SPECIES: Ailanthus altissima

Choose from the following categories of information.

INTRODUCTORY

SPECIES: Ailanthus altissima

Photo courtesy of David J. Moorehead, Forestry Images

AUTHORSHIP AND CITATION:
Howard, Janet L. 2004. Ailanthus altissima. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [2007, September 24].

FEIS ABBREVIATION:
AILALT

SYNONYMS:
Ailanthus glandulosa [81]
Ailanthus altissima forma *erythrocarpa* (Carr.) Schneider [143]

NRCS PLANT CODE [161]:
AIAL

COMMON NAMES:
tree-of-heaven
tree of heaven
smoke tree
stink tree
Chinese sumac

TAXONOMY:
The scientific name of tree-of-heaven is *Ailanthus altissima* (Mill.) Swingle. It is in quassia (Simaroubaceae), a family of mostly tropical woody plants [35,52,53,58,70,71,106,114,131,151,172,174].

LIFE FORM:
Tree

FEDERAL LEGAL STATUS:
No special status

OTHER STATUS:
As of 2004, tree-of-heaven is listed as noxious in 6 states and 2 Forest Service Regions. It is classified as a severe threat (could spread easily into native plant communities and displace native vegetation) in Virginia [166], Kentucky [88], Tennessee [147,161], and California [161]. The state of Vermont ranks tree-of-heaven as a Category 2 species: having potential to displace native plants on a localized or widespread scale [164]. Tree-of-heaven is also state-listed as an invasive weed in Wisconsin [161].

The Eastern and Southern regions of the U.S. Forest Service rank tree-of-heaven in Weed Category 1: an exotic species known to be invasive and persistent throughout all or most of the Regions. Weed Category 1 species can spread into and persist in native plant communities, displacing native species and posing a demonstrable threat to plant communities. Use of tree-of-heaven is prohibited on National Forest System Lands [159,160].

DISTRIBUTION AND OCCURRENCE

SPECIES: Ailanthus altissima

GENERAL DISTRIBUTION:

Tree-of-heaven is native to Taiwan and central China, where it occurs from 22 to 34^{o} North in latitude [163]. In North America it occurs from British Columbia, southern Ontario, and Massachusetts south to Florida, Texas, and southern California [83,176]. Tree-of-heaven spread in North America apparently followed 3 distinct introductions from China. It was 1st imported to Pennsylvania in 1784 as an ornamental [35,45,72,154,155,169]. Another introduction occurred in New York in 1820, where tree-of-heaven was

again planted as an ornamental [31]. Both eastern introductions were from English stock imported from China. Tree-of-heaven was commercially available in eastern nurseries by 1840, and is now widespread in the Northeast. The 3rd introduction was in California during the mid-1800s gold rush. Chinese immigrating to work in the gold fields and in construction of the transcontinental railroad brought tree-of-heaven to California, probably because of the tree's medicinal and cultural importance in their homeland (see Other Uses) [72,155].

A century after the North American introductions, tree-of-heaven is most common in its initial centers of distribution: the Northeast and California. In the East, it is invasive from New England south to the mid-Atlantic states [45,125]. Tree-of-heaven is frequently found in the Midwest, becoming uncommon in the Great Plains and the South. It is weakly invasive in the Great Plains [58,138] and is rare south of North Carolina in the Southeast and South [39,125,174]. In the West, tree-of-heaven is common in California and locally frequent in Oregon and Washington [45,70]. In California tree-of-heaven occurs in the Bay Area, the Central Valley, and in foothill counties with a history of gold mining [72,81]. In the Pacific Northwest it grows along waterways, including banks of the Snake and Columbia rivers [70]. In the Southwest it occurs in riparian zones and mesic canyons [154]. Plants database provides a map of tree-of-heaven distribution in the United States.

Tree-of-heaven has established in temperate climates throughout the world. Its earliest introductions may have been in Japan and Korea, where it is probably not native [101]. It was introduced in Europe in the 1700s. and became widespread there [88,155]. Introductions in Argentina, Australia, and Africa followed, using seed from European trees [72,74].

Because of its scattered and disjunct distribution in North America, tree-of-heaven occurrence is not well documented for all plant communities where it may occur [112]. The following lists are not restrictive, but include plant communities where tree-of-heaven is a known invader.

ECOSYSTEMS [51]:
FRES12 Longleaf-slash pine
FRES13 Loblolly-shortleaf pine
FRES14 Oak-pine
FRES15 Oak-hickory
FRES17 Elm-ash-cottonwood
FRES18 Maple-beech-birch
FRES20 Douglas-fir
FRES21 Ponderosa pine
FRES28 Western hardwoods
FRES29 Sagebrush
FRES30 Desert shrub
FRES32 Texas savanna
FRES33 Southwestern shrubsteppe
FRES34 Chaparral-mountain shrub
FRES35 Pinyon-juniper
FRES38 Plains grasslands
FRES39 Prairie
FRES42 Annual grasslands

STATES/PROVINCES: (key to state/province abbreviations)
UNITED STATES

AL	AK	AZ	AR	CA	CO	CT	DE	FL	GA
ID	IL	IN	IA	KS	KY	LA	ME	MD	MA

MI	MS	MO	NE	NV	NH	NJ	NM	NY	NC
OH	OK	OR	PA	RI	SC	TN	TX	UT	VT
VA	WA	WV	WI	DC	PR				

CANADA

BC	ON

BLM PHYSIOGRAPHIC REGIONS [12]:
1 Northern Pacific Border
2 Cascade Mountains
3 Southern Pacific Border
4 Sierra Mountains
5 Columbia Plateau
6 Upper Basin and Range
7 Lower Basin and Range
11 Southern Rocky Mountains
12 Colorado Plateau
13 Rocky Mountain Piedmont
14 Great Plains

KUCHLER [95] PLANT ASSOCIATIONS:
K005 Mixed conifer forest
K009 Pine-cypress forest
K023 Juniper-pinyon woodland
K025 Alder-ash forest
K026 Oregon oakwoods
K029 California mixed evergreen forest
K030 California oakwoods
K033 Chaparral
K035 Coastal sagebrush
K036 Mosaic of K030 and K035
K038 Great Basin sagebrush
K048 California steppe
K054 Grama-tobosa prairie
K055 Sagebrush steppe
K056 Wheatgrass-needlegrass shrubsteppe
K058 Grama-tobosa shrubsteppe
K069 Bluestem-grama prairie
K070 Sandsage-bluestem prairie
K074 Bluestem prairie
K081 Oak savanna
K083 Cedar glades
K098 Northern floodplain forest
K099 Maple-basswood forest
K100 Oak-hickory forest
K101 Elm-ash forest
K102 Beech-maple forest
K106 Northern hardwoods
K110 Northeastern oak-pine forest

K111 Oak-hickory-pine
K112 Southern mixed forest

SAF COVER TYPES [40]:
17 Pin cherry
23 Eastern hemlock
24 Hemlock-yellow birch
25 Sugar maple-beech-yellow birch
26 Sugar maple-basswood
27 Sugar maple
28 Black cherry-maple
39 Black ash-American elm-red maple
40 Post oak-blackjack oak
46 Eastern redcedar
50 Black locust
52 White oak-black oak-northern red oak
53 White oak
57 Yellow-poplar
58 Yellow-poplar-eastern hemlock
59 Yellow-poplar-white oak-northern red oak
60 Beech-sugar maple
61 River birch-sycamore
63 Cottonwood
64 Sassafras-persimmon
65 Pin oak-sweetgum
70 Longleaf pine
72 Southern scrub oak
75 Shortleaf pine
76 Shortleaf pine-oak
79 Virginia pine
80 Loblolly pine-shortleaf pine
82 Loblolly pine-hardwood
83 Longleaf pine-slash pine
84 Slash pine
85 Slash pine-hardwood
87 Sweetgum-yellow-poplar
93 Sugarberry-American elm-green ash
94 Sycamore-sweetgum-American elm
108 Red maple
109 Hawthorn
110 Black oak
221 Red alder
222 Black cottonwood-willow
233 Oregon white oak
234 Douglas-fir-tanoak-Pacific madrone
235 Cottonwood-willow
239 Pinyon-juniper
243 Sierra Nevada mixed conifer
245 Pacific ponderosa pine
246 California black oak
248 Knobcone pine

249 Canyon live oak
250 Blue oak-foothills pine
255 California coast live oak

SRM (RANGELAND) COVER TYPES [146]:
201 Blue oak woodland
202 Coast live oak woodland
203 Riparian woodland
204 North coastal shrub
205 Coastal sage shrub
206 Chamise chaparral
214 Coastal prairie
215 Valley grassland
401 Basin big sagebrush
412 Juniper-pinyon woodland
413 Gambel oak
422 Riparian
502 Grama-galleta
504 Juniper-pinyon pine woodland
505 Grama-tobosa shrub
601 Bluestem prairie
602 Bluestem-prairie sandreed
604 Bluestem-grama prairie
611 Blue grama-buffalo grass
612 Sagebrush-grass
703 Black grama-sideoats grama
705 Blue grama-galleta
706 Blue grama-sideoats grama
707 Blue grama-sideoats grama-black grama
708 Bluestem-dropseed
709 Bluestem-grama
710 Bluestem prairie
714 Grama-bluestem
715 Grama-buffalo grass
716 Grama-feathergrass
805 Riparian
809 Mixed hardwood and pine
812 North Florida flatwoods

HABITAT TYPES AND PLANT COMMUNITIES:
Tree-of-heaven is most common in urban areas [75]. It may be an important, occasional, to minor component of wildland vegetation anywhere within its North American range [112]. In wildlands of the **East** and **Midwest**, tree-of-heaven is a common component in oak-hickory (*Quercus-Carya* spp.) and maple-birch-beech (*Acer-Betula-Fagus* spp.) forest canopies [153]. For example, tree-of-heaven has infested hundreds of acres of oak-hickory forest in Shenandoah National Park, Virginia [104,162]. Tree-of-heaven is frequently associated with black locust (*Robinia pseudoacacia*), a native early successional species, and nonnative Norway maple (*Acer platanoides*), in eastern oak-hickory forests [23,24,60,130]. Other early seral associates are black cherry (*Prunus serotina*), gray birch (*Betula populifolia*), sweetgum (*Liquidambar styraciflua*), and eastern redcedar (*Juniperus virginiana*) [60]. In oak-hickory woodlands of Gettysburg National Military Park, Pennsylvania, tree-of-heaven associates in the overstory with black oak (*Q. velutina*), red oak (*Q. rubra*), scarlet oak (*Q. coccinea*), mockernut hickory (*C. tomentosa*), and bitternut hickory (*C.*

cordiformis). Weedy invaders other than tree-of-heaven include Japanese barberry (*Berberis thunbergii*) and multiflora rose (*Rosa multiflora*). Late-successional understory species include white ash (*Fraxinus americana*), black cherry, sassafras (*Sassafras albidum*), and boxelder (*Acer negundo*) [43]. In white oak-red oak-sugar maple (*Acer saccharinum*) forests of Ohio, tree-of-heaven occurs with American elm (*Ulmus americana*), hickories (*Carya* spp.), black locust, black walnut (*Juglans nigra*), and black cherry [33].

On the **Georgia Piedmont**, tree-of-heaven is an important species in early successional loblolly pine (*Pinus taeda*)-black oak-white oak forests. Flowering dogwood (*Cornus florida*), yellow-poplar (*Liriodendron tulipifera*), Chinese privet (*Ligustrum sinense*), and winged elm (*U. alata*) are common associates [27].

Tree-of-heaven is invasive in riparian zones of the **Southwest** and elsewhere [69,142]. In the middle Rio Grande Basin of New Mexico, tree-of-heaven occurs in Fremont cottonwood-Rio Grande cottonwood-sandbar willow (*Populus fremontii-P. deltoides* var. *wislizenii-Salix exigua*) bosques along with nonnative, invasive Siberian elm (*U. pumila*) and white mulberry (*Morus alba*) [48]. Tree-of-heaven has invaded arroyos of the Sandia National Laboratory, New Mexico, associating with Siberian elm, saltcedar (*Tamarix ramossima*), Apache plume (*Fallugia paradoxa*), and fourwing saltbush (*Atriplex canescens*). Upland, it associates in Colorado pinyon-oneseed juniper (*Pinus edulis-Juniperus monosperma*) stands with Gambel oak (*Quercus gambelii*) and Siberian elm [108].

In southern **California**, tree-of-heaven frequently associates with Fremont cottonwood, California sycamore (*Platanus racemosa*), mule fat (*Baccharis salicifolia*), and poison-oak (*Toxicodendron diversilobum*). A 1990-1992 survey in Chino Hills State Park showed 15% frequency for tree-of-heaven, with its geographic range and "vigor" increasing over the study period [87].

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Ailanthus altissima

Photo courtesy of Chuck Bargeron, Forestry Images

GENERAL BOTANICAL CHARACTERISTICS:
The following description of tree-of-heaven provides characteristics that may be relevant to fire ecology, and is not meant for identification. Keys for identification are available (e.g. [35,52,53,69,106,172,174]).

