Quarantine evaluation of *Eucryptorrhynchus brandti* (Harold) (Coleoptera: Curculionidae), a potential biological control agent of tree of heaven, *Ailanthus altissima*, in Virginia, USA

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Summary

Tree of heaven, *Ailanthus altissima* (Mill.) Swingle, is an imported invasive weed tree from China that has become established throughout much of the continental USA. It colonizes disturbed forest sites and often out-competes native vegetation. Short-term cultural and chemical controls of this weed are expensive and have limited efficacy. *Eucryptorrhynchus brandti* (Harold) and *Eucryptorrhynchus chinensis* (Olivier), two curculionid species, are pests of *A. altissima* in China and have no other known hosts. The objectives of our project are to (1) assess the pest status of *A. altissima* in Virginia and (2) evaluate *E. brandti* for its potential as a biological control agent. A statewide survey showed significant presence of tree of heaven but no native herbivores with potential of controlling it, suggesting biological control to be an attractive method of management. As *E. brandti* requires live trees for development, quarantine studies have focused on developing a rearing technique and testing the host specificity on native plants approved by the Technical Advisory Group for Biological Control Agents of Weeds. Preliminary results indicate that *E. brandti* feeds only on tree of heaven, with greatly reduced feeding observed on corkwood, *Leitneria floridana* Chapman, and paradise tree, *Simarouba glauca* DC.

Keywords: rearing, *Eucryptorrhynchus brandti*, host specificity testing, natural enemy.

Introduction

Ailanthus altissima, tree of heaven, is an introduced species in Europe (Ballero *et al.*, 2003; Lenzin *et al.*, 2004), Africa, South America and North America (Ding *et al.*, 2006). Seeds were introduced from China to Paris between 1740 and 1750 (Hu, 1979; Tellman, 2002) and in North America as an ornamental shade tree during the late 18th century from Europe into Philadelphia, Pennsylvania (Feret, 1985; Tellman, 1997). Multiple introductions into New York occurred during the early 19th century (Davies, 1942; Dame and Brooks, 1972; Hu, 1979).

Currently, tree of heaven is found in 41 of the lower 48 continental USA from Washington to New England and south to Florida, Texas and Southern California (USDA-NRCS Plants Database, 2007). It is often used as an ornamental adjacent to sidewalks, streets and in parking lots. In Virginia, tree of heaven is a dominant species along roadsides and occupies hundreds of acres in the Shenandoah National Park (Marler, 2000).

Tree of heaven has many beneficial attributes and often is regarded as an important ornamental species in the countries of origin because of its aesthetic value and ability to withstand environmental pollutants and water stress in an environment caused by human activities (Ding *et al.*, 2006). Traditional Chinese culture has used tree of heaven for its anti-tumour properties (Ammirante *et al.*, 2006). In its native range, tree of heaven is fed upon by more than 40 phytophagous arthropod species and is susceptible to nearly 20 pathogens (Ding

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et al., 2006). Few pathogens occur in the USA, and only one has caused isolated fatality of an individual tree of heaven plant (Ding *et al.*, 2006). None of the pathogens occurring in the USA appears to be specific to tree of heaven (Ding *et al.*, 2006). Tree of heaven produces allelopathic compounds capable of inhibiting the growth of nearly 90 tree species (Mergen, 1959; Heisey, 1990a,b; Lawrence *et al.*, 1991; Heisey and Heisey, 2003). The lack of natural enemies of tree of heaven and its ability to suppress plant growth over a wide range of habitats allow it to out-compete native flora in North America.

Chemical control of tree of heaven is the most common control method. Herbicides registered for tree of heaven control are dicamba, glyphosate, imazapyr, metasulfuron methyl and triclopyr. They are applied as foliar sprays, basal-bark treatments, injection or applied to cut stumps. However, chemicals often cause treated sites to be barren of any plant life resulting in the re-intrusion of invasive species like tree of heaven. There is a concern that continued large-scale herbicide applications may become detrimental to the environment in addition to being labor intensive and costly. For example, at a heavily infested 4-ha site on the median of interstate 81 in Virginia, the Virginia Department of Transportation estimated that the cost to control tree of heaven was $8750 per ha and produced only ‘reasonable’ control.

