Ailanthus, the so-called tree-of-heaven, is probably the most famous invasive tree in the United States. It’s the title tree in Betty Smith’s classic 1943 novel A Tree Grows in Brooklyn, where it is used as a metaphor for persistence and toughness in the face of adversity. However, that toughness makes this tree—Ailanthus altissima (aka ailanthus, tree-of-heaven, stink tree, and Chinese sumac)—a serious problem wherever it grows.

It usually grows in urban settings, industrial wastelands, and mine spoils, and along railroad and highway corridors. It survives in hot, dry, and toxic soils, and sends down its roots around and through concrete and paving cracks. It sends out seeds in enormous numbers, smells bad, and is allelopathic (toxic to other plants). Ailanthus can create dense clonal thickets, almost monocultures. It grows very quickly, often displacing native plants, which may affect wildlife. It is extremely difficult to eradicate, and cutting down the trunk and/or pesticide treatment only result in new shoots growing up from the roots.

Botanists, ecologists, and foresters plus forest owners and managers have realized that ailanthus has now spread into eastern forests and is endangering regeneration and restoration efforts, especially in the mixed-oak forests of West Virginia, Ohio, and Pennsylvania. Forest ailanthus may be trees descended from those planted at abandoned farmsteads or from seeds brought along transportation corridors.
Many scientists in the U.S. Forest Service’s Northern Research Station (NRS) are working to improve oak regeneration and restoration in eastern forests, which has become problematic in past decades. Ailanthus exacerbates the challenges of regenerating oaks, especially in natural disturbances, timber harvests, and prescribed or wild fires. Although ailanthus tends to check itself, it can overrun understubs and then grow vigorously even with slight clearings, interfering with growth of native oaks and other trees and spreading into larger size patches.

**Ailanthus Response to Forest Disturbances and Interactions with Native Plants**

NRS research botanist Cynthia Huebner is working with a team including NRS researchers Rakesh Minocha (Durham, NH), Matthew Dickinson (Delaware, OH), and Gary Miller (Morgantown, WV), as well as Janie Mahaffey (Ohio University), and David McGill (West Virginia University) and their students to define the ecology and mechanisms of ailanthus growth and competition in the forest. How much sunlight do ailanthus seedlings need to germinate and grow? Can natives outgrow ailanthus under particular light and forest conditions? There are many questions to be answered!

The team evaluated germination, survival, and growth of three invasives (ailanthus as well as garlic mustard and Japanese stiltgrass) typically found in disturbed forests. They studied these species under five management regimes (control or unmanaged forests, single burns, repeated burns, selection harvests on the margins, and heavy shelterwood harvests). They also evaluated regional and local factors and gradients at 56 field sites in West Virginia, Ohio, and Virginia. They found that once a germinated ailanthus is likely to survive in each of the 20 combined management and environment types tested. However, ailanthus were more likely to germinate and grow in the heavy shelterwood sites (20% full sunlight) than in the control forests (2 to 5%) and the selection harvests (10%). Harvested sites with more cover of native species in the understory showed lower germination and growth of ailanthus, indicating that healthier forest sites that respond to disturbances with relatively rapid growth at early successional stages may have reduced proliferation of invasive plant species. In other research, NRS found that dogwood sites can out-compete ailanthus under a light/low light condition and maple sites can out-compete all three species under lower light conditions (tension gradient forest) and that mycorrhizae play a key role in alder’s competitive ability.

To determine the effects of more specific light levels on growth, Hutchinson and Minocha grew the same three invasives under growth chamber conditions. They found that the invasives showed significantly less shoot growth at lower light levels, roughly equivalent to a forest that had been thinned or harvested as a light shelterwood. Adequate oak growth in the field has been achieved at these same lower light levels (10% full sunlight) by others. These results were also supported by plant biochemical and stress indicators, including chlorophyll a/b, the polyamines putrescine, spermidine, and spermine, and the amino acid proline. Thus, management resulting in lower light levels (around 10% full sunlight) may reduce the likelihood of non-native species invasion but still enable oak regeneration.

The team has used these data to define an invasive potential value (IPV) for each combined forest management and environment type. The team has now scored stand growth and yield models (Forest Vegetation Simulator) to evaluate if such harvesting limitations are commercially viable. If harvesting at lower light levels (10% full sunlight) is commercially viable, land owners and managers may be willing to change their current harvesting preferences.

**Forest Management Practices Affect Ailanthus Distribution in Forested Landscapes**

NRS research plant physiologist Joanne Rebbeck is working with a team including NRS ecologists Todd Hutchinson and Louis Iverson and GIS specialist Matthew Peters (Delaware, OH) to determine how fire and harvesting practices affect the distribution of Ailanthus altissima in forested landscapes.
and abundance of ailanthus is related to seed sources, timber harvesting near
pruned trees, and landscape features. The team developed an effective
mapping tool to identify seed-bearing ailanthus trees across
thousands of acres of forest land. In all, 62 variables were considered in the
models, including those related to management activities, soil
characteristics, topography, and vegetation structure. Harvest history within the last 25
years was the best predictor of ailanthus presence or absence. A
noteworthily significant predictor. The team is currently validating these
predictions results in other forests so that this risk assessment tool can be
used for forest managers throughout the eastern United States.