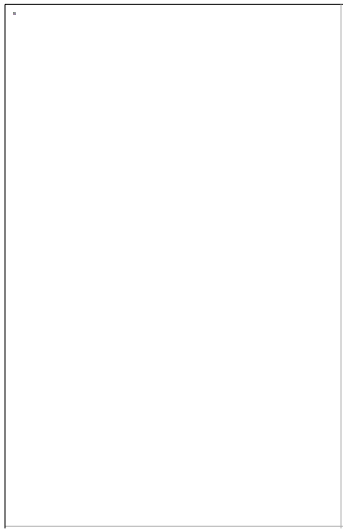
Tree-of-heaven is a nonnative, deciduous tree. It may reach 60 to 70 feet (18-21 m) in height, 80 feet (24 m) in crown width, and 3 feet (0.9 m) in trunk diameter at maturity [35,53,165]. The champion tree is in Tennessee, and reaches 67 feet (20 m) in height, 64 feet (19 m) in spread, and 20.6 feet (6.3 m) in diameter [73]. Trees may be shrubby when suppressed or regularly pruned [52]. Tree-of-heaven has smooth, thin bark

and a straight bole. Branches are brittle and self-pruning. The large, malodorous leaves are pinnately compound, with prominent glands on the back of each leaflet. Surface-to-volume ratio of leaves is high: leaflets range from 15 to 41 in number, and total leaf length may reach 3 feet (1 m) [35,52,53,165]. Leaf stipules have nectaries that excrete sugars [14].

Most flowers are unisexual, but some trees may have perfect flowers [176]. The inflorescence is a 0.3- to 0.6-foot (10-20 cm) panicle with 6- to 8-mm-long flowers. Staminate flowers have a strong, objectionable odor. Fruits grow in clusters of 1-seeded, dry schizocarps
with wings. They are 2.5 to 5 cm in length and propeller-shaped, resembling maple (*Acer* spp.) fruits [35,52,69,71,77,79,131,172]. A fruit cluster contains hundreds of seeds [88] that average 0.6 × 0.25 cm in size [5] and 27 mg in mass [107].

Roots are shallow, widely spreading, and capable of sprouting [112]. Young trees have a taproot and several large laterals [123,129,130], although the taproot may diminish with tree age [112]. Ramets do not have taproots. In dry, rocky soil or beneath pavement, trees grow long horizontal roots that do not branch until more favorable soil is found [123,129,130]. Roots near the trunk thicken with age, serving as storage organs. Most roots occur in the upper 18 inches (46 cm) of soil. Deep roots send out smaller roots that grow near the soil surface; adventitious shoots generally arise from these shallow roots [112].

Stand structure: Tree-of-heaven typically occurs in clumps, although it may form rows along streams, roads, and fences and occasionally grows as widely spaced, single stems. Clumping can result from an even-aged seedling establishment or from colonial expansion through root sprouting [130]. Open-grown colonies may eventually become dense by sprouting. Davis [30] observed a half-acre (0.2 ha) stand in Kentucky consisting of 32 stems. Stands subject to infrequent control measures may develop into even-aged thickets. Untreated stands self-thin, eventually forming uneven-aged sprouts. Two years after tree harvest in Pennsylvania, tree-of-heaven sprout density was 17,860 2-year-old sprouts/acre (mean height=9 feet) and 10,019 1-year-old sprouts/acre (mean height=2 feet). After 3 years many of the sprouts had died, so dead stems were more common than live stems [80]. Sprouts volunteering in closed-canopy understories remain suppressed and few in number. For example, Hunter [78] reports single-stem tree-of-heaven growth, rather than thickets, in the understory of an undisturbed mixed-evergreen forest in northern California.



Investigations of tree-of-heaven in China give little clue as to the species' natural growth habit. Tree-of-heaven grows in a densely populated area of China where no wildlands are left. As valued ornamentals, mature trees-of-heaven in China are pruned to aesthetically pleasing, single-stemmed forms. Sprouts are harvested for firewood and medicinal uses [74,130].

Life span: Tree-of-heaven is typically short lived, with an average life span of 30 to 50 years [88,112]. Cloning from root sprouts can extend ramet life hundreds of years [78]. Sprouts from the 1st tree-of-heaven in North America, planted in Philadelphia's Bartram Botanical Garden 1784, still exist today [23].

Physiology: Tree-of-heaven appears to be allelopathic [32,97,100,109,111,115]. Chemical extracts from the leaves, barks, roots, and seeds have inhibited germination and growth of other species in the laboratory [64,65,66,97]. Allelopathic chemicals (ailanthone and other compounds identified in [5,6,32,109]) are most

concentrated in roots, with young ramets producing more toxins than older trees [64,97]. Reciprocal transplant experiments [25] may help determine the degree of tree-of-heaven allelopathy under natural conditions.

Open-grown trees-of-heaven are highly efficient at photosynthesis, and store large quantities of photosynthate in stems and roots [14,17,18,103,110]. Foliar nectaries appear to maintain carbohydrate balance during growth and flower initiation by excreting photosynthates [15].

Tree-of-heaven is sensitive to ozone pollution [55]; however, it is highly tolerant of most industrial pollutants [110,133]. In a highly polluted area of Armenia, tree-of-heaven showed the least damage and best growth of 8 urban tree species (Derojan, as cited in [45]).

RAUNKIAER [134] LIFE FORM:
Phanerophyte
Geophyte

REGENERATION PROCESSES:
Tree-of-heaven reproduces from seed and root sprouts [35,69,169]. Both methods are important to tree-of-heaven's invasiveness and reproductive success [130].

Breeding system: Tree-of-heaven is mostly dioecious. Rarely, either bisexual trees or trees with both bisexual and unisexual flowers are found [35,52,78,112,176].

As with most species with wind-dispersed seed, tree-of-heaven appears to have a relatively uniform genetic system, with most diversity occurring among rather than within populations [46,130]. Because North American tree-of-heaven populations originated from only 3 introductions [35,72,155,169], they may be even less genetically diverse than native Asian populations. A comparison of seedlings germinated from seed collections from 5 locations across the United States and 5 locations across China showed significant differences in height growth (p=0.01), root:shoot ratios (p=0.05), and leaf area (p=0.05) among United States and Chinese seedlings. Populations from the United States were taller, allocated relatively less biomass to roots than stems, and had greater leaf areas, compared to Chinese populations [46]. In a common garden study comparing seedling populations within the United States, Feret and others [47] found California populations were significantly (p=0.01) taller than eastern populations. Seed width and biomass were correlated with latitude (t=0.96), with northern populations having the widest, heaviest seeds. Feret [45] found some tree-of-heaven seed and seedling growth characteristics of provenances from the East and California appeared random, and were not correlated (nor appeared best adapted) to site or geographic location. He reported significant differences between North American and Chinese tree-of-heaven provenances for seed and seedling characteristics. Contrary to expectations, allozyme analysis showed no evidence of inbreeding depression in North American provenances compared to native Chinese provenances.

Pollination: Tree-of-heaven is pollinated by a variety of nectar- and pollen-feeding insects [120]. Although disagreeable to humans, the strong odor of male flowers attracts honey bees, beetles, and other insects [112].

Seed production:

Tree-of-heaven produces many small, light seeds. Flower, fruit, and seed production begin early. Six-week-old seedlings have flowered in the greenhouse [44], and 1-year-old saplings and 2-year-old root sprouts have been observed with fruit [78,88,147]. Trees in California produce viable seed by 10 years of age [78]. Best seed production is from 12 to 20 years of age [112]. In France, which has a climate similar to California, 1.6- to 3.3-foot-long (0.5-1 m) root sprouts produced seeds [14]. Mature female trees may produce several hundred inflorescences in a year. Hunter [78] reports 5-year production of a female tree in

Martinez, California, as 150, 183, 219, 439, and 56 inflorescences. An individual flower contains hundreds of seeds, so individual trees can produce 325,000 or more seeds per year [14,78]. Illick and Brouse [80] estimated that a small, 12-inch-diameter (30-cm) tree in Pennsylvania produced over a million seeds. Most seed are viable, even those that overwinter on the tree and disperse in spring [78,102]. Repeated top-kill lowers seed production [112].

Seed dispersal: The winged fruits are easily and widely dispersed by wind [39,88]. Water and machinery also disperse seeds [124]. In the laboratory, Matlack [107] reported the following dispersal characteristics for tree-of-heaven seed collected in Delaware (data are means and 1 standard deviation):

Rate of descent	Lateral movement in still air	Lateral distance in a 10 km/hr breeze (estimated)
0.56 m/sec (0.09)	0.87 m (0.10)	111.6 m

Distance traveled was significantly greater ($p<0.05$) compared to seed of 37 other wind-dispersed species [107]. On Staten Island, New York, tree-of-heaven seedlings volunteered on a restored landfill site planted to native woody species. A year after restoration plantings, tree-of-heaven count on fifty 10 × 30 meter plots totaled 65 seedlings, the 6th highest among 32 naturally regenerating taxa. Distance to the nearest seed-bearing tree-of-heaven was 299 feet (70 m) [137].

In Ithaca, New York, new tree-of-heaven seed clusters often fell and dispersed in clumps, resulting in patches of closely related seedlings. Seeds dispersed individually as the fruit clusters disintegrated over the winter [123].

Seed banking:

Seeds retain dormancy for less than a year, so seeds do not build up long-term seed banks [79,93]. Tree-of-heaven does establish temporary soil seed banks from on- and off-site sources of seed [176]. In Tennessee, for example, Dobberpuhl [37] found viable tree-of-heaven seed in the soil seed bank. There were no trees-of-heaven in the overstory.

Germination:

Hand-collected, freshly dried tree-of-heaven seed yields 60% to 85% germination in the laboratory [112,165]. Hunter [78] reports 30% germination of seeds that overwintered on the tree and dispersed in spring. Tree-of-heaven embryos are dormant, and stratification improves germination rates [56,78,112]. Seed can germinate in highly compacted soil [130], and is salt tolerant. Studies of eastern hardwood species found roadside salt does not appreciably affect tree-of-heaven germination; native oak and birch seed is far more adversely affected by salt [13]. The tree-of-heaven embryo is well equipped for rapid growth. Although it lacks an endosperm, it has 2 large cotyledons with stored oils [52,92,105,112,176]. Litter has both negative and positive effects on germination. In eastern deciduous forests, oak (*Quercus* spp.) leaf litter has been shown to delay tree-of-heaven germination and increase mortality, but not affect subsequent biomass of surviving seedlings [41]. Litter may have positive effects on tree-of-heaven germination and establishment by reducing competition from herbaceous species [42].

Seedling establishment/growth:

Although seed production is prolific, tree-of-heaven seedling establishment is infrequent on many sites [124]. Dry climate may limit tree-of-heaven recruitment in the Great Plains and the arid West [45,124]. Even so, tree-of-heaven has successfully expanded its range through seed spread [89,128,137,139], and seedling establishment appears to be more common than indicated in general literature [88,147]. For example, in a root excavation study, Knapp and Canham [89] found initial tree-of-heaven recruitment in New York eastern hemlock forest gaps was from off-site seed, not root sprouts.

Whether initial regeneration is accomplished from seed or by cloning, once established, tree-of-heaven growth is extremely rapid. It may be the fastest-growing tree in North America [89,127]. Both the species' common and scientific (*Ailanthus*, sky-tree) names refer to its ability to attain height quickly [35,165]. Seedlings attain 3.3 to 6.6 feet (1-2 m) in their 1st year [112]. Growth of tree-of-heaven seedlings relative to native sweetgum (*Liquidambar styraciflua*) and nonnative Norway maple seedlings 2 years after planting in a New York City common garden was [123]:

	Lateral root length (cm)		Shoot length (cm)	
	Mean	Minimum/ maximum	Mean	Minimum/ maximum
tree-of-heaven	114.4	53/ 200	82.2	31/ 172
sweetgum	23.8	2/ 46	51.0	12/ 77
Norway maple	33.2	14/ 66	36.1	23/ 49

Saplings average an additional meter of height growth per year for at least 4 years [1]. Relatively rapid growth continues for pole-sized trees: in New York, pole-size trees-of-heaven growing in canopy gaps gained 2 to 4 mm of radial growth annually, the highest rate recorded for the 6 tree species measured (the other 5 species were native) [89]. In a New England survey, tree-of-heaven reached 33 to 49 feet (10-15 m) in height and 3.7 to 4.3 inches (9-11 cm) dbh in 30 years [1]. Growth is fastest in California trees, which are typically 35 to 63 feet (10-20 m) high by 12 to 20 years of age [79]. Growth slows greatly after age 20 to 25, with height increases of 3 inches (7.6 cm) or less per year [80]. Once established, tree-of-heaven density increases by root sprouting. One ramet may occupy over an acre (0.4 ha). Sprout growth slows to several centimeters per year if sprout stems become shaded [79]. In West Virginia, Kowarik [91] reported an average growth rate of 0.36 foot/year (0.11 m) for tree-of-heaven sprouts suppressed in the understory of an oak (*Quercus* spp.)-sugar maple forest.

