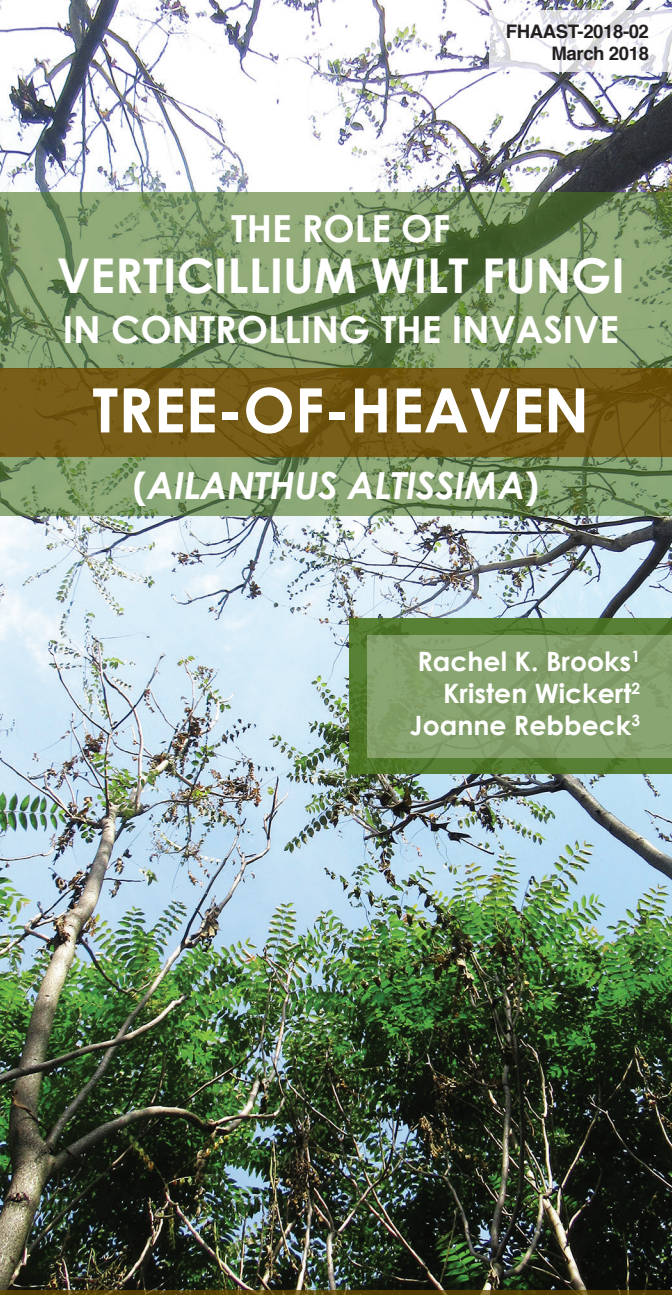
FHAAST-2018-02
March 2018

THE ROLE OF VERTICILLIUM WILT FUNGI IN CONTROLLING THE INVASIVE TREE-OF-HEAVEN (*AILANTHUS ALTISSIMA*)



Rachel K. Brooks[1]
Kristen Wickert[2]
Joanne Rebbeck[3]

[1]Dept. Plant Pathology, Physiology, and Weed Science, Virginia Tech, Blacksburg, VA
[2]Div. Plant and Soil Sciences, West Virginia University, Morgantown, WV
[3]Northern Research Station, USDA Forest Service, Delaware, OH

USDA FOREST SERVICE DEPARTMENT OF AGRICULTURE
Forest Health Assessment and Applied Sciences Team

This publication is available online at:

https://www.fs.fed.us/foresthealth/technology/pdfs/FHAAST-2018-02_Verticillium_Wilt_Fungi.pdf

The Forest Health Technology Enterprise Team (FHTET) was created in 1995 by the Deputy Chief for State and Private Forestry, USDA Forest Service, to develop and deliver technologies to protect and improve the health of American forests.

FHTET became Forest Health Assessment and Applied Sciences Team (FHAAST) in 2016. This booklet was published by FHAAST as part of the technology transfer series.

http://www.fs.fed.us/foresthealth/technology/

Acknowledgments

The authors wish to thank Matthew Kasson (West Virginia University), Scott Salom (Virginia Tech), and Anton Baudoin (Virginia Tech) for their support of this project and assistance with this booklet. Funding for this project was provided by the USDA Forest Service Forest Health Protection Special Technology Development Program and Biological Control of Invasive Plant Program. The layout of this brochure was designed by Rachel Winston, MIA Consulting.