The lack of natural enemies of tree of heaven in the USA and the potential for biological control led to foreign exploration to identify potential biocontrol agents in China. A survey of the Chinese literature suggested that *Eucryptorrhynchus brandti* Harold and *Eucryptorrhynchus chinensis* (Olivier) (Coleoptera: Curculionidae) would be potential agents to investigate (Ding *et al.*, 2006). *E. brandti* is a univoltine beetle species native to China where it is considered a pest. In some areas of China, 80% to 100% of tree of heaven trees surveyed were attacked by *E. brandti* and *E. chinensis* causing 12% to 37% mortality (Ge, 2000; Ding *et al.*, 2006). Chinese people make considerable efforts to control *E. brandti* with chemicals and have found a nematode (*Steinernema feltiae*) that can produce 70% mortality in the field (Dong *et al.*, 1993; Jianguang *et al.*, 2004). The general biology of *E. brandti* is not well known. However, its development is probably similar to that of other curculionid species associated with woody trees (Barrett, 1967). Adults feed on leaves, buds and petioles (Ding *et al.*, 2006). Larvae develop under the bark and emerge as adults, leaving round emergence holes approximately 4 mm in diameter.

Our goal was to identify insect herbivores that can reduce the spread of tree of heaven. Specific objectives were to (1) survey for native insect herbivory on *A. altissima* in different regions of Virginia to identify any species with potential to impact tree of heaven and (2) import selected herbivores from the native habitat of *A. altissima* for host-specificity evaluation under quarantine to determine their potential for survival and development in Virginia.

Materials and methods

Tree of heaven in Virginia

Locations distributed throughout three different regions of Virginia were identified to determine the extent of *A. altissima* colonization. The regions were Ridge and Valley (Appalachian Mountains), Piedmont and Coastal Plain (Fig. 1). Within each region, at least two sites each along highways, rights-of-way or natural forest disturbance areas were selected. At each site, all tree species and their percent cover within the tree of heaven infestation were recorded. Observations of herbivores feeding on tree-of-heaven were done by visually examining at least 200 leaflets for herbivores. Herbivores were also collected by beating leaves over 1 m^2 beat sheets. Any herbivores found were collected and identified. Insect sampling also consisted of whole tree observation for activity and damage from insects. Whole tree observation included detailed examination of foliage, stems, buds and seeds (when available). Where obvious insect damage was detected, insects were collected if located. Our objective was not to carry out a biodiversity study or complete census of insects found on tree of heaven but to focus on insects colonizing or feeding on tree tissue causing observable damage. The survey began in the summer of 2004 and continued in 2005. Each site was visited monthly during the growing season (May to October).

Concurrent with the survey effort was the assessment of impact of identified herbivores on the growth, reproduction and survival of tree of heaven. When damage associated with insect feeding or colonization was found, it was followed by more intensive sampling of the causal agents. The intention was to determine, for each identified herbivore, the level and timing of activity across all regions and site types. We recognize that native herbivores are not likely to effectively control tree of heaven, as the weed has been highly successful thus far. However, this information will be helpful, as we evaluate exotic biological control agents and their potential interaction with our existing fauna.

Quarantine testing of an exotic weevil imported from China

As part of a collaborative project with Dr. Ding Jianqing, Biological Control Institute, Chinese Academy of Agricultural Sciences, two weevil species, *E. brandti* and *E. chinensis*, identified as important pests of *A. altissima*, were studied in China. *E. brandti* was imported into the US Department of Agriculture’s (USDA) Animal and Plant Health Inspection Service (APHIS) approved Quarantine facility at Virginia Tech beginning in 2004.