Cattle, deer, and small rodent browsing may retard tree-of-heaven establishment and growth [122]. Browsing effects probably vary by site and animal density. In a New York oak-hickory woodland, Forgione [49] found no significant differences in tree-of-heaven seedling establishment on open plots and plots exclosed to white-tailed deer.

Asexual regeneration: Tree-of-heaven sprouts from the roots, root crown, and bole [45,98]. Although tree-of-heaven reproduces well from seed, sprouting is the more common method of regeneration [88]. In Ithaca, New York, 42% of 1-year-old, excavated tree-of-heaven stems were seedlings, and 58% were root sprouts [123]. Young trees, cut to the root crown before bark becomes thick and corky, often sprout from both the root crown and roots [88,147]. Bole damage promotes root, root crown, and bole sprouting [78,88]. Complete top-kill of the root crown by fire, frost, or other means usually results in prolific root sprouting [112]. Top-growth damage is not necessary for root sprouting to occur, however. Even as seedlings, trees-of-heaven produce horizontal roots capable of sprouting [23]. Root sprouting is an uncommon regeneration strategy for woody species (e.g., see FEIS reviews on quaking aspen and Sierra mountain misery (*Chamaebatia foliolosa*)), but it is a powerful strategy for species employing it. Roots have more nutrient- and photosynthate-storing capacity than rhizomes, conferring better protection from aboveground disturbances such as fire, and a more vigorous sprouting response after top-kill has promoted sprouting by removing apical dominance [84,85].

With tree-of-heaven's spreading root system, root sprouts may appear as far as 50 to 90 feet (15-27 m) from the parent stem [80,88,147]. Sprouts of all types (root, root crown, or bole) generally grow faster than seedlings. In the East, average rate of growth is reported as 6 feet (1.8 m) per year for bole sprouts, 2.7 feet (0.8 m) for root sprouts, and 1.3 feet (6.5 m) for seedlings [80]. Root sprouts in California may exceed 3.5

feet (1 m) in their 1st year [78]. During drought, tree-of-heaven pulls stem water into roots and begins stem die-back. Stem die-back may be extensive during extended droughts, but tree-of-heaven typically survives drought by sprouting from the roots when there is sufficient water to support new growth. Frost die-back and regrowth is common in tree-of-heaven's northern limits [45].

On the Himalayan foothills of India, trees-of-heaven with root crown girths between 12 and 16 inches (30 and 40 cm) showed greatest root sprout production following road construction. Trees in the largest-diameter class did not produce sprouts. Mean sprout production was [96]:

Girth class (cm)	sprouts/root	Sprout height (cm)	Sprout root crown diameter (cm)
10-20	1.0	55.00	0.65
20-30	2.0	55.50	0.68
30-40	3.5	65.11	0.78
40-50	1.0	62.50	0.76
50-60	0.5	64.00	0.70
60-70+	0	----	----

SITE CHARACTERISTICS:
Little information is available on tree-of-heaven's natural habitat in China [72], but tree-of-heaven has a wide ecological amplitude in North America. Kowarik [90] views human settlements as centers of distribution for tree-of-heaven, with roads providing the migration routes. Tree-of-heaven occupies a wide range of conditions, from very poor to very productive sites. In Ithaca, New York, tree-of-heaven was significantly correlated (p=0.05) with urban areas where rooting space was limited and other species could not establish [123,129]. In Central Valley of California, tree-of-heaven has an 8-month growing season and grows in soils that are among the most nutrient-rich and productive in the world.

Tree-of-heaven has been termed "the most adaptable and pollution tolerant tree available" [36]. Highly tolerant of industrial gases, dust, and smoke, tree-of-heaven is common on disturbed sites, especially alleyways, roadsides, and fence rows [35,53,58,114,174]. In wildlands, tree-of-heaven occurs on disturbed sites, open woodlands, and riparian zones [58,70,151,169]. In the Southwest, tree-of-heaven invades canyons, arroyos, and riparian zones including the banks of the Rio Grande [3,108]. After Hurricane Camille, it was associated with debris avalanche chutes in Virginia [76]. Tree-of-heaven occurrence in an oak-hickory forest of West Virginia was also associated with disturbance [75]:

Habitat	Percent occurrence
roadsides	26
streams	19
mature forest	13
open forest	7
railroad rights-of-way	6
trails	3
old fields	0
residential	6
other	20

Soils/topography: Tree-of-heaven tolerates a wide range of soil conditions [39,112]. For example, in oak-hickory woodland of Sussex County, New Jersey, tree-of-heaven occurs in permanently swampy, ridgebottom soils of an abandoned Boy Scout camp [10]. At the other moisture extreme, large, water-storing roots enable tree-of-heaven to tolerate dry, rocky soils and extended drought. Even seedlings show drought tolerance, often volunteering in pavement cracks and other dry sites [57,156]. In Kansas, mature eastern redcedar and tree-of-heaven showed best survivorship to the drought of 1934 compared to associated tree species [149].

Tree-of-heaven also tolerates a range of nutrient conditions. Best growth occurs on nutrient-rich, loamy soils such as those in the Central Valley of California, but tree-of-heaven tolerates nutrient-poor soils [45,88,112,176]. In reclamation studies, tree-of-heaven tolerated acid mine spoils better than calcareous spoils, and grew on low-phosphorus soils [112]. Tree-of-heaven can grow on soils as low as 4.1 pH, in soluble salt concentrations of 0.25 mmhos/cm, and in soils with phosphorus levels as low as 1.8 ppm [128]. It tolerates compacted soils [123].

Tree-of-heaven's spreading root system permits establishment and growth on cliff faces and other steep inclines [4].

Climate: Tree-of-heaven is the only species in its genus that tolerates cold climates [74]. Climate within tree-of-heaven's North American distribution varies widely, from subtropical and wet in Florida, arid in the Great Plains and Great Basin, to cold and wet in the Northeast. Tree-of-heaven tolerates as little as 14 inches (360 mm) of annual precipitation under 8 months of drought in the arid West, and as much as 90 inches (2,290 mm) annual precipitation in the Appalachian Mountains. Annual mean maximum and minimum temperatures are 15 and 97 ^{o}F (-9 and 36 ^{o}C). Large, water-storing roots confer drought tolerance. Extreme cold and prolonged snow cover restrict its occurrence to lower slopes in mountainous regions, as seedlings are not cold resistant. Tree-of-heaven may be able to colonize cold regions that experience several successive years of mild climate [112].

Elevation: Tree-of-heaven grows from 4,900 to 5,900 feet (1,500-1,800 m) elevation in China [163]. It is reported at the following elevations in the western United States:

State	elevation
California	< 6,600 feet (2,000 m) [69,79]
New Mexico	4,500-7,000 feet (1,400-2,100 m) [106]
Utah	790-5,900 feet (780-1,800 m) [172]

SUCCESSIONAL STATUS:
Tree-of-heaven is an early successional species [137]. Starting with a few stems along roadside or woodland edges, tree-of-heaven may encroach into meadows, woodlands, and open forests [88,131,147]. It commonly invades open eastern hardwood forests, eventually sharing the canopy with native hardwoods [151]. As of this writing (2004), tree-of-heaven and empress tree (*Paulownia tomentosa*) are the 2 most successful nonnative trees invading hardwood forests in the East [120], where it often invades after tree harvest or other disturbance [112,137]. Huebner [75] found tree-of-heaven was significantly ($p<0.05$) associated with either highly disturbed or urbanized counties in West Virginia. On logged sites on the Jefferson National Forest, Virginia, tree-of-heaven was most common on clearcut plots, less common on low-leave shelterwood plots, and least common on high-leave shelterwood plots, respectively [24]. It is widely reported from Natural Areas nationwide [132].

Tree-of-heaven rarely invades closed-canopy, late-successional hardwood forests, but can invade old-growth

canopy gaps created by windstorms, gypsy moth or woolly adelgid defoliation, or fire [18,88,89,91,121]. Its growth rate is such that tree-of-heaven reaches the surrounding canopy rapidly, without further need of disturbance [89]. Besides its genetic capacity for growth, its relative unpalatability compared to associated hardwood species may confer further growth and successional advantage to tree-of-heaven in eastern hardwood forests with dense white-tailed deer populations [49,89].

Tree-of-heaven also occurs in middle old-field succession. It is not reported in very early old field succession, but was found in Pennsylvania old fields that were abandoned approximately 20 years before the old field survey. At 20 years, hardwoods were forming a 23- to 39-foot (7-12 m) canopy over the old fields. Tree-of-heaven was common in these early hardwood stands [86]. Once established, tree-of-heaven can invade the surrounding understory by root sprouts, which grow slowly but persist under low light conditions. A stand-replacement disturbance such as fire, insect attack, or hurricane releases tree-of-heaven. Tree-of-heaven chute colonization rate 10 years after Hurricane Camille was [76]:

	Frequency (%)	Density (stems/ha)	Relative cover (%)	Importance value
Site 1	11.9	671	4.1	14.6
Site 2	18.8	1,667	2.0	

Tree-of-heaven is intolerant of deep shade [49,61,91]. Seed plantings in New Jersey plant communities showed best tree-of-heaven establishment was in an open-grown herbaceous community, with intermediate establishment in an eastern redcedar/little bluestem woodland (*Juniperus virginiana/Schizachyrium scoparium*) and least establishment in a closed-canopy oak-hickory forest. Mortality rate was over 90% for experimentally planted tree-of-heaven seed planted under a closed-canopy oak-hickory forest [49]. Similarly, mortality of naturally established tree-of-heaven seedlings under an oak (*Quercus* spp.)-maple sugar canopy in West Virginia was 100%. Although tree-of-heaven cannot successfully regenerate from seed under its own canopy [91], it does produce under-canopy sprouts [67,78,91]. Without canopy-opening disturbance, under-canopy sprouts remain suppressed and grow slowly [61,78,91]. For example, in a mid-successional mixed oak-hickory forest in southern Illinois, tree-of-heaven was scarce, with 2.5 stems/ha, relative dominance of 0.1%, and relative importance of 0.4% [99]. Tree-of-heaven does not photosynthesize efficiently in shade [17,18]. Bourdeau and Laverick [18] found high light compensation points for tree-of-heaven in the laboratory. Shaded sprouts respond to release [91].

Tree-of-heaven's reputed allelopathy may slow succession in plant communities where it is invasive [64,88]. Concentration of allelopathic chemicals is highest in young tree-of-heaven stands [23,97]. Seasonally, toxins are greatest in spring and decline as the growing season progresses. Allelopathic chemicals are present in all portions of the tree, but are most concentrated in roots. The litter is also allelopathic. For example, slash (*Pinus elliottii*) and Monterey pine (*P. radiata*) seed germination is inhibited by fresh tree-of-heaven litter. The allelopathic effect dwindles through the growing season. By fall (when pine seeds would not normally germinate), pine seed germination is no longer inhibited by tree-of-heaven litter [168].

SEASONAL DEVELOPMENT:
Leaf expansion begins in early spring, and flowering and pollination follow in late spring [78,112]. Seed ripening begins in late summer and continues through fall. Fruits usually persist on female trees through winter, but may disperse anytime from October through the next spring [112]. Entire seed clusters may break off and disperse as a unit. In New York, seed clusters were more likely to break off in fall, while individual seeds were more likely to persist until spring, when their peduncles had deteriorated [123].

The following table shows tree-of-heaven phenological events by state and region:

Area	Event	Time
Arkansas	flowers	April-May
	fruits	Sept.-spring [77]
California	flowers	May
	seeds ripen	Sept.-Oct. [79]
Carolinas	flowers	late May-early June
	fruits	July-Oct. [131]
Florida	flowers	spring [174]
Illinois	flowers	June-July [114]
New Mexico	flowers	June-July [106]
New York	seeds germinate	June
	seeds disperse	Oct.-April [130]
Texas	flowers	April-May
	fruits	Sept.-Oct. [165]
West Virginia	flowers	June-July [151]
Great Plains	flowers	mid-May-June [58]
New England	fruits	mid-Aug.-mid-Oct. [143]
Pacific Northwest	flowers	June-July [70]
Southeast	flowers	May-July [39]

FIRE ECOLOGY

SPECIES: Ailanthus altissima

FIRE ECOLOGY OR ADAPTATIONS:

Fire adaptations: Tree-of-heaven sprouts from the roots, root crown, and bole after top-kill by fire [98,167]. To date (2004), studies on postfire growth rates and competitive ability are lacking for tree-of-heaven. It is likely, however, that given tree-of-heaven's large, extended root system [112,123,129,130] and its ability to root sprout and show increased growth rates under fertilization [63], tree-of-heaven would flourish in postfire environments. Apparently the fastest-growing tree in North America [89,127], tree-of-heaven would probably outcompete native woody species for light and the flush of nutrients that occurs after fire. Studies on the fire ecology of tree-of-heaven are needed.

Flammability

of tree-of-heaven is not reported in the literature as of this writing. Its growth habit and stand structure suggest that once ignited, tree-of-heaven stands probably burn easily. The trees have large, finely divided leaves [35,52,53,131,165] that provide a surface-to-volume ratio favorable for ignition and burning. The trees produce prodigious litter, not only from the large leaves, but also from broken branches in all size classes. Downed woody fuels are common in tree-of-heaven stands. The brittle branches break easily even when green, and branch die-back from drought or frost is common [78,80].