THE GOAL OF CONTROLLING TREE-OF-HEAVEN (AILANTHUS) IS TO PROTECT OUR NATIVE FORESTS, WOODLOTS, AGRICULTURAL LANDS, AND SENSITIVE ECOSYSTEMS BY REDUCING ITS PRESENCE AND AGGRESSIVE SPREAD

KEY FINDINGS

- ***Verticillium nonalfalfae*** is a native soil-borne fungus that causes a vascular wilt disease and has been found naturally killing Ailanthus (**Fig. 1**) in Pennsylvania, Virginia, and Ohio
- *V. nonalfalfae* can rapidly spread throughout an Ailanthus stand after only a few one-time stem inoculations
- Severe decline and spread by this species-specific *V. nonalfalfae* isolate is limited to Ailanthus, with no indications that other plant species would be severely impacted

Fig. 1. Ailanthus in the foreground are displaying wilting symptoms one month after being inoculated with *Verticillium nonalfalfae.* (Photo: Kristen Wickert, West Virginia University) **Booklet front cover image:** Foliar symptoms on *V. nonalfalfae*-inoculated Ailanthus (top) compared to un-inoculated healthy Ailanthus (bottom) (Photo: Rachel K. Brooks, Virginia Tech)

AILANTHUS BACKGROUND INFORMATION

Deciduous hardwood tree native to eastern China that was brought to Pennsylvania in 1784 as an ornamental tree

Has spread throughout the northern and southern hemispheres, including most of North America where it has invaded over 40 US states

Invades our forests, outcompetes and displaces native vegetation important for wildlife habitat, timber, biodiversity, and recreational activities

Grows aggressively into right-of-ways and urban areas, and takes over agricultural lands in as little as a few years (**Fig. 2**)

Appears to help support other invasive species including the brown marmorated stink bug and the newly introduced spotted lanternfly

Grows quickly and spreads easily by producing thousands of seeds at an early age and sprouting clonally

Scientific name is *Ailanthus altissima,* but is also known as tree-of-heaven, Ailanthus, Chinese sumac, varnish tree, and stink tree

Fig. 2. Ailanthus infestation (Photo: Joanne Rebbeck, USDA Forest Service)

AILANTHUS IDENTIFICATION

- Long, pinnately compound leaves (**Figs. 3a, 4a**), whose leaflets have smooth margins and slightly lobed bases tipped by raised glands (**Figs. 3b, 4b**)
- Large amounts of seeds that turn from green/yellow to orange/red to brown on female trees visible in late summer through winter (**Figs. 3c, 4c**)
- Large triangular leaf scars that are edged by a line of bundle scars (**Fig. 3d, 4d**)
- Smooth cantaloupe-skin-like bark
- Pungent, rotten peanut-butter odor when touched
- Native look-a-like trees include walnut and sumac

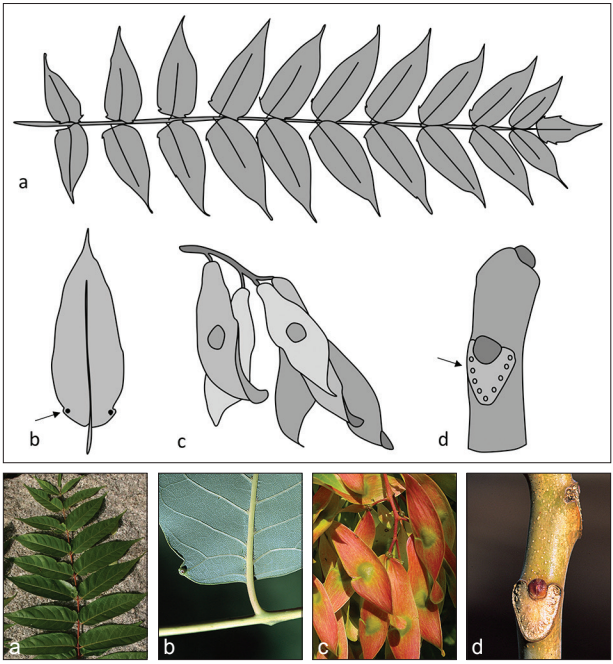


Fig. 3 (top), 4 (bottom). Key identification characteristics of Ailanthus including leaf shape (a), leaflet glands (b), seed structure (c), and leaf scars (d). (Illustrations: Rachel K. Brooks, Virginia Tech; Photos: a. Leslie J. Mehrhoff, University of Connecticut, b,d. James H. Miller Forest Service, c. Chuck Bargeron, University of Georgia, a-d bugwood.org)

How Will Verticillium Fungi Help?