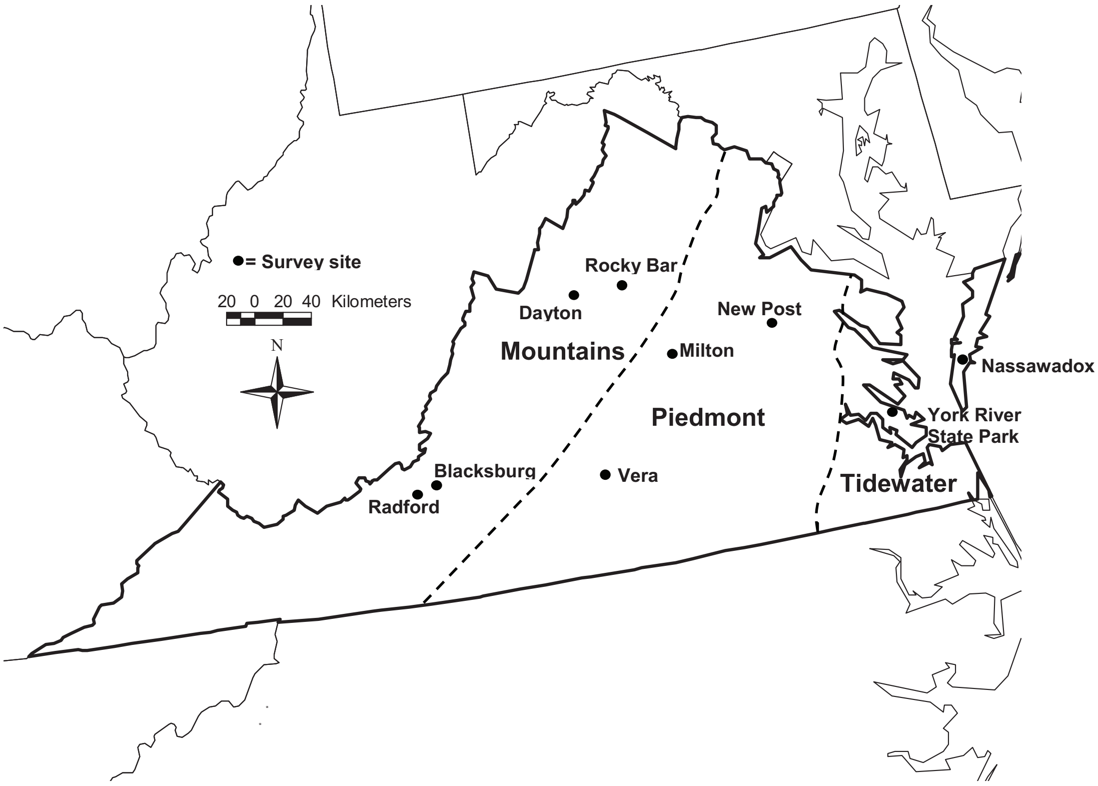

Figure 1. *Ailanthus altissima* (Mill.) Swingle survey sites in Virginia, USA: (1) Mountain, including Radford (forest), Blacksburg (forest), Dayton (forest) and Rockbar (roadside); (2) Piedmont, including Vera (forest), Milton (roadside) and New Post (roadside); (3) Coastal plain, including York River State Park (roadside) and Nassawadox (forest).

Survival and development: Adult *E. brandti* is reared on tree of heaven foliage and stems in containers at several constant temperatures (20°C to 30°C) within the range that the species will encounter in the US release areas. Biological data recorded included survival and development times of the egg, larval and adult stages, as well as fecundity of the females and egg hatch rates. Two colonies were established; one colony was maintained for production and the second used for biological and host specificity studies.

Production colony: This colony has been maintained and caged in screened plastic boxes (30 × 15 × 165 cm) at 22°C. Groups of five males and five females were placed in the cages. In each cage, tree of heaven billets, with the upper ends sealed with heated paraffin to reduce desiccation, were provided for oviposition and foliage added for adult feeding. Vermiculite was added to the bottom of the cage and kept moist. Weekly, billets were removed and placed in separate cages for larval development. Newly emerged adults were transferred to new oviposition cages.

Fecundity: Single pairs of male and female were caged in screened plastic boxes, as in the production colony cages, and replicated. Tree of heaven billets were added and checked for oviposition daily by removing the bark and examining the cambium for eggs. After initiation of oviposition, the bark was checked daily for eggs.

Egg and larval development: Eggs recovered from the billets were placed in Petri dishes with moistened filter paper and reared at several constant temperatures and checked daily for hatching. Newly hatched larvae were inoculated in tree of heaven billets by drilling a 7-mm diameter hole into the cambium and inserting one larva into the hole. Billets were checked at an appropriate time after inoculation to determine when development to the second instar occurred. This procedure was repeated at least three times for subsequent instars until pupation.