Fire regimes:

Tree-of-heaven is native to a long-settled, densely populated region of China. Although its pharmacological use is mentioned in early Chinese writings, early references about its ecology have not been found [74]. Its native fire regime is lost to prehistory. Its ability to sprout from photosynthate-storing roots and establish from off-site, wind-dispersed seed; its extraordinarily rapid growth rate; early age of seed production; and its appearance in early successional plant communities in North America (see Botanical and Ecological Characteristics) suggest tree-of-heaven has been subject to evolutionary pressures of frequent, stand-replacement disturbances. Tree-of-heaven shows flooding tolerance [10], but its consistent association in upland habitats may indicate a past association in both flood-prone and fire-prone ecosystems.

In North America, tree-of-heaven has invaded ecosystems where, for the most part, historic fire regimes are no longer functional (e.g., see [7,126,170,173]). It is difficult to assess how tree-of-heaven may further alter historic fire regimes in ecosystems and plant communities where it is present. It may encourage fire spread in eastern hardwood forests, since its propensity to self-prune and grow in thickets can alter historic stand structure. Its impact in the arid West, where tree-of-heaven growth is more restricted to mesic sites and riparian zones [78], is even more difficult to judge. Further information, especially on postfire response of tree-of-heaven, is needed on how tree-of-heaven affects fire regimes in North America.

The following table provides historic fire return intervals for plant communities and ecosystems where tree-of-heaven may be important. For further information on fire regimes in these communities or ecosystems, see the corresponding FEIS summary for the dominant taxa listed below. If you are interested in the fire regime of a plant community that is not listed here, please consult the complete FEIS fire regime table.

Community or Ecosystem	Dominant Species	Fire Return Interval Range (years)
maple-beech-birch	*Acer-Fagus-Betula*	> 1,000
sugar maple	*A. saccharum*	> 1,000
sugar maple-basswood	*A. saccharum-Tilia americana*	> 1,000 [170]
California chaparral	*Adenostoma* and/or *Arctostaphylos* spp.	< 35 to < 100 [126]
bluestem prairie	*Andropogon gerardii* var. *gerardii-Schizachyrium scoparium*	< 10 [94,126]
sagebrush steppe	*Artemisia tridentata/Pseudoroegneria spicata*	20-70 [126]
basin big sagebrush	*A. tridentata* var. *tridentata*	12-43 [141]
coastal sagebrush	*A. californica*	< 35 to < 100 [126]
plains grasslands	*Bouteloua* spp.	< 35
blue grama-buffalo grass	*B. gracilis-Buchloe dactyloides*	< 35 [126,173]
grama-galleta steppe	*Bouteloua gracilis-Pleuraphis jamesii*	< 35 to < 100
blue grama-tobosa prairie	*B. gracilis-Pleuraphis mutica*	< 35 to < 100 [126]
sugarberry-America elm-green ash	*Celtis laevigata-Ulmus americana-Fraxinus pennsylvanica*	< 35 to 200
beech-sugar maple	*Fagus* spp.-*Acer saccharum*	> 1,000 [170]
California steppe	*Festuca-Danthonia* spp.	< 35 [126,150]
black ash	*Fraxinus nigra*	< 35 to 200 [170]
cedar glades	*Juniperus virginiana*	3-7 [62,126]

yellow-poplar	*Liriodendron tulipifera*	< 35
shortleaf pine	*Pinus echinata*	2-15
shortleaf pine-oak	*P. echinata-Quercus* spp.	< 10
slash pine	*P. elliottii*	3-8
slash pine-hardwood	*P. elliottii*-variable	< 35 [170]
longleaf-slash pine	*P. palustris-P. elliottii*	1-4 [118,170]
longleaf pine-scrub oak	*P. palustris-Quercus* spp.	6-10 [170]
Pacific ponderosa pine*	*P. ponderosa* var. *ponderosa*	1-47 [7]
loblolly pine	*P. taeda*	3-8
loblolly-shortleaf pine	*P. taeda-P. echinata*	10 to < 35
sycamore-sweetgum-American elm	*Platanus occidentalis-Liquidambar styraciflua-Ulmus americana*	< 35 to 200 [170]
galleta-threeawn shrubsteppe	*Pleuraphis jamesii-Aristida purpurea*	< 35 to < 100
eastern cottonwood	*Populus deltoides*	< 35 to 200 [126]
black cherry-sugar maple	*Prunus serotina-Acer saccharum*	> 1,000 [170]
coastal Douglas-fir*	*Pseudotsuga menziesii* var. *menziesii*	40-240 [7,116,136]
California mixed evergreen	*P. menziesii* var. *menziesii-Lithocarpus densiflorus-Arbutus menziesii*	< 35
California oakwoods	*Quercus* spp.	< 35 [7]
oak-hickory	*Quercus-Carya* spp.	< 35
northeastern oak-pine	*Quercus-Pinus* spp.	10 to < 35
southeastern oak-pine	*Quercus-Pinus* spp.	< 10 [170]
coast live oak	*Q. agrifolia*	2-75 [59]
white oak-black oak-northern red oak	*Q. alba-Q. velutina-Q. rubra*	< 35 [170]
canyon live oak	*Q. chrysolepis*	<35 to 200
blue oak-foothills pine	*Q. douglasii-P. sabiniana*	<35
Oregon white oak	*Q. garryana*	< 35 [7]
California black oak	*Q. kelloggii*	5-30 [126]
interior live oak	*Q. wislizenii*	< 35 [7]
little bluestem-grama prairie	*Schizachyrium scoparium-Bouteloua* spp.	< 35 [126]
eastern hemlock-yellow birch	*Tsuga canadensis-Betula alleghaniensis*	> 200 [170]
elm-ash-cottonwood	*Ulmus-Fraxinus-Populus* spp.	< 35 to 200 [38,170]

*fire return interval varies widely; trends in variation are noted in the species review

POSTFIRE REGENERATION STRATEGY [148]:
Tree with adventitious bud/root crown/soboliferous species root sucker
Geophyte, growing points deep in soil
Initial off-site colonizer (off-site, initial community)
Secondary colonizer (on-site or off-site seed sources)

FIRE EFFECTS

SPECIES: Ailanthus altissima

IMMEDIATE FIRE EFFECT ON PLANT:
Possessing large, pinnate leaves with a high surface-to-volume ratio and often, many dead branches, [35,52,53,131,165], tree-of-heaven has good potential for crowning fire behavior. As a thin-barked species [35,52,53,165], tree-of-heaven stems are probably easily killed by fire; however, burned trees are only top-killed. Insulated from heat damage by soil, most roots survive fire damage [112].

DISCUSSION AND QUALIFICATION OF FIRE EFFECT:
No additional information is available on this topic.

PLANT RESPONSE TO FIRE:
After partial to complete top-kill, tree-of-heaven sprouts from the bole, root crown, and/or roots, depending upon the extent of the fire damage. Tree-of-heaven produces an abundance of rapidly growing root sprouts after complete top-kill [98,167]. Postfire growth rates of tree-of-heaven have not been quantified in the literature as of this writing (2004), but root sprouts typically show growth rates of 10 to 13 feet (3-4 m) in their 1st year [112].

Tree-of-heaven probably establishes from seed after fire. Its seed disperses easily by wind [39,88,147], and tree-of-heaven is known to establish from seed in early successional, disturbed environments other than burns [18,88,89,121] (see Successional Status). Further information is needed on tree-of-heaven's ability to establish from seed in postfire environments.

DISCUSSION AND QUALIFICATION OF PLANT RESPONSE:
No additional information is available on this topic.

FIRE MANAGEMENT CONSIDERATIONS:
Fire is not recommended as a control measure for tree-of-heaven [77,88,147]. Limited information suggests that it sprouts vigorously after fire damage [98,167]; certainly, its regeneration strategies suggest that it is a disturbance-adapted species. Capable of rapid growth even under adverse conditions, tree-of-heaven shows best growth with the increased nutrient and open canopy conditions [8,18,63,88,89,91,121] that fire creates.

Whenever there is a nearby tree-of-heaven seed source, disturbed sites require monitoring and follow-up treatments to prevent tree-of-heaven invasion and spread. Roadways, skid trails, and other disturbed grounds are corridors for tree-of-heaven invasion [21,24]. By disturbing soil, fire suppression efforts may lead to postfire establishment if there are nearby trees-of-heaven. Fire-fighting machinery can also disperse tree-of-heaven seed. Washing equipment before it enters fire suppression zones can help prevent tree-of-heaven invasion on burned sites. Postfire monitoring and treatment of skid trails is also advised [124].

MANAGEMENT CONSIDERATIONS

SPECIES: Ailanthus altissima

IMPORTANCE TO LIVESTOCK AND WILDLIFE:
There are few reports of either wildlife or domestic animal use of tree-of-heaven. A few birds such as pine grosbeak and crossbills eat the seeds [77]. White-tailed deer and domestic goats browse the foliage [19,77,165]. Since free-choice trials or other palatability studies have not been conducted for white-tailed deer and domestic goats, it is difficult to assess relative preference for tree-of-heaven for either browser.

Palatability/nutritional value:

Although browsed, tree-of-heaven is not reported as preferred browse for ungulate species [49]. The bark and leaves contain saponins, quassinoids, and other bitter compounds that may discourage consumption [6,66,100,165]. Small animal use of tree-of-heaven is largely unknown. One old-field study in New York showed white-footed mice preferred browsing eastern white pine, sugar maple, and white ash over tree-of-heaven. The same study noted meadow voles preferred tree-of-heaven seedlings over eastern white pine seedlings [122]. Further research is needed on animal use of tree-of-heaven.

Tree-of-heaven is a fairly good source of protein. Nutritional content (%) of tree-of-heaven browse in Pakistan was as follows [9]:

	Digestible matter	Crude protein	Neutral-detergent fiber	Acid-detergent fiber	Hemicellulose	Acid-detergent lignin	Ash	Dry matter digestibility*
Spring	65.3	27.2	22.3	17.9	4.4	4.8	9.4	78.56
Winter	66.3	10.5	26.0	18.3	7.7	2.6	13.5	67.26

*for domestic goats

The seeds are a good source of fatty oils [16]. Seed collected in the U.S. had 56% fatty oil and 23% protein content [6]. Kapoor and others [82] identified palmitic, oleic, and lineleic as the major fatty acids.

Cover value: No information is available on this topic.

OTHER USES:
Tree-of-heaven provides shade, medicine, wood, clothing, and food [74]. It has been widely planted as an ornamental because it grows quickly, can be trained into an attractive shape, and has attractive foliage and fruits. Once widely cultivated in North America, it is rarely planted anymore [169,174]. It is occasionally used for shelterbelts and urban planting, but its disagreeable odor and strong tendency to spread into areas where it is not wanted discourages its use [112,176].

Tree-of-heaven is a bioindicator of ozone pollution. When subjected to heavy ozone concentrations, the leaves show spotting damage and drop off [55]. Conversely, tree-of-heaven tolerates high levels of sulfur and mercury pollution, concentrating mercury in its leaves ([92] and references therein). It has been used to rehabilitate mine spoils in the East. Tolerant of saline soils and low pH, tree-of-heaven shows better growth on mine spoils compared to native species [128]. Due to its tendency to spread on disturbed sites, however, it is not recommended for rehabilitation [77,95].

Possibly allelopathic, tree-of-heaven extracts have reduced germination and growth of other weed species.

Tree-of-heaven extracts have potential use as herbicides [32,100].

The species has a long history of folk medicine and cultural use in Asia [74]. It is used as an astringent, antispasmotic, anthelmintic, and parasitide. In powdered form it is a narcotic, with depressant effects similar to tobacco (*Nicotiana*
spp.). Fresh stem bark is used to treat diarrhea and dysentery; root bark is used for heat ailments, epilepsy, and asthma. The fruits are used as an emmenagogue and to treat ophthalmic diseases. Leaves are an astringent and used in lotions for seborrhea and scabies [5,74]. Laboratory studies show tree-of-heaven has a potential role in modern medicine. Pharmacological research is focusing on possible use of tree-of-heaven extracts for treating cancer, malaria, and HIV-1 infection [5,20,26,119].

Wood Products: Tree-of-heaven wood resembles ash (*Fraxinus* spp.) wood in appearance and quality. It is easily worked with tools and glue, and takes a finish well. Tree-of-heaven wood properties are summarized in Alden [2] and Moslemi and Bhagwat [117]. Berchem and others [11] and Adamik and Brauns [1] provide information on properties and potential uses of tree-of-heaven wood fiber. Zasada and Little [176] provide information on tree-of-heaven cultivation.

Tree-of-heaven is an important timber and fuelwood tree in China, and is planted for timber and afforestation in New Zealand, the Middle East, eastern Europe, and South America [8,74,144,163,176].

Other products: In China, tree-of-heaven is grown commercially as a host for *Attacus cynthia*, a silkworm that produces coarse, durable silk [74,165]. Tree-of-heaven is a food for honey bees worldwide. Initially bad-tasting, tree-of-heaven honey ages to a high-quality, flavorful product [29,112].