- Chemical and mechanical control can remove Ailanthus from a small area. However, because Ailanthus is such an aggressive species, it will re-sprout, requiring multiple treatments and making large-scale, long-term eradication impractical and expensive
- Research shows that *V. nonalfalfae* will be cost-effective, largely Ailanthus-specific, long-lasting, and effective at removing Ailanthus from a landscape
- *V. nonalfalfae* is easy to apply by land managers and homeowners, unlike herbicides. The fungus is currently not available to the public and must be cultured under sterile conditions in a laboratory setting

Recognizing Ailanthus Impacted by *V. nonalfalfae*

- Foliar (leaves) symptoms: rapid onset of wilting, chlorosis (yellowing), necrosis (browning, **Fig. 5**), premature leaf drop, emergence of new leaves late in the season (epicormic sprouting and flushing, **Fig. 6**)
- Wood symptoms: branch drop and orange coloration of wood visible when bark is removed (**Fig. 7**)
- Stand symptoms: numerous disease or dead Ailanthus in one area (**Fig. 8**)

Fig. 5. Foliar symptoms on a *V. nonalfalfae*-inoculated Ailanthus (Photo: Donald Davis, The Pennsylvania State University)

Fig. 6. Epicormic sprouting on a *V. nonalfalfae*-inoculated Ailanthus (Photo: Rachel K. Brooks, Virginia Tech)

Fig. 7. Bark removed exposing color differences between healthy (left) and infected Ailanthus (right) (Photo: Kristen Wickert, West Virginia University)

Fig. 8. Aerial view of an Ailanthus stand with several trees exhibiting foliar symptoms following *V. nonalfalfae* inoculations (Photo: The Pennsylvania State University)

What Has *V. nonalfalfae* Research Proven?

- It has been confirmed that *V. nonalfalfae* can spread within a stand to neighboring Ailanthus through functional root grafts (roots that have grown together, **Fig. 9**), effectively killing Ailanthus within an area
- *V. nonalfalfae* isolates have been shown to cause severe and widespread decline only on Ailanthus in forest stands, and have little or no effect on other plants. Host-range testing of *V. nonalfalfae* has included over 70 species of plants with no major impact
- *V. nonalfalfae* can be applied to Ailanthus using hack-and-squirt stem-injection methods (**Fig. 10**) with most effective results achieved during spring-time inoculations
- *V. nonalfalfae* can be cheaply and efficiently cultured in large quantities in a laboratory setting

Fig. 9. Excavated Ailanthus roots showing a functional root graft (Photo: Kristen Wickert, West Virginia University)

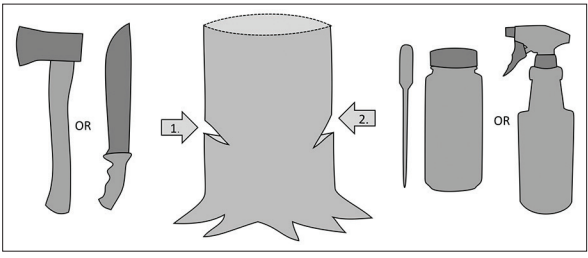


Fig. 10. Typical tools and procedure for hack-and-squirt inoculation methods appropriate for inoculating *V. nonalfalfae* into Ailanthus: (1) wound the plant with an axe or machete and then (2) inoculate the wound with the control agent using a pipette or a spray bottle. (Illustration: Rachel K. Brooks, Virginia Tech)

What to Expect in the Next Few Years:

- Research will continue to focus on:
  - insect vectors that may be able to help quickly spread the fungus from stand to stand
  - best management practices to restore vegetation after Ailanthus has been removed
  - climatic and geographic limits of *V. nonalfalfae* throughout Ailanthus's invaded North American range. These *V. nonalfalfae* isolates are currently only known to occur naturally in Pennsylvania, Virginia, and Ohio
  - determining any risk this *V. nonalfalfae* isolate has on other native species, including devil's walkingstick (*Aralia spinosa*), American ginseng (*Panax quinquefolius*), staghorn sumac (*Rhus typhina*), and striped maple (*Acer pensylvanicum*)
  - examining any other risks associated with using *V. nonalfalfae* as a biocontrol agent
  - further work on *V. nonalfalfae* production at an operational level (for large-scale production, inoculation, and distribution)
- Efforts to register *V. nonalfalfae* as a minor-use bio-herbicide with the US EPA are ongoing
- After registration, large-scale production and distribution will hopefully be taken on by a business or university

Until Then
Do's and Don'ts

- **Don't:** Movement of infected plant material or associated soil is highly discouraged as this practice can lead to the spread of other pests or diseases (such as spotted lantern fly or fusarium canker)

- **Don't:** Movement of *V. nonalfalfae* across state borders requires a government permit. Movement without a permit is punishable by law

- **Don't:** Use, production, or sale of *V. nonalfalfae* as a bio-herbicide requires US EPA registration

- **Do:** Continue to control Ailanthus using legal means (a combination of mechanical and chemical control) to limit future spread

- **Do:** When controlling Ailanthus with current legal means, remember:

  - to target seed-bearing trees first
  - that a combination of chemical and mechanical control works best
  - to plan on resurveying and retreating the area yearly

Booklet back cover image: An Ailanthus stand whose center-most trees were inoculated with *V. nonalfalfae* two months prior to this photo (Photo: Rachel K. Brooks, Virginia Tech)

Federal Recycling Program
Printed on Recycled Paper