Physiological host specificity testing: Host-range studies included a series of no-choice and choice feeding and oviposition tests. Test plant species were from three groups, with a total of 30 species: 18 taxonomically related species (Simaroubaceae, Meliaceae and Rutaceae), six ecologically related species, and six economically related species. The taxonomically related species were chosen based on Wapshere's method of centrifugal phylogentic testing (Wapshere, 1974). This method involves exposing the biological control agent to a sequence of plants from those most closely related to the target species progressing to successively more and more distantly related plants until the host range

Table 1. Plant species to be tested for their suitability as hosts of *Eucryptorrhynchus brandti* (Harold). Species are listed with the most closely related listed first and the most distant last.

Family	Species	Common name
Simaroubaceae	Chinese *Ailanthus altissima* (Mill.) Swingle	Tree of heaven
	Simarouba glauca DC	Paradise tree
	Simarouba tulae Urban	Aceitillo falso
	Leitneria floridana Chapman	Corkwood
	Castela emoryi (Gray) Moran & Felger	Crucifixion thorn
	Castela erecta Turp.	Cockspur, goat-bush, retama, rupagüita
	Holacantha stewartii C. H. Muell.	Stewart crucifixion thorn
Picramniaceae	*Alvaradoa amorphoides* Liebm.	Mexican alvaradoa
	Picramnia pentandra Sw.	Florida bitterbush
Meliaceae	*Swietenia mahagoni* (L.) Jacq.	West Indian mahogany
	Citrus aurantifolia (Christm.) Swingle	Lime
	Citrus aurantium L.	Sour orange
	Citrus limon (L.) Burm. F.	Lemon
	Citrus paradisi Macfad.	Grapefruit
	Citrus reticulate Blanco	Tangerine
	Citrus sinensis Osbeck	Sweet orange
	Ptelea trifoliate L.	Common hop tree
	Zanthoxylum americanum Mill.	Northern prickly-ash

is thoroughly determined. The ecologically associated species were chosen based on our observations in Virginia. This species list is currently under review by the Technical Advisory Group (TAG) USDA/APHIS. A suitable host is defined as a plant species that will support feeding, oviposition and larval development of the insect to the adult stage, and the latter is capable of producing viable progeny. If any of these four conditions is not met, the insect will not be able to survive and is therefore not able to sustain a population solely on the plant species in question.

Table 2. Economically important and ecologically associated plant species to be tested.

Family	Species	Common name
Economically important		
Aceraceae	*Acer rubrum* L.	Red maple
Fagaceae	*Quercus alba* L.	White oak
	Quercus rubra L.	Red oak
Juglandaceae	*Carya glabra* (Mill.) Sweet	Pignut hickory
	Juglans nigra L.	Black walnut
Magnoliaceae	*Liriodendron tulipifera* L.	Tulip poplar
Ecologically associated		
Anacardiaceae	*Rhus typhina* L.	Staghorn sumac
Cuppressaceae	*Juniperus virginiana* L.	Eastern redcedar
Leguminosae	*Robinia pseudoacacia* L.	Black locust
Pinaceae	*Pinus virginiana* Mill.	Virginia pine
Rosaceae	*Crataegus* spp.	Hawthorne
	Prunus serotina Ehrh.	Black cherry

Feeding tests: Foliage and billets of the species listed in Tables 1 and 2 were used in choice and no-choice tests to date. Tests were conducted for 7 days at 20°C.

No-choice. Leaf clusters of each test plant species were caged with three adults. The amount of feeding was determined by placing a transparent millimeter square grid over the fed upon portion of the leaves. The control cage maintained at the same time with tree of heaven was without weevils.

Choice. Two series of tests were conducted, one with tree of heaven in the cage and one without. In the first test series, one cluster of tree of heaven leaves together with leaf clusters of one or more non-target species was placed in cages with adult beetles. In the second series, two or more non-target test species based on availability were placed in the cage with no tree of heaven. The available target species were selected randomly. Feeding was recorded as described above.

Oviposition tests: No-choice. Billets of one test plant species were placed in cages with one gravid female and compared with control billets of tree of heaven without weevils. The cambium was examined for eggs after 1 week. Foliage of the same species as the billet was placed in the cage with the adults for food.