IMPACTS AND CONTROL:

Impacts:

Ecological - An early seral species favoring disturbed sites (see Successional Status), tree-of-heaven grows extremely rapidly and interferes with growth of native species. It often grows in large thickets, displacing native vegetation [90,91]. It affects natural successional trajectories, in part from competition for light and nutrients in early successional environments, and possibly from allelopathy [64,65,66,74,97]. Tree-of-heaven takes advantage of disturbance gaps in eastern deciduous forests, outcompeting and overtopping native trees [28,74]. Frankel [50] lists it among the 10 most invasive weeds in the Bronx River Parkway Reservation of New York. Tellman [154] states it is "rapidly becoming a problem species" in the Southwest, where it invades riparian zones and other areas with favorable moisture regimes. Tree-of-heaven's large, interconnected storage roots effectively occupy and compete for a site. Vegetative regeneration ensures continued exclusion of other species [123].

There is controversy about tree-of-heaven's invasiveness. Some authors note that although tree-of-heaven established in North America over 100 years ago, it has not spread to many sites that appear to be good habitat for the species [117]. Tree-of-heaven seems most invasive in disturbed eastern hardwood ecosystems [18,86,88,89,91,121]. Tree-of-heaven was 1st collected in North Carolina in 1911; it has now established in at least 48 counties in that state [125]. Tree-of-heaven appears less invasive in the arid West. It is an important pest species in California [72], invading disturbed mesic areas and riparian zones where water relations allow seedling establishment. It has not invaded closed-canopy forests [45,78]. Outside mesic areas, Hunter [78] considers it "only potentially invasive, and also potentially eradicable" in California.

Socio-economic - In developed areas, tree-of-heaven roots can damage buildings and foundations [74]. The rapidly growing, extensive root system also allows the tree to establish on steep to vertical inclines including roofs and cracked walls, which are damaged if seedlings are not promptly killed [4,139]. Tree-of-heaven roots damaged the walls and roof of the 800-year-old Sé Velha of Coimbra Cathedral in Portugal after establishing in the wall mortar and clay roof tiles [4]. The water-seeking roots can stop up sewer lines and

invade wells and cisterns, damaging infrastructures and giving potable water an unpleasant taste [31,74].

Tree-of-heaven sap causes a dermatitis reaction in some people. The pollen can cause an allergic reaction [34].

Control:

Effective tree-of-heaven control requires vigilance due to its strong sprouting ability and prolific seed production. Roadways and trails are the usual corridor for tree-of-heaven infestations [21,24,75]. For example, in a West Virginia study tree-of-heaven occurrence was heaviest along interstate freeways (I-79 and I-68) [75]. Fortunately, roadside and trail invasion makes accessibility, early detection, and treatment relatively easy [21].

Posttreatment monitoring and retreatment is essential for this root-sprouting, rapidly growing species (see Regeneration Processes). Treated areas should be checked once or twice a year, with any new sprouts or seedlings retreated (cut, sprayed, or pulled) as soon as possible so that roots do not have time to build up carbohydrate reserves and grow larger. Plan on several treatments a year. Initially, summer treatment is desired to impact trees when their root reserves are low. Establishing a thick cover of native trees or grass helps shade out tree-of-heaven and discourages regrowth. Targeting female trees-of-heaven for control helps slow seed dissemination [72]. Monitoring should continue for at least a year after tree-of-heaven sprouting appears controlled [79]. Hoshovsky [72] reviews best application methods for many of the tree-of-heaven control methods discussed below.

As an early seral, potential invasive with wind-dispersed seed, tree-of-heaven may show up on sites where treatments for other invasive weeds have created open, disturbed conditions. Whenever there is a nearby tree-of-heaven seed source, disturbed sites require monitoring and follow-up treatments to prevent tree-of-heaven invasion and spread. For example, tree-of-heaven and Norway maple seedlings invaded a New Jersey site after Norway maple removal treatments (cutting mature trees and hand-pulling Norway maple seedlings). Tree-of-heaven was not present on study plots prior to Norway maple removal [171]. Further information and research are needed to recognize undisturbed sites at risk for tree-of-heaven invasion [72].

Prevention:

The most efficient and effective method of managing invasive species is to prevent their invasion and spread [145]. Preventing the establishment of nonnative invasive plants in Natural Areas is achieved by maintaining healthy natural communities and by conducting aggressive surveying and monitoring several times each year. Monitoring efforts are best concentrated on the most disturbed areas in a site, particularly along potential pathways for tree-of-heaven invasion: roadsides, parking lots, fencelines, trails, and waterways. The Center for Invasive Plant Management provides an online guide to noxious weed prevention practices.

Integrated management:

A combination of complementary control methods may be helpful for rapid and effective control of tree-of-heaven. Integrated management includes not only killing the target plant, but establishing desirable species and discouraging nonnative, invasive species over the long term.

Physical/mechanical:

Mechanical treatments including cutting or girdling are a good 1st step in controlling tree-of-heaven. Cutting encourages both stump and root sprouts, so follow-up treatments are required. Cut stems before flowering to prevent seed spread, cutting at the ground level to prevent bole sprouts. Depending on bole size, mechanical tools including loppers, machetes, brush cutters, and power saws can be used on tree-of-heaven [79]. Sprouts can be controlled by further cutting treatments or herbicides [72,79,95]. Unless the treatment area is heavily shaded, it usually takes 5 or more years of follow-up treatment to control sprouts [72].

In small areas, seedlings can be controlled by hand pulling. Seedlings quickly develop extensive root systems, so the entire root needs to be removed to prevent sprouting. It is easiest to remove the entire seedling root when soils are softened by rain [95]. Top-growth of seedlings and root sprouts is similar, but root sprouts are connected by large, pre-existing lateral roots. Tree-of-heaven seedlings can sometimes be distinguished without digging by their cotyledons (if still present), trifoliate 1st leaflets, and thinner stems compared to the thicker stems and variable number of leaflets found on sprouts [79]. Grubbing roots may be effective for saplings [157]. Except for small infestations, grubbing roots is seldom practical for mature trees or well established tree-of-heaven colonies. The root systems are extensive and nearly impossible to entirely remove, and even a small root fragment can produce root sprouts [72,79].

Fire:
Fire has limited use in controlling tree-of-heaven, but may be useful for spot treatment. Instead of using mechanical or chemical methods to kill stems, a flame thrower or weed burner can heat-girdle tree-of-heaven boles. As with all top-kill methods, tree-of-heaven sprouts after heat-girdling [28].

Hunter [79] recommends against using fire to control tree-of-heaven colonies, speculating that burning is likely to promote vigorous sprouting. To date (2004), broadcast burning has not been attempted on tree-of-heaven, probably in large part for fear that a top-killing fire compounded by the nutrient flush that follows will result in dense postfire sprouting. Small-scale research is needed to compare long-term efficacy of fire vs. other methods in controlling tree-of-heaven.

Biological: As of this writing (2004), there are no biological control agents approved for tree-of-heaven [157]. As a disease-resistant, unpalatable species, tree-of-heaven may be a poor candidate for biological control. Containing quassinoid compounds that inhibit development of most insect larvae and retard rotting [66], it is resistant to insect predation, root-feeding nematodes, and fungi [1,45,54,68,112,140]. Leaf-browsing lepidoptera (*Atteva punctella* and *Samia synthia*) damage tree-of-heaven [112,113], but usually inflict more damage to more palatable associated species such as wild cherries and plums (*Prunus* spp.). Asiatic garden beetles (*Maladera castenea*) feed on tree-of-heaven, but also damage numerous desirable plant species. Although cattle and deer browsing may reduce tree-of-heaven [78,152], large mammalian browsers may prefer associated species to tree-of-heaven. Tree-of-heaven is less susceptible to root rots (*Phymatotrichum* spp.) than many native hardwoods. Two crop-infesting fungi, *Verticillium dahliae* and *Fusarium oxysporum*, have been isolated from dead and dying tree-of-heaven in the Northeast. These fungi may be candidates for fungal control of tree-of-heaven if strains affecting only *Ailanthus* species can be isolated [112,135].

Plant competition
is not a reliable method of control. With 1 of the fastest growth rates of any tree in North America [89], tree-of-heaven will probably grow faster and outcompete whatever native species co-occur or are planted with it [79,89,91]. Maintaining a healthy overstory can help minimize invasive potential for tree-of-heaven [145].

Chemical:
Herbicides may provide initial control of a new invasion or a severe infestation, but are rarely a complete or long-term solution to invasive species management [22]. Herbicides are more effective on large infestations when incorporated into long-term management plans that include replacement of weeds with desirable species, careful land use management, and prevention of new infestations. Control with herbicides is temporary, as it does not change conditions that allow infestations to occur in the 1st place (e.g. [175]). See The Nature Conservancy's Weed Control Methods Handbook for considerations on the use of herbicides in Natural Areas and detailed information on specific chemicals.

Systemic herbicides (e.g., triclopyr and glyphosate), which kill roots, currently provide the best chemical

control for tree-of-heaven. Dicamba, imazapyr, and methsulfuron methyl have also provided tree-of-heaven control [72,95,147]. Applying herbicides late in the growing season, when tree-of-heaven is fully leafed out and translocating nutrients to the roots, is the only effective way to kill the roots [72,167]. Aerial spraying may be indicated when there are large thickets without nontarget species, or as a follow-up treatment to other control methods. In mixed stands, aerial application of herbicides will probably have a greater impact on nontarget species that lack tree-of-heaven's ability to root sprout. When trees-of-heaven are interspersed with nontarget trees, the foliage, stumps, or basal bark of individual trees can be treated with herbicides. The stems can be cut, with immediate application of triclopyr or glyphosate to the stump. Coating the lower bole with herbicide, or girdling the stem and injecting the bole cuts with herbicide spray (hack-and-squirt), is also effective [72,95,147,157]. Basal bark herbicide treatment (imazapyr or triclopyr) is most effective in late winter or early spring before trees begin to leaf out, although summer application also works [147]. Swearingen and Pannill [152] provide information on applying foliar and basal bark chemicals to trees-of-heaven in wildlands.

In Shenandoah National Park, low-volume basal application of herbicides (triclopyr, picloram, imazapyr, and combinations) gave better tree-of-heaven control than cutting. At posttreatment year 2, a shift toward native herbs had occurred on plots where tree-of-heaven was controlled, while nonnative herbs including garlic mustard (*Alliaria petiolata*) and burdock (*Arctium minus*) were more prevalent on plots where tree-of-heaven density remained high. Mean tree-of-heaven density at posttreatment year 2 was [21]:

Treatment	Stems/acre
cutting	5,645
imazapyr	363
picloram + triclopyr*	81

*Several herbicide combinations and application rates were used. See Burch and Zedaker [21] for further details.

Chemical control programs targeting herbaceous species may unintentionally increase tree-of-heaven, depending upon the herbicides used. In West Virginia, diuron, simazine, and terbacil treatments for rough pigweed (*Amaranthus retroflexus*), barnyard grass (*Echinochloa crus-galli*), and other herbaceous weeds in an apple (*Malus sylvestris*) orchard successfully reduced most herbaceous weeds; however, tree-of-heaven and tall fescue (*Festuca arundinacea*) dominated plots treated with diuron and simazine. Terbacil alone gave best control of tree-of-heaven [158].

Cultural: No information is available on this topic.

