbicide:oil mixture ratio can vary from 33:67 to 50:50 v/v depending on the number and size of plants to be treated and the application technique used. A lower ratio (33:67) is typically used when applications are made with a low volume backpack sprayer or hand-held spray bottle, whereas a higher ratio (50:50) can be used when the solution is brushed directly onto the cut stump. A blue indicator dye should be added to the spray mixture to show that a stump has been treated.

The mortality rate from cut-stump treatments is directly related to care taken when treating cut surfaces. Control can be 60 to 80 percent under optimal conditions, but overall plant kills may be much lower due to difficulties associated with this method. Therefore, followup treatment using ground-based foliar applications should be anticipated.

Girdling or frilling with herbicide is effective for larger diameter trunks (i.e., those over 8 inches) of tree-of-heaven with thicker, more mature bark. Using an ax or hatchet, make a horizontal cut or groove (0.5 to 1.5 inches deep and 2 to 8 inches wide) through bark and cambial tissue around the entire circumference of the trunk. The width and depth of the groove should be in proportion to the tree’s diameter. Girdling can be done more quickly if a chain saw is used to make two horizontal cuts through the bark that are circumferential around the entire trunk; one cut should be 2 to 4 inches above the other. Frilling is a variation of girdling in which the groove made by an ax or hatchet around the tree still has the partially severed bark and wood attached at the bottom of the groove to allow retention of the applied herbicide.

Tree-of-heaven should not be girdled or frilled without chemical treatment as it will respond by producing fast growing root and stem sprouts. **Cut surfaces from girdling or frilling should be sprayed or painted until thoroughly wet with a herbicide solution within 5 minutes.** Commonly used herbicides for this method include a 2 to 5 percent solution with either glyphosate, imazapyr, triclopyr, or picloram with 2,4-D. The most effective time for using this method is during summer (June or early July) when tree-of-heaven has fully leafed out and is actively growing. Leave the tree in place following girdling or frilling to reduce stump sprouting.

Table 3. Herbicide recommendations for foliar spraying

Common Chemical Name (active ingredient)	Product Example ¹	Product Example Rate per Acre (broadcast)	Backpack Sprayer Treatment Using Product Example ²	Time of Application	Remarks

Glyphosate	RoundUp Pro (41%) and others	2–5 quarts	2% (use with 0.5 percent surfactant and a blue indicator dye)	Summer/early fall; apply when tree is actively growing and fully leafed, but before fall color begins.	Nonselective herbicide; overspray can injure surrounding plants and open more area for weeds.
Imazapyr	Arsenal, Habitat, Chopper, Stalker, and others	Arsenal: 1–1.5 pints Chopper: 2–3 pints	Arsenal: 1–5% Chopper: 5%	Same as above.	Nonselective herbicide; overspray can injure surrounding plants and open additional area for weeds. Nontarget plants may also be killed or injured by root transfer of imazapyr between intertwined root systems.
Aminocyclopyrachlor + imazapyr + metsulfuron methyl	Viewpoint	13–20 ounces	Consult label for spot applications.	Apply as high volume or broadcast foliar spray.	Nonselective herbicide used on noncrop sites; may cause temporary injury to some grass species.
Triclopyr	Garlon 4, Remedy, and others	3–6 quarts	1–2%	Summer/early fall; apply when tree is actively growing and fully leafed, but before fall color	Selective, systemic herbicide; will not impact grasses but can harm other trees,

				begins	shrubs, and broadleaf plants.
Dicamba	Vanquish, Banvel, and others	2 quarts	5%	Same as above.	Same as above.

¹ Trade names for products are provided for example purposes only, and other products with the same active ingredient(s) may be available. Individual product labels should be examined for specific information and appropriate use with tree-of-heaven.

² Herbicide/water ratio - As an example, a gallon of spray water with a 3 percent mixture is made by adding a sufficient volume of water to 4 ounces of liquid herbicide until a volume of 1 gallon is reached ($4 \text{ oz} \div 128 \text{ oz/gal} = 0.03$ or 3 percent). For dry formulations, particulates should be added to sufficient water as specified by the label until the required concentration or volume of spray water is reached.

Stem injection (hack-and-squirt) is similar to the frilling method described above except that the bark is not continuously cut around the tree trunk. Using a hand ax or hatchet, a line of downward angled or nearly vertical cuts are spaced about an inch apart around the trunk at a convenient height. Cuts should be made so as to leave a partially severed piece of bark and cambium attached at the bottom of the cut. **With a spray bottle or wand in the other hand, squirt the herbicide directly onto all cut areas within 5 minutes of cutting.** On average, there will be one hack/squirt per each inch of stem diameter. There are some commercially available cutting tools (hatchets) that are equipped to allow the herbicide to be directly injected with each cut. If using a spray bottle, read the herbicide label to determine the exact quantity of chemical to be used in each cut. About 1 milliliter of a fairly concentrated herbicide solution should be applied to each cut. Generally, 1 to 2 squirts from a quart or pint trigger spray bottle is equivalent to 1 to 2 milliliters (1/4 to 1/2 teaspoon). Apply herbicide so that it is wet within the cut, but the solution is not running out. Triclopyr is most often recommended for the hackand-squirt method; however, other herbicides (imazapyr, dicamba, and picloram) may also be used. Glyphosate has usually been found to be not as effective with this cut surface approach.

Control Strategies

Numerous strategies have been used for tree-of-heaven control, and the local situation usually dictates the best approach to follow. A popular approach is to use a basal spray or a cut surface treatment initially and then follow this up later by using a foliar active herbicide to spot spray new seedlings, sprouts, and root suckers. Once controlled, restoration activities may be used to help prevent the problem from re-occurring. This includes establishing a thick cover of competing vegetation (i.e., desirable trees, shrubs, and grasses).

Regardless of the strategy used, the key to successful longterm control of tree-of-heaven is to monitor treated areas for several years after initial treatment. Always be prepared to remove

any new plants quickly. Failure to perform followup monitoring and treatment could result in a return to pretreatment density levels.

References and Further Information

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Suggested Web Sites

For information about calibrating spray equipment:

NMSU Cooperative Extension Service Guide

A-613 Sprayer Calibration at http://aces.nmsu.edu/pubs/_a/A-613.pdf

Herbicide labels online:

<http://www.cdms.net/LabelsMsds/LMDefault.aspx>

Invasive Plant Atlas of the United States:

<http://www.invasive.org/weedus/index.html>

USDA Plants Database:

<http://plants.usda.gov/index.html>