Choice. Two or more species of billets were placed in cages with one gravid female. Two series of tests were carried out, with tree of heaven plus one or more other species in the cage and one with only a non-target

Table 3. Tree species composition and their percent coverage (%) at nine survey sites in Virginia, USA.

Species	Mountain				Piedmont			Coastal plain		Mean
	Dayton	RockBar	Blacksburg	Radford	New Post	Milton	Vera	Nassawadox	York River State Park	
Ailanthus altissima (P. Mill.) Swingle	15	85	80	30	35	70	15	20	15	32
Quercus palustris Muenchh	25	5			15		60	10	15	14
Pinus virginiana P. Mill.				95						11
Juniperus virginiana L.		10			15	10	15			6
Pinus taeda L.								40		4
Robinia pseudoacacia L.	15	10	15				20			5
Liquidambar styraciflua L.					10			15	40	7
Pinus strobi L.	10					50				7
Rhus glabra L.	20	15								4
Prunus virginiana L.	15	10	25	20	5					6
Liriodendron tulipifera L.	20				20					4
Acer negundo L.		10				15				3
Ilex opaca Ait.								30		3
Juglans nigra L.					5				20	3
Acer rubrum L.	10	10								2
Ulmus americana L.					5					1
Acer saccharinum L.						10				1

test plant species. Foliage was added for food. After 1 week, the billets were checked for eggs.

Results

Survey of VA and impact assessment of native herbivores

Seventeen tree species were found to co-exist with tree of heaven in Virginia, with coverage of tree of heaven ranging from 15% to 85% (Table 3). The common associates found with tree of heaven were *Quercus* spp., observed in six of the nine survey sites, with coverage ranging from 5% to 60%. Twenty insect herbivore species were collected from tree of heaven in 2004 and 2005 (Table 4). The 12 beetles (Coleoptera) in Table 4 had little impact on tree of heaven. Their potential as biological control agents is minimal because of their low abundance and broad host range. The only abundant Coleoptera herbivore that may be causing serious damage to tree of heaven are the ambrosia beetles *Euwallacea validus* (Eichoff) and *Xyleborus atratus* Eichoff. These emerged from dying tree of heaven. We suspect that these species only attacked the dying or dead trees and had little effect on healthy tree of heaven. Based on our observations of herbivores in Virginia in 2004 and 2005, these herbivores had a negligible impact on tree of heaven.

Table 5. Mean (±SD) number of webworm, *Atteva punctella* Cramer, including eggs, larvae, pupae and adults, in 2004 and 2005, at three survey regions: Piedmont, Mountain and Coastal Plain.

Month	Region		
	Mountain	Piedmont	Coastal Plain
2004			
June	4.0 ± 1.4	37	28
July	11.5 ± 8.9	54.3 ± 17.9	37.5 ± 26.2
Aug.	46.5 ± 17.0	91.3 ± 15.0	58.0 ± 2.8
Sept.	36.3 ± 30.4	21.7 ± 13.0	5.0 ± 5.7
2005			
May	2.0 ± 2.8	0.3 ± 0.6	0
June	6.5 ± 7.5	17.0 ± 23.6	21.0 ± 5.7
July	12.0 ± 5.7	111.0 ± 163.7	75.0 ± 19.8
Aug.	12.5 ± 10.6	46.3 ± 55.6	84.5 ± 50.2
Sept.	102.5 ± 88.4	106.0 ± 112.2	52.5 ± 31.8

Table 4. Insect herbivores found on *Ailanthus altissima* (Mill.) Swingle in 2004 and 2005 from nine survey sites in Virginia, USA.