Ailanthus altissima: References

1.
Adamik, Karl; Brauns, Friedrich E. 1957. Ailanthus glandulosa (tree-of-heaven) as pulpwood. Part II. Tappi. 40(7): 522-527. [46739]

2.
Alden, Harry A. 1995. Hardwoods of North America. Gen. Tech. Rep. FPL-GTR-83. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 136 p. Available: http://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr83.pdf [2004, January 6]. [46270]

3.
Allen, Craig Daniel. 1989. Changes in the landscape of the Jemez Mountains, New Mexico. Berkeley, CA: University of California Berkeley. 346 p. Dissertation. [42116]

4.
Almeida, M. T.; Mouga, T.; Barracosa, P. 1994. The weathering ability of higher plants. The case of Ailanthus altissima (Miller) Swingle. International Biodeterioration and Biodegradation. 33(4): 333-343. [45754]

5.
Ansari, S. H.; Ali, M. 1999. Recent developments in the chemistry of Ailanthus altissima. Hamdard Medicus. 42(3): 58-63. [46264]

6.
Ansari, S. H.; Ali, M. 2003. Two new phytosterols from Ailanthus altissima (Mill) Swingle. In: Bernath, J.; [and others], eds. Proceedings of the international conference on medicinal and aromatic plants; 2001 July 8-11; Budapest, Hungary. In: Acta Horticulture. 597: 91-94. [46145]

7.
Arno, Stephen F. 2000. Fire in western forest ecosystems. In: Brown, James K.; Smith, Jane Kapler, eds. Wildland fire in ecosystems: Effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 97-120. [36984]

8.
Ashraf, Mohammad, Rehman, Sham-ur. 2001. A short note on the vegetative propagation of Ailanthus and Prosopis. The Pakistan Journal of Forestry. 51(1): 85. [46216]

9.
Azim, A.; Khan, A. G.; Ahmad, J.; Ayaz, M.; Mirza, I. H. 2002. Nutritional evaluation of fodder tree leaves with goats. Asian Australian Journal of Animal Science. 15(1): 34-37. [46153]

10.
Barringer, Kerry; Pannaman, Laura. 2003. Vascular plants of the Fairview Lake watershed, Sussex County, New Jersey. Journal of the Torrey Botanical Society. 130(1): 47-54. [46143]

11.
Berchem, T. E.; Moslemi, A. A.; Sutula, P. R. 1972. Fiber length in the wood of tree-of-heaven. Wood Fiber. 4(3): 234-235. [46455]

12.
Bernard, Stephen R.; Brown, Kenneth F. 1977. Distribution of mammals, reptiles, and amphibians by BLM physiographic regions and A.W. Kuchler's associations for the eleven western states. Tech. Note 301. Denver, CO: U.S. Department of the Interior, Bureau of Land Management. 169 p. [434]

13.
Bicknell, Susan H.; Smith, William H. 1975. Influence of soil salt, at levels characteristic of some roadside environments, on the germination of certain tree seeds. Plant and Soil. 43(3): 719-722. [46740]

14.
Bory, G.; Clair-Maczulajtys, D. 1980. Production, dissemination, and polymorphism of seeds in Ailanthus altissima. Revue Gererale de Botanique. 88(1049/1051): 297-311. [45847]

15.
Bory, G.; Clair-Maczulajtys, Danielle. 1986. Composition of nectar and role of extrafloral nectaries in Ailanthus glandulosa. Canadian Journal of Botany. 64(1): 247-253. [46147]

16.
Bory, G.; Clair-Maezulajtys, D. 1989. Lipid content and fatty acid composition of seeds of Ailanthus altissima (Mill) Swingle (Simaroubaceae). Indian Journal of Plant Physiology. 31(1): 12-16. [46745]

17.
Bourdeau, Philippe F. 1958. Photosynthetic behavior of sun- and shade-grown leaves in certain tolerant and intolerant tree species. Bulletin of the Ecological Society of America. 39(3): 84. Abstract. [46134]

18.
Bourdeau, Philippe F.; Laverick, Miriam L. 1958. Tolerance and photosynthetic adaptability to light intensity in white pine, red pine, hemlock and ailanthus seedlings. Forest Science. 4(3): 196-207. [46152]

19.
Bourke, C. A. 1996. Lack of toxicity of Ailanthus altissima (tree-of-heaven) for goats. Australian Veterinary Journal. 74(6): 465. [45850]

20.
Bray, D. H.; Boardman, P.; O'Neill, M. J.; Chan, K. L.; Phillipson, J. D.; Warhurst, D. C.; Suffness, M. 1987. Plants as a source of antimalarial drugs. 5. Activities of Ailanthus altissima stem constituents and of some related quassinoids. Phytotherapy Research. 1(1): 22-24. [46125]

21.
Burch, Patrick L.; Zedaker, Shepard M. 2003. Removing the invasive tree Ailanthus altissima and restoring natural cover. Journal of Arboriculture. 29(1): 18-24. [45788]

22.
Bussan, Alvin J.; Dyer, William E. 1999. Herbicides and rangeland. In: Sheley, Roger L.; Petroff, Janet K., eds. Biology and management of noxious rangeland weeds. Corvallis, OR: Oregon State University Press: 116-132. [35716]

23.
Call, Lara J. 2002. Analysis of intraspecific and interspecific interactions between the invasive exotic tree-of-heaven (Ailanthus altissima (Miller) Swingle) and the native black locust (Robinia pseudoacacia L.). Blacksburg, VA: Virginia Polytechnic Institute. 80 p. Thesis. [45299]

24.
Call, Lara J.; Nilsen, Erik T. 2003. Analysis of spatial patterns and spatial association between the invasive tree-of-heaven (Ailanthus altissima) and the native black locust (Robinia pseudoacacia). The American Midland Naturalist. 150(1): 1-14. [45002]

25.
Callaway, Ragan M.; Walker, Lawrence R. 1997. Competition and facilitation: a synthetic approach to interactions in plant communities. Ecology. 78(7): 1958-1965. [27660]

26.
Chang, Young-Su; Woo, Eun-Rhan. 2003. Korean medicinal plants inhibiting to human immunodeficiency virus type 1 (HIV-1) fusion. Phytotherapy Research. 17(4): 426-429. [46074]

27.

Cowell, C. Mark. 1993. Environmental gradients in secondary forests of the Georgia Piedmont, U.S.A. Journal of Biogeography. 20: 199-207. [24132]

28.
Cozzo, Domingo. 1972. Initial behavior of Ailanthus altissima in experimental plantation. Revista Forestal Argentina. 16(2): 47-52. [46731]

29.
Dalby, Richard. 2000. Minor bee plants in a major key: tamarisk, ailanthus and teasel. American Bee Journal. 140(1): 60-61. [43996]

30.
Davies, P. A. 1935. Ecology of Ailanthus altissima thickets. Transactions, Kentucky Academy of Science. 7: 21. [46730]

31.
Davies, P. A. 1942. The history, distribution, and value of Ailanthus in North America. Transactions, Kentucky Academy of Science. 9: 12-14. [45812]

32.
De Feo, Vincenzo; De Martino, Laura; Quaranta, Emilia; Pizza, Cosimo. 2003. Isolation of phytotoxic compounds from tree-of-heaven (Ailanthus altissima Swingle). Journal of Agricultural and Food Chemistry. 51(5): 1177-1180. [46076]

33.
DeMars, Brent G.; Runkle, James R. 1992. Groundlayer vegetation ordination and site-factor analysis of the Wright State University Woods (Greene County, Ohio). Ohio Journal of Science. 92(4): 98-106. [19823]

34.
Derrick, Elizabeth K.; Darley, Charles R. 1994. Contact reaction to the tree of heaven. Contact Dermatitis. 30(3): 178. [45520]

35.
Diggs, George M., Jr.; Lipscomb, Barney L.; O'Kennon, Robert J. 1999. Illustrated flora of north-central Texas. Sida Botanical Miscellany No. 16. Fort Worth, TX: Botanical Research Institute of Texas. 1626 p. [35698]

36.
Dirr, Michael A. 1990. Manual of woody landscape plants: their identification, ornamental characteristics, culture, propagation and uses. Champagne, IL: Stipes Publishing Company. 1007 p. [46754]

37.
Dobberpuhl, J. 1980. Seed banks of forest soils in east Tennessee. Knoxville, TN: University of Tennessee. 219 p. Thesis. [46755]

38.
Duchesne, Luc C.; Hawkes, Brad C. 2000. Fire in northern ecosystems. In: Brown, James K.; Smith, Jane Kapler, eds. Wildland fire in ecosystems: Effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 35-51. [36982]

39.
Duncan, Wilbur H.; Duncan, Marion B. 1988. Trees of the southeastern United States. Athens, GA: The University of Georgia Press. 322 p. [12764]

40.
Eyre, F. H., ed. 1980. Forest cover types of the United States and Canada. Washington, DC: Society of American Foresters. 148 p. [905]

41.
Facelli, Jose M. 1994. Multiple indirect effects of plant litter affect the establishment of woody seedlings in old fields. Ecology. 75(6): 1727-1735. [23541]

42.
Facelli, Jose M.; Pickett, S. T. A. 1991. Indirect effects of litter on woody seedlings subject to herb competition. Oikos. 62(2): 129-138. [46146]

43.
Fairweather, Stephen E.; Cavanaugh, Cecile M. 1990. Identification, restoration, and maintenance of historic woodlots at Gettysburg National Military Park. Tech. Rep. NPS/MAR/NRTR - 90/049. Philadelphia, PA: U.S. Department of the Interior, National Park Service, Mid-Atlantic Region. 123 p. [17985]

44. Feret, Peter P. 1973. Early flowering in Ailanthus. Forest Science. 19(3): 237-239. [45855]

45.
Feret, Peter P. 1985. Ailanthus: variation, cultivation, and frustration. Journal of Arboriculture. 11(12): 361-368. [46741]

46.
Feret, Peter P.; Bryant, Richard L. 1974. Genetic differences between American and Chinese ailanthus seedlings. Silvae Genetica. 23(5): 144-148. [45518]

47.
Feret, Peter P.; Bryant, Richard L.; Ramsey, James A. 1974. Genetic variation among American seed sources of Ailanthus altissima (Mill.) Swingle. Scientia Horticulturae. 2(4): 405-411. [46124]

48.
Finch, Deborah M.; Wolters, Gale L.; Yong, Wang; Mund, Mary J. 1995. Plants, arthropods, and birds of the Rio Grande. In: Finch, Deborah M.; Tainter, Joseph A., eds. Ecology, diversity, and sustainability of the Middle Rio Grande Basin. Gen. Tech. Rep. RM-GTR-268. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 133-164. [26190]

49.
Forgione, Helen M. 1993. Limits to the establishment and growth of tree-of-heaven explored. Restoration & Management Notes. 11(1): 70-71. [22459]

50.
Frankel, Edward. 1999. A floristic survey of vascular plants of the Bronx River Parkway Reservation in Westchester, New York: compilation 1973-1998. Journal of the Torrey Botanical Society. 126(4): 359-366. [37376]

51.
Garrison, George A.; Bjugstad, Ardell J.; Duncan, Don A.; Lewis, Mont E.; Smith, Dixie R. 1977. Vegetation and environmental features of forest and range ecosystems. Agric. Handb. 475. Washington, DC: U.S. Department of Agriculture, Forest Service. 68 p. [998]

52.
Gleason, Henry A.; Cronquist, Arthur. 1991. Manual of vascular plants of northeastern United States and adjacent Canada. 2nd ed. New York: New York Botanical Garden. 910 p. [20329]

53.
Godfrey, Robert K. 1988. Trees, shrubs, and woody vines of northern Florida and adjacent Georgia and Alabama. Athens, GA: The University of Georgia Press. 734 p. [10239]

54.
Goor, A. Y.; Barney, C. W. 1968. Forest tree planting in arid zones. New York: Ronald Press. 409 p. [46759]

55.
Gravano, Elisabetta; Giulietti, Valentina; Desotgiu, Rosanna; Bussotti, Filippo; Grossoni, Paolo; Gerosa, Giacomo; Tani, Corrado. 2003. Foliar response of an Ailanthus altissima clone in two sites with different levels of ozone-pollution. Environmental Pollution. 121(1): 137-148. [46737]

56.
Graves, William R. 1990. Stratification not required for tree-of-heaven seed germination. Tree Planters' Notes. 41(2): 10-12. [46149]

57.
Graves, William R.; Dana, Michael N.; Joly, Robert J. 1989. Influence of root-zone temperature on growth of Ailanthus altissima (Mill.) Swingle. Journal of Environmental Horticulture. 7(2): 79-82. [46130]

58.
Great Plains Flora Association. 1986. Flora of the Great Plains. Lawrence, KS: University Press of Kansas. 1392 p. [1603]

59.
Greenlee, Jason M.; Langenheim, Jean H. 1990. Historic fire regimes and their relation to vegetation patterns in the Monterey Bay area of California. The American Midland Naturalist. 124(2): 239-253. [15144]

60.
Greller, Andrew M. 1977. A classification of mature forests on Long Island, New York. Bulletin

of the Torrey Botanical Club. 104(4): 376-382. [22020]

61. Grime, J. P. 1965. Shade tolerance in flowering plants. Nature. 28(5006): 161-163. [46122]

62.
Guyette, Richard; McGinnes, E. A., Jr. 1982. Fire history of an Ozark glade in Missouri. Transactions, Missouri Academy of Science. 16: 85-93. [5170]

63.
Hanover, James W.; Wood, Bruce W.; Hart, John W.; Brissette, John C.; Dickmann, Donald I.; Stadt, Thomas J.; Lemmien, Walter A.; Kowalewski, Greg. 1978. Accelerated growth of hardwood seedlings. In: Central hardwood forest conference: Proceedings; 1978 November 14-16; West Lafayette, IN. West Lafayette, IN: Purdue University, Department of Forestry and Natural Resources: 370-388. [46133]

64.
Heisey, Rod M. 1990. Allelopathic and herbicidal effects of extracts from tree of heaven (Ailanthus altissima). American Journal of Botany. 77(5): 662-670. [45477]

65.
Heisey, Rod M. 1990. Evidence for allelopathy by tree-of-heaven. Journal of Chemical Ecology. 16(6): 2039-2055. [45481]

66.
Heisey, Rod M. 1996. Identification of an allelopathic compound from Ailanthus altissima (Simaroubaceae) and characterization of its herbicidal activity. American Journal of Botany. 83(2): 192-200. [45475]

67.
Heisey, Rod M. 1997. Allelopathy and the secret life of Ailanthus altissima. Arnoldia. 57(3): 28-36. [46157]

68.
Hepting, George H. 1971. Diseases of forest and shade trees of the United States. Agric. Handb. 386. Washington, DC: U.S. Department of Agriculture. 658 p. [20880]