Aerial Detection Guides Ground Treatment
As part of the above effort, scientists from the NRS Delaware (OH)
laboratory partnered with Ohio Department of Natural Resources (ODNR)
and Alpines National Forest personnel to develop a combination of aerial
detection and ground treatments to find and eradicate ailanthus in forests
and parks. Helicopters can spot a female ailanthus from 600 feet in the air.
This technique works because ailanthus is a dioecious species (meaning that
individual trees are either male or female) and female trees produce huge
clusters of seeds that are particularly visible in winter. These can be seen
from a helicopter and mapped digitally. Usually, male trees grow near females, so
both sexes can be treated. Helicopter-based detection allows the female
assistants to focus on the spread. After the location data are collected, they are
transferred to handheld GPS (global positioning system) devices, which are
then given to ground crews that go out, locate the trees, and apply the
“hack-n-squirt” treatment with herbicide. Seedlings can be hand-pulled, but a full
removal effort would involve removing roots because roots can resprout.

Unfortunately, ailanthus is tough to control with most nonherbicidal methods
either do not work or only partially. If the herbicide treatment is applied to the
trunk and stem, sprouts can be removed from the base. At the base, the bark is
removed, and the trunk is treated with the herbicide. The bark is then
reapplied. This technique has been very successful, providing timely
management with a cost-effective result. A typical application costs only
40 cents an acre. Preharvesting steps are needed. Ambrosia beetles may also
infect the life cycle of the fungus. Since the fungus is
specifically targeted at ailanthus and can survive in the soil for many years,
this method has great potential as a biological control. Although it is not a magic
bullet that will completely kill all ailanthus from our forests, it will improve the
chance for successful restoration of native vegetation as ailanthus dies out.

A Promising Alternative Method for Controlling Ailanthus
The good news is that there may be a biological control method for
ailanthus in the near future. NRS collaborator Donald Davis and graduate
students at the Pennsylvania State University discovered a species-specific
and deadly-acting fungus on ailanthus. In 2002, they isolated
Verticillium nonalfalfae from dead and dying ailanthus trees within forested
areas in Pennsylvania. The fungus is native to North America, so it does
not have to be handled according to strict APHIS regulations. Davis and his
graduate students tested this fungus in the greenhouse and in the field and
achieved 100% mortality within 10 to 16 weeks. To date, they have treated
more than 70 trees and found them unaffected. In 2008, the
same fungus was isolated from multiple forest stands in Virginia, and in 2012,
Rebbeck found and isolated the same ailanthus-killing fungus in Ohio. The
preliminary greenhouse results are very positive. Ailanthus is a
biocontrol; the fungus can spread from tree to tree through root grafting and
naturally build up in the forest. That makes work easier. Ailanthus is also
resistant to many other ailments, such as a disease that kills trees. Ambrosia
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Ailanthus: An Asian Native

The ailanthus tree is a deciduous native of northeast and central China and Taiwan. It grows rapidly and can grow to 15 meters (49 feet) in 25 years and can live more than 100 to 125 years. Ailanthus was imported into eastern North America in 1784 by gardeners attracted to its rapid growth and toughness, as well as its exoticism. It became a popular street and yard tree and was also cultivated to furnish and other rural-sheltering tribes. Later, when farms were abandoned, ailanthus trees became part of regrowing forests and survived in the shady understory. Whenever these second-growth forests were harvested, small ailanthus grew rapidly in the sunny clearings and took over. In the western United States, ailanthus was brought in by immigrants for use in traditional Chinese medicine. It has been grown extensively both in China and abroad as a host plant for the ailanthus silk moth, which is grown for production of Shantung silk.

BIographies

Research botanist Cynthia Huebner (right) joined the "Ecology and Management of Invasive Species and Forest Ecosystems" unit in Morgantown, WV, in August of 2000. Huebner's current research focuses on the biology and ecology of invasive plant species in forest systems, especially in association with anthropogenic and natural disturbances. She is working to determine how the common forest invader tree of heaven, Japanese stiltgrass, and garlic mustard interact with native species under various environmental conditions. Huebner is an adjunct associate professor in the Biology Department at West Virginia University. She received her PhD in botany from Miami University, Oxford, OH; an MS in environmental science and an MA in plant ecology from Indiana University, Bloomington; and a BS in biology from the University of California, Riverside.

Joanne Rebbeck (left) is a research plant physiologist with the "Sustaining Forests in a Changing Environment" unit located in Delaware, OH. Her primary research focuses on the interactive effects of silvicultural practices such as timber harvesting and prescribed fire, invasive plants, and site and stand characteristics on the growth and ecophysiological responses of oaks and other hardwoods. She has recently expanded research to develop biological control methods for ailanthus. Rebbeck is also actively involved in educational outreach programs with local schools and youth and resource organizations. Rebbeck is an adjunct associate professor in the Environmental and Plant Biology Department at Ohio University (Athens, OH). She received her PhD in botany from North Carolina State University, a MS in plant pathology and a BS in plant science from Rutgers University. She joined the Forest Service in 1988.
I can still recall the near shock of my first encounter with ailanthus in the woods in Ohio. Being a New Jersey native, I immediately thought: "What in the world is ailanthus doing out here in the woods? It’s not supposed to be growing here! It’s an urban tree, a problem along highways, railroads, and rights-of-way." Then, a few years later, I observed first-hand a blanket of ailanthus seedlings covering the forest floor shortly after a timber harvest and a prescribed burn. To say that it was scary is an understatement. I realized I was watching an invasion that worries foresters and scientists alike.

Joanne Rebbeck

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There are 135 NRS scientists working at 20 field offices, 24 experimental forests, and universities, located across 20 states, from Maine to Maryland, Missouri to Minnesota.

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