Herbivores	Common Name	Number individuals/ site
Coleoptera		
Odontota dorsalis (Thunberg)	Locust leaf miner	0.7
Chrysomelidae spp.	Leaf beetle	2.5
Bruchid spp.	Seed beetle	1.3
Popillia japonica Newman	Japanese beetle	3.4
Neotrichophorus spp.	Click beetle	5.2
Chrysolina quadrigemina Suffrian	Flea beetle	0.3
Apion spp.	Weevil	<0.1
Merhynchites spp.	Leaf rolling weevil	<0.1
Sphenophorus spp.	Snout beetle	0.3
Orchestes spp.	Weevil	<0.1
Scolytinae spp.	Ambrosia beetle	<0.1
Lepidoptera		<0.1
Ectropis crepuscularia D. and S.	The small engrailed	<0.1
Thyridopteryx ephemeraeformis (Haworth)	Bagworm	<0.1
Atteva punctella (Cram.)	*Ailanthus* webworm moth	>30
Saturniidae spp.	Silkworm moths	<0.1
Hemiptera		
Empoasca sp.	Leaf hopper	0.7
Anormenis sp.	Plant hopper	2.3
Acanalonia sp.	Plant hopper	1.2
Orthoptera		
Scudderia furcata Brunner	Katydid	0.5

Ailanthus webworm, *Atteva punctella* Cramer, was the only herbivore consistently present in all sites with a total of over 30 (eggs, larvae, pupae and adults) per visit. *A. punctella* caused ≥50% defoliation for 1-year-old seedlings. However, its effect on larger trees (>3 cm diameter) was minimal, causing less than 5% defoliation with no visible impact. The population of this species peaked around August (Table 5) with no significant difference among the three geographic regions [$F_{(22,11)} = 0.63$, $p = 0.83$) Two other insect species have been reported to feed on tree of heaven foliage: Cynthia moth, *Samia cynthia* (Drury), and the Asiatic garden weevil, *Maladera castanea* (Arrow) in eastern USA (Drooz, 1985). However, their presence was not identified in this survey, and it is unlikely that these two insect species will have any impact on the tree of heaven in Virginia.

Quarantine testing of *E. brandti* imported from China: Development and rearing of *E. brandti* in the laboratory

A total of 500 and 1200 *E. brandti* adults were received from our cooperator in China in 2005 and 2006, respectively. In 2005, we initiated a study to evaluate the optimum conditions for rearing *E. brandti*. Eighteen adults (nine females, seven males and two unsexed) emerged from tree of heaven billets in Spring

Table 6. No choice foliage feeding tests of *Eucryptorrhynchus brandti* (Harold) adults on target and test species.

Family	Species	Common name	N	$\bar{X} \pm$ SD (mm[2] per adult per day)
Simaroubaceae	*Ailanthus altissima* (Mill.) Swingle	Tree of heaven	9	56.4 ± 21.0[a]a
	Simarouba glauca DC	Paradise tree	9	8.5 ± 0.4.8 b
	Leitneria floridana Chapman	Corkwood	9	21.0 ± 9.2 b
Rutaceae	*Citrus aurantifolia* (Christm.) Swingle	Lime	3	0 c
	Citrus aurantium L.	Sour orange	3	0 c
Aceraceae	*Acer rubrum* L.	Red maple	4	0 c
Anacardiaceae	*Rhus typhina* L.	Staghorn sumac	4	0 c
Cupressaceae	*Juniperus virginiana* L.	Eastern redcedar	4	0 c
Fagaceae	*Quercus alba* L.	White oak	2	0 c
	Quercus ruba L	Red oak	2	0 c
Juglandaceae	*Carya glabra* (Mill.) Sweet	Pignut hickory	4	0 c
	Juglans nigra L.	Black walnut	2	0 c
Leguminosae	*Robinia pseudoacacia* L.	Black locust	4	0 c
Magnoliaceae	*Liriodendron tulipifera* L.	Tulip poplar	4	0 c
Pinaceae	*Pinus virginiana* Mill.	Virginia pine	2	0 c
Rosaceae	*Crataegus* spp.	Hawthorne	4	0 c
	Prunus serotina Ehrh.	Black cherry	2	0 c

[a] Means within a column followed by different letters are significantly different at $P < 0.05$, Tukey–Kramer multiple comparison test.

2006, indicating that the weevil could complete its life cycle in a cut tree of heaven log.

At approximately 20°C, most *E. brandti* developed from egg to adult in 3 months. However, some individuals did not complete within 9 months and were still larvae after 9 months.