69.
Hickman, James C., ed. 1993. The Jepson manual: Higher plants of California. Berkeley, CA: University of California Press. 1400 p. [21992]

70.
Hitchcock, C. Leo; Cronquist, Arthur. 1961. Vascular plants of the Pacific Northwest. Part 3: Saxifragaceae to Ericaceae. Seattle, WA: University of Washington Press. 614 p. [1167]

71.
Hitchcock, C. Leo; Cronquist, Arthur. 1973. Flora of the Pacific Northwest. Seattle, WA: University of Washington Press. 730 p. [1168]

72.
Hoshovsky, Marc C. 1988. Element stewardship abstract: Ailanthus altissima, [Online]. In: Invasives on the web: The Nature Conservancy wildland invasive species program. Davis, CA: The Nature Conservancy (Producer). Available: http://tncweeds.ucdavis.edu/esadocs/documnts/ailaalt.html [2004, January 9]. [46265]

73.
Houge, Robert. 1998. Tree-of-heaven Ailanthus altissima, [Online]. In: National Register of Big Trees. American Forests (Producer). Available: http://www.americanforests.org/resources/bigtrees/register.php?details=1724 [2004, January 6]. [46268]

74. Hu, Shiu Ying. 1979. Ailanthus. Arnoldia. 39(2): 29-50. [45755]

75.
Huebner, Cynthia D. 2003. Vulnerability of oak-dominated forests in West Virginia to invasive exotic plants: temporal and spatial patterns of nine exotic species using herbarium records and land classification data. Castanea. 68(1): 1-14. [46144]

76.
Hull, James C.; Scott, Ralph C. 1982. Plant succession on debris avalanches of Nelson County, Virginia. Castanea. 47(2): 158-176. [41715]

77.
Hunter, Carl G. 1989. Trees, shrubs, and vines of Arkansas. Little Rock, AR: The Ozark Society

Foundation. 207 p. [21266]

78.
Hunter, John C. 1995. Ailanthus altissima (Miller) Swingle: its biology and recent history. California Exotic Pest Plant Council News. 3(4): 4-5. [45846]

79.
Hunter, John. 2000. Ailanthus altissima (Miller) Swingle. In: Bossard, Carla C.; Randall, John M.; Hoshovsky, Marc C., eds. Invasive plants of California's wildlands. Berkeley, CA: University of California Press: 32-36. [46752]

80.
Illick, Joseph S.; Brouse, E. F. 1926. The ailanthus tree in Pennsylvania. Bulletin 38. Harrisburg, PA: Pennsylvania Department of Forests and Waters. 29 p. [46734]

81.
Jepson, Willis Linn. 1925. A manual of the flowering plants of California. Berkeley, CA: University of California Press. 1238. [19365]

82.
Kapoor, N.; Bedi, K. L.; Tikoo, M. K.; Kapoor, S. K.; Sarin, Y. K. 1990. Some lesser known tree-borne oilseeds of India. Journal of the Oil Technologists Association of India. 22(3): 65-66. [46156]

83.
Kartesz, John T.; Meacham, Christopher A. 1999. Synthesis of the North American flora (Windows Version 1.0), [CD-ROM]. Available: North Carolina Botanical Garden. In cooperation with the Nature Conservancy, Natural Resources Conservation Service, and U.S. Fish and Wildlife Service [2001, January 16]. [36715]

84.
Keeley, Jon E. 1981. Reproductive cycles and fire regimes. In: Mooney, H. A.; Bonnicksen, T. M.; Christensen, N. L.; Lotan, J. E.; Reiners, W. A., technical coordinators. Fire regimes and ecosystem properties: Proceedings of the conference; 1978 December 11-15; Honolulu, HI. Gen. Tech. Rep. WO-26. Washington, DC: U.S. Department of Agriculture, Forest Service: 231-277. [4395]

85.
Keeley, Jon E. 1986. Resilience of Mediterranean shrub communities to fires. In: Dell, B.; Hopkins, A. J. N.; Lamont B. B., eds. Resilience in Mediterranean-type ecosystems. Dordrecht, The Netherlands: Dr. W. Junk Publishers: 95-112. [9826]

86.
Keever, Catherine. 1979. Mechanisms of plant succession on old fields of Lancaster County, Pennsylvania. Bulletin of the Torrey Botanical Club. 106(4): 299-308. [41717]

87.
Keller, Terry. 1993. Riparian zone plant ecology and hydrology in Aliso Creek, Chino Hills State Park, southern California. In: Keeley, Jon E., ed. Interface between ecology and land development in California: Proceedings of the symposium; 1992 May 1-2; Los Angeles, CA. Los Angeles, CA: The Southern California Academy of Sciences: 137-141. [21702]

88.
Kentucky Exotic Pest Plant Council. 2001. Invasive exotic plant list, [Online]. Southeast Exotic Pest Plant Council (Producer). Available: http://www.se-eppc.org/states/KY/KYlists.html [2005, April 13]. [44948]

89.
Knapp, Liza B.; Canham, Charles D. 2000. Invasion of an old-growth forest in New York by Ailanthus altissima: sapling growth and recruitment in canopy gaps. Journal of the Torrey Botanical Society. 127(4): 307-315. [46142]

90.
Kowarik, Ingo. 1983. The acclimatization and phytogeographical behavior of the tree of heaven in the French Mediterranean area. Phytocoenologia. 11(3): 389-406. [46757]

91.
Kowarik, Ingo. 1995. Clonal growth in Ailanthus altissima on a natural site in West Virginia. Journal of Vegetation Science. 6: 853-856. [45195]

92.
Kozlowski, T. T. 2002. Physiological ecology of natural regeneration of harvested and disturbed forest stands: implications for forest management. Forest Ecology and Management. 158(1-3): 195-221. [42122]

93.
Krussmann, Gerd; Wennemuth, Georg; Thon, Heinz Edgar. 1981. Die baumschule. 5th ed. Berlin: Parey. 565 p. [46761]

94.
Kucera, Clair L. 1981. Grasslands and fire. In: Mooney, H. A.; Bonnicksen, T. M.; Christensen, N. L.; Lotan, J. E.; Reiners, W. A., technical coordinators. Fire regimes and ecosystem properties: Proceedings of the conference; 1978 December 11-15; Honolulu, HI. Gen. Tech. Rep. WO-26. Washington, DC: U.S. Department of Agriculture, Forest Service: 90-111. [4389]

95.
Kuchler, A. W. 1964. United States [Potential natural vegetation of the conterminous United States]. Special Publication No. 36. New York: American Geographical Society. 1:3,168,000; colored. [3455]

96.
Lalhal, J. S.; Singh, Ombir. 1992. Sucker development in Ailanthus glandulosa Desf. Van Vigyan. [Dehra Dun, India: Journal of the Society of Indian Foresters]. 30(3&4): 179-180. [46155]

97.
Lawrence, Jeffrey G.; Colwell, Alison; Sexton, Owen J. 1991. The ecological impact of allelopathy in Ailanthus altissima (Simaroubaceae). American Journal of Botany. 78(7): 948-958. [15283]

98.
Lepart, J.; Debussche, M. 1991. Invasion processes as related to succession and disturbance. In: Groves, R. H.; Di Castri, F., eds. Biogeography of Mediterranean invasions. Cambridge: Cambridge University Press: 159-177. [46742]

99.
Lhotka, John M.; Zaczek, James J. 2003. Effects of scarification disturbance on the seedling and midstory layer in a successional mixed-oak forest. Northern Journal of Applied Forestry. 20(2): 85-91. [44594]

100.
Lin, Lee-Juian; Peiser, Galen; Ying, Bai-Ping; Mathias, Kristina; Karasina, Faina; Wang, Zhan; Itatani, Joyce; Green, Laddie; Hwang, Yih-Shen. 1995. Identification of plant growth inhibitory principles in Ailanthus altissima and Castela tortuosa. Journal of Agricultural Food Chemistry.

43(6): 1708-1711. [45851]

101.
Little, Elbert L., Jr. 1979. Checklist of United States trees (native and naturalized). Agric. Handb. 541. Washington, DC: U.S. Department of Agriculture, Forest Service. 375 p. [2952]

102.
Little, Silas. 1974. Ailanthus altissima (Mill.) Swingle ailanthus. In: Schopmeyer, C. S., technical coordinator. Seeds of woody plants in the United States. Agric. Handb. 450. Washington, DC: U.S. Department of Agriculture, Forest Service: 201-202. [7503]

103.
Marek, M. 1988. Photosynthetic characteristics of Ailanthus leaves. Photosynthetica. 22(2): 179-183. [46744]

104.
Marler, Marilyn. 2000. A survey of exotic plants in federal wilderness areas. In: Cole, David N.; McCool, Stephen F.; Borrie, William T.; O'Loughlin, Jennifer, comps. Wilderness science in a time of change conference--Volume 5: wilderness ecosystems, threats, and management; 1999 May 23-27; Missoula, MT. Proceedings RMRS-P-15-VOL-5. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 318-327. [40580]

105.
Marshall, P. E.; Kozlowski, T. T. 1973. Cotyledon inactivation and early seedling development. American Journal of Botany. 60(4): 25-26. [46135]

106.
Martin, William C.; Hutchins, Charles R. 1981. A flora of New Mexico. Volume 2. Germany: J. Cramer. 2589 p. [37176]

107.
Matlack, Glenn R. 1987. Diaspore size, shape, and fall behavior in wind-dispersed plant species. American Journal of Botany. 74(8): 1150-1160. [28]

108.
McAllister, C.; Beckert, H.; Abrams, C.; Bilyard, G.; Cadwell, K.; Friant, S.; Glantz, C.; Mazaika, R.; Miller, K. 1996. Survey of ecological resources at selected U.S. Department of

Energy sites, [Online]. U.S. Department of Energy (Producer). Available: http://homer.ornl.gov/oepa/guidance/risk/ecores.pdf [2004, January 21]. [46457]

109.
McFarland, Lisa. 1996. Isolation and characterization of seed germination inhibitors from Ailanthus altissima. Orono, ME: University of Maine. 214 p. Thesis. [45752]

110.
McTavish, Hugh. 1988. A demonstration of photosynthetic state transitions in nature: Shading by photosynthetic tissue causes conversion to state 1. Photosynthesis Research. 17(3): 247-254. [46141]

111.
Mergen, Francois. 1959. A toxic principle in the leaves of Ailanthus. Botanical Gazette. 121(1): 32-36. [45478]

112.
Miller, James H. 1990. Ailanthus altissima (Mill.) Swingle ailanthus. In: Burns, Russell M.; Honkala, Barbara H., tech. coords. Silvics of North America: Vol. 2. Hardwoods. Agriculture Handbook 654. Washington, DC: U.S. Department of Agriculture, Forest Service: 101-104. [46753]

113.
Mohanadas, K.; Verma, R. V. 1984. A new host record for Atteva fabriciella (Lepidoptera: Yponomeutidae) a pest of Ailanthus. Journal of Tree Science. 3(1/2): 128. [45521]

114.
Mohlenbrock, Robert H. 1986. [Revised edition]. Guide to the vascular flora of Illinois. Carbondale, IL: Southern Illinois University Press. 507 p. [17383]

115.
Moradshahi, A.; Yaghmaee, P.; Ghadiri, H. 2002. Allelopathic potential of tree of heaven (Ailanthus altissima Swingle). Iran Agricultural Research. 21(1): 27-38. [46154]

116.
Morrison, Peter H.; Swanson, Frederick J. 1990. Fire history and pattern in a Cascade Range landscape. Gen. Tech. Rep. PNW-GTR-254. Portland, OR: U.S. Department of Agriculture,

Forest Service, Pacific Northwest Research Station. 77 p. [13074]

117.
Moslemi, A. A.; Bhagwat, S. G. 1970. Physical and mechanical properties of the wood of tree-of-heaven. Wood and Fiber. 1(4): 319-323. [46128]

118.
Myers, Ronald L. 2000. Fire in tropical and subtropical ecosystems. In: Brown, James K.; Smith, Jane Kapler, eds. Wildland fire in ecosystems: Effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 161-173. [36985]

119.
O'Neill, M. J.; Bray, D. H.; Boardman, P.; Phillipson, J. D.; Warhurst, D. C. 1985. Plants as sources of antimalarial drugs. Part 1. In vitro test method for the evaluation of crude extracts from plants. Planta Medica. 1985(5): 394-398. [46131]

120.
Orians, G. H.. 1986. Site characteristics favoring invasions. In: Mooney, Harold A.; Drake, James A., eds. Ecology of biological invasions of North America and Hawaii. Ecological Studies 58. New York: Springer-Verlag: 133-148. [17513]

121.
Orwig, David A.; Foster, David R. 1998. Forest response to the introduced hemlock woolly adelgid in southern New England, USA. Journal of the Torrey Botanical Club. 125(1): 60-73. [44642]

122.
Ostfeld, Richard S.; Manson, Robert H.; Canham, Charles D. 1997. Effects of rodents on survival of tree seeds and seedlings invading old fields. Ecology. 78(5): 1531-1542. [46148]

123.
Pan, Elizabeth; Bassuk, Nina. 1985. Effects of soil type and compaction on the growth of Ailanthus altissima seedlings. Journal of Environmental Horticulture. 3(4): 158-162. [45476]

124.
Parsons, W. T.; Cuthbertson, E. G. 1992. Noxious weeds of Australia. Melbourne: Indata Press.

692 p. [45830]

125.
Patterson, David T. 1976. The history and distribution of five exotic weeds in North Carolina. Castanea. 41(2): 177-180. [21454]

126.
Paysen, Timothy E.; Ansley, R. James; Brown, James K.; [and others]. 2000. Fire in western shrubland, woodland, and grassland ecosystems. In: Brown, James K.; Smith, Jane Kapler, eds. Wildland fire in ecosystems: Effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-volume 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 121-159. [36978]

127.
Petrides, G. A.; Peterson, Roger Troy. 1986. A field guide to North American trees and shrubs: Northeastern and north-central United States and southeastern and south-central Canada. 2nd ed. Boston: Houghton Mifflin Co. 428 p. [46760]

128.
Plass, William T. 1975. An evaluation of trees and shrubs for planting surface-mine spoils. Res. Pap. NE-317. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 8 p. [46129]

129.
Rabe, Elizabeth P.; Bassuk, Nina. 1984. Adaptation of Ailanthus altissima to the urban environment through analysis of habitat usage and growth response to soil compaction. Hortscience. 19(3): 572. [Abstract]. [45852]

130.
Rabe, Elizabeth Pan. 1985. Distribution and growth response of Ailanthus altissima in the urban environment. Ithaca, NY: Cornell University. 87 p. Thesis. [45753]

131.
Radford, Albert E.; Ahles, Harry E.; Bell, C. Ritchie. 1968. Manual of the vascular flora of the Carolinas. Chapel Hill, NC: The University of North Carolina Press. 1183 p. [7606]

132.

Randall, John M. 1997. Defining weeds of natural areas. In: Luken, James O.; Thieret, John W., eds. Assessment and management of plant invasions. Springer Series on Environmental Management. New York: Springer-Verlag: 18-25. [41098]

133.
Rank, B. 1997. Oxidative stress response and photosystem 2 efficiency in trees of urban areas. Phytosynthetica. 33(3-4): 467-481. [45848]

134.
Raunkiaer, C. 1934. The life forms of plants and statistical plant geography. Oxford: Clarendon Press. 632 p. [2843]

135.
Riffle, Jerry W.; Peterson, Glenn W., technical coordinators. 1986. Diseases of trees in the Great Plains. Gen. Tech. Rep. RM-129. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 149 p. [16989]

136.
Ripple, William J. 1994. Historic spatial patterns of old forests in western Oregon. Journal of Forestry. 92(11): 45-49. [33881]

137.
Robinson, George R.; Handel, Steven N. 1993. Forest restoration on a closed landfill: rapid addition of new species by bird dispersal. Conservation Biology. 7(2): 271-278. [22062]

138.
Root, Thomas W. 1985. Addition to the vascular flora of Rock Island County, Illinois. Transactions, Illinois Academy of Science. 78(3-4): 281-284. [37532]

139.
Santamour, Frank S., Jr. 1983. Woody-plant succession in the urban forest: filling cracks and crevices. Journal of Arboriculture. 9(10): 267-270. [45849]

140.
Santamour, Frank S., Jr.; Riedel, Louise G. H. 1993. Susceptibility of various landscape trees to root-knot nematodes. Journal of Arboriculture. 19(5): 257-259. [46140]

141.
Sapsis, David B. 1990. Ecological effects of spring and fall prescribed burning on basin big sagebrush/Idaho fescue--bluebunch wheatgrass communities. Corvallis, OR: Oregon State University. 105 p. Thesis. [16579]

142.
Schwartz, Mark W.; Porter, Daniel J.; Randall, John M.; Lyons, Kelly E. 1996. Impact of nonindigenous plants. In: Status of the Sierra Nevada. Sierra Nevada Ecosystem Project: Final report to Congress. Volume II: Assessments and scientific basis for management options. Wildland Resources Center Report No. 37. Davis, CA: University of California, Centers for Water and Wildland Resources: 1203-1218. [28977]

143.
Seymour, Frank Conkling. 1982. The flora of New England. 2d ed. Phytologia Memoirs 5. Plainfield, NJ: Harold N. Moldenke and Alma L. Moldenke. 611 p. [7604]

144.
Shafiq, Muhammad; Nizami, M. I. 1986. Growth behaviour of different plants under gullied area of Pothwar Plateau. The Pakistan Journal of Forestry. 36(1): 9-15. [46127]

145.
Sheley, Roger; Manoukian, Mark; Marks, Gerald. 1999. Preventing noxious weed invasion. In: Sheley, Roger L.; Petroff, Janet K., eds. Biology and management of noxious rangeland weeds. Corvallis, OR: Oregon State University Press: 69-72. [35711]

146.
Shiflet, Thomas N., ed. 1994. Rangeland cover types of the United States. Denver, CO: Society for Range Management. 152 p. [23362]

147.
Southeast Exotic Pest Plant Council, Tennessee Chapter. 2001. Invasive exotic pest plants in Tennessee, [Online]. Athens, GA: University of Georgia; Southeast Exotic Pest Plant Council (Producer). Available: http://www.se-eppc.org/states/TN/TNIList.html [2004, February 12]. [46747]

148.
Stickney, Peter F. 1989. FEIS postfire regeneration workshop--April 12: Seral origin of species

comprising secondary plant succession in Northern Rocky Mountain forests. 10 p. Unpublished draft on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Fire Sciences Laboratory, Missoula, MT. [20090]

149.
Stiles, Elsa Horn; Melchers, Leo E. 1935. The drought of 1934 and its effect on trees in Kansas. Part I: Meteorological conditions, 1934. Kansas Academy of Sciences. 38: 107-127. [46732]

150.
Stomberg, Mark R.; Kephart, Paul; Yadon, Vern. 2001. Composition, invasibility, and diversity in coastal California grasslands. Madrono. 48(4): 236-252. [41371]

151.
Strausbaugh, P. D.; Core, Earl L. 1977. Flora of West Virginia. 2nd ed. Morgantown, WV: Seneca Books, Inc. 1079 p. [23213]

152.
Swearingen, Jil; Pannill, Phil. 2003. Fact sheet: Tree-of-heaven Ailanthus altissima (Mill.) Swingle, [Online]. In: Weeds gone wild: Alien plant invaders of natural areas. The Plant Conservation Alliance's Alien Plant Working Group (Producer). Available: http://www.nps.gov/plants/alien/fact/aial1.htm [2004, January 9]. [46267]

153.
Tajchman, Stanislaw J; Fu, Hailiang; Kochenderfer, James N.; Chunshen, Pan. 1995. Spatial characteristics of topography, energy exchange, and forest cover in a central Appalachian watershed. In: Gottschalk, Kurt W.; Fosbroke, Sandra L., eds. Proceedings, 10th central hardwood forest conference; 1995 March 5-8; Morgantown, WV. Gen. Tech. Rep. NE-197. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 297-314. [25870]

154.
Tellman, Barbara. 1997. Exotic pest plant introduction in the American Southwest. Desert Plants. 13(1): 3-10. [27408]

155.
Tellman, Barbara. 1998. Stowaways and invited guests: how some exotic plant species reached the American Southwest. In: Tellman, Barbara; Finch, Deborah M.; Edminster, Carl; Hamre, Robert, eds. The future of arid grasslands: identifying issues, seeking solutions: Proceedings; 1996 October 9-13; Tucson, AZ. Proceedings RMRS-P-3. Fort Collins, CO: U.S. Department of

Agriculture, Forest Service, Rocky Mountain Research Station: 144-149. [29294]

156.
Trifilo, P.; Raimondo, F.; Nardini, A.; Lo Gullo, M. A.; Salleo, S. 2004. Drought resistance of Ailanthus altissima: root hydraulics and water relations. Tree Physiology. 24: 107-114. [46736]

157.
Tu, Mandy; Hurd, Callie; Randall, John M., eds. 2001. Weed control methods handbook: tools and techniques for use in natural areas. Davis, CA: The Nature Conservancy. 194 p. [37787]

158.
Tworkoski, Thomas J.; Welker, William V.; Vass, George D. 2000. Weed community changes following diuron, simazine, or terbacil application. Weed Technology. 14(1): 197-203. [46077]

159.
U.S. Department of Agriculture, Forest Service, Eastern Region. 2004. Eastern Region invasive plants ranked by degree of invasiveness, [Online]. In: Noxious weeds and non-native invasive plants. Section 3: Invasive plants. Milwaukee, WI: Eastern Region (Producer). Available: http://www.fs.fed.us/r9/wildlife/range/weed/Sec3B.htm [2004, February 16]. [46748]

160.
U.S. Department of Agriculture, Forest Service, Southern Region. 2001. Regional invasive exotic plant species list, [Online]. In: Regional Forester's list and ranking structure: invasive exotic plant species of management concern. In: Invasive plants of southern states list. Southeast Exotic Pest Plant Council (Producer). Available: http://www.se-eppc.org/fslist.cfm [2003, August 25]. [44944]

161.
U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. PLANTS database (2005), [Online]. Available: http://plants.usda.gov/. [34262]

162.
U.S. Department of the Interior, National Park Service, Shenandoah National Park. 2003. Nature & science: Non-native species, [Online]. U.S. Department of the Interior, National Park Service (Producer). Available: http://www.nps.gov/shen/pphtml/subenvironmentalfactors28.html [2004, January 21]. [46456]

163.
Udvardy, L. 1998. Spreading and coenological circumstances of the tree of heaven (Ailanthus altissima) in Hungary. Acta Botanica Hungarica. 41(1-4): 299-314. [46454]

164.
Vermont Agency of Natural Resources. 1998. Invasive exotic plants of Vermont: A list of the state's most troublesome weeds. Vermont Invasive Exotic Plant Fact Sheet Series. Waterbury, VT: Department of Environmental Conservation; Department of Fish and Wildlife, Nongame and Natural Hertiage Program. 2 p. In cooperation with: The Nature Conservancy of Vermont. [38461]

165.
Vines, Robert A. 1960. Trees, shrubs, and woody vines of the Southwest. Austin, TX: University of Texas Press. 1104 p. [7707]

166.
Virginia Department of Conservation and Recreation, Division of Natural Heritage. 2003. Invasive alien plant species of Virginia, [Online]. Available: http://www.dcr.state.va.us/dnh/invlist.pdf [2005, June 17]. [44942]

167.
Virginia Department of Conservation and Recreation. 2003. Fact sheet: Tree-of-heaven (Ailanthus altissima (Miller) Swingle). In: Invasive alien plant species of Virginia, [Online]. Division of Natural Heritage (Producer). Available: http://www.dcr.state.va.us/dnh/fsaial.pdf [2003, November 6]. [45525]

168.
Voigt, Garth K.; Mergen, Francois. 1962. Seasonal variation in toxicity of Ailanthus leaves to pine seedlings. Botanical Gazette. 123(4): 262-265. [46735]

169.
Voss, Edward G. 1985. Michigan flora. Part II. Dicots (Saururaceae--Cornaceae). Bull. 59. Bloomfield Hills, MI: Cranbrook Institute of Science; Ann Arbor, MI: University of Michigan Herbarium. 724 p. [11472]

170.
Wade, Dale D.; Brock, Brent L.; Brose, Patrick H.; [and others]. 2000. Fire in eastern ecosystems. In: Brown, James K.; Smith, Jane Kapler, eds. Wildland fire in ecosystems: Effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of

Agriculture, Forest Service, Rocky Mountain Research Station: 53-96. [36983]

171.
Webb, Sara L.; Pendergast, Thomas H., IV; Dwyer, Marc E. 2001. Response of native and exotic maple seedling banks to removal of the exotic, invasive Norway maple (Acer platanoides). Journal of the Torrey Botanical Society. 128(2): 141-149. [42560]

172.
Welsh, Stanley L.; Atwood, N. Duane; Goodrich, Sherel; Higgins, Larry C., eds. 1987. A Utah flora. The Great Basin Naturalist Memoir No. 9. Provo, UT: Brigham Young University. 894 p. [2944]

173.
Wright, Henry A.; Bailey, Arthur W. 1982. Fire ecology: United States and southern Canada. New York: John Wiley & Sons. 501 p. [2620]

174.
Wunderlin, Richard P. 1998. Guide to the vascular plants of Florida. Gainesville, FL: University Press of Florida. 806 p. [28655]

175.
Youtie, Berta; Soll, Jonathan. 1990. Diffuse knapweed control on the Tom McCall Preserve and Mayer State Park. Unpublished report (prepared for the Mazama Research Committee) on file at: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, MT. 18 p. [38353]

176.
Zasada, John C.; Little, Silas. 2002. Ailanthus altissima (P. Mill.) Swingle ailanthus. In: Bonner, Franklin T., tech. coord. Woody plant seed manual, [Online]. Washington, DC: U.S. Department of Agriculture, Forest Service (Producer). Available: http://wpsm.net/Ailanthus.pdf [2004, January 6]. [46269]

FEIS Home Page