E. brandti did not expel frass from the billet. Frass remained in the billet within the feeding galleries. This made it difficult to know where the weevils were located and their life stage without dissecting the billet. Only 15% (18/119) of the weevils completed their life cycle and emerged. A few weevils that completed development failed to emerge, possibly due to poor food quality and quantity. Three young larvae were removed from one billet and transferred to another by inserting them into a 7-mm diameter hole. Frass was observed 3, 6, 9 and 11 days after the transfer, and two larvae completed development to the adult stage. They developed into adults but died inside the tunnel. This suggests that transfer of larvae into an artificially drilled hole has the potential to be used as a bioassay to test larval development on non-target species.

Based on the above observations, we developed a rearing procedure in 2006. Live tree of heaven trees were periodically cut into 1-m lengths, with diameter ranging from 10 to 22 cm. One end was treated with paraffin and the other end was placed in a 5-cm water bath to help maintain viable phloem tissue as long as possible. Groups of four billets were placed in a cage together with up to 150 weevils (male and female) for

Table 7. Two choice foliage feeding tests of *Eucryptorrhynchus brandti* (Harold) adults on target and test plant species.

Family	Species	Common name	n	Test species	*A. altissima*
				$\bar{X} \pm$ SD (mm[2] per adult per day)	$\bar{X} \pm$ SD (mm[2] per adult per day)
Simaroubaceae	*Simarouba glauca* DC	Paradise tree	9	0.9 ± 1.7[a]	40.4 ± 15.0[a]
	Leitneria floridana Chapman	Corkwood	9	2.7 ± 1.9[a]	41.6 ± 18.5[a]
Aceraceae	*Acer rubrum* L.	Red maple	4	0[a]	26.6 ± 1.6[a]
Magnoliaceae	*Liriodendron tulipifera* L.	Tulip poplar	4	0[a]	28.7 ± 16.8[a]
Anacardiaceae	*Rhus typhina* L.	Staghorn sumac	4	0[a]	22.3 ± 16.8[a]
Leguminosae	*Robinia pseudoacacia* L.	Black locust	4	0[a]	27.0 ± 5.0[a]
Rosaceae	*Prunus serotina* Ehrh.	Black cherry	2	0[a]	26.0 ± 8.4[a]

[a] Denotes significant differences ($P \leq 0.05$) between *Ailanthus altissima* and the test species (Student's t test).

2 to 3 weeks. The billets and developing larvae were maintained at 22°C. After 2 months, the billets were checked daily to capture emerging adults. Through 2006, 523 F1 generation adults emerged. Generally, their size was smaller than weevils shipped from China. As we refine this rearing method, we will focus on using fewer weevils in the oviposition cages to reduce competition among developing larvae in the billets.

Adult feeding test

Of the species tested, feeding by *E. brandti* adults occurred only on species in Simaroubaceae. Tree of heaven was highly favored for feeding over the non-target species tested (Table 6). In no-choice tests, adults consumed nearly seven and three times more of tree of heaven foliage than *S. glauca* and *L. floridana*, respectively. No feeding occurred on 15 other non-target species. In two-choice tests, an even less non-target species foliage was consumed. When given a choice of tree of heaven and *S. glauca* or *L. floridana*, *E. brandti* adults consumed 48 and 15 times more tree of heaven foliage than the two non-target species, respectively. No feeding occurred on five species outside of Simaroubaceae (Table 7).

Billet inoculation assay

Seven *E. brandti* larvae were inoculated into 7.5-cm diameter × 76-cm long billets of tree of heaven, *Robinia pseudoacacia*, *Prunus serotina* and *Citrus aurantifolia* to determine if young larvae (<30 days old, approximately second instar) can survive on plants other than tree of heaven. These preliminary assays were replicated twice, and larvae remained in billets for 30 days. Our results indicate a high level of specificity for tree of heaven. No feeding occurred in species other than tree of heaven, resulting in 100% larval mortality (Fig. 2). This is compared with 36% larval survival in *A. altissima* past the instar when the larvae were inoculated.

Conclusions

The survey work in Virginia helped characterize tree species associated with tree of heaven, with *Quercus* spp. being the predominant associate regardless of region. The insects found feeding on tree of heaven were of inconsequential value in terms of damaging the weed tree and contributing to its overall control. Rearing studies have improved to the point that a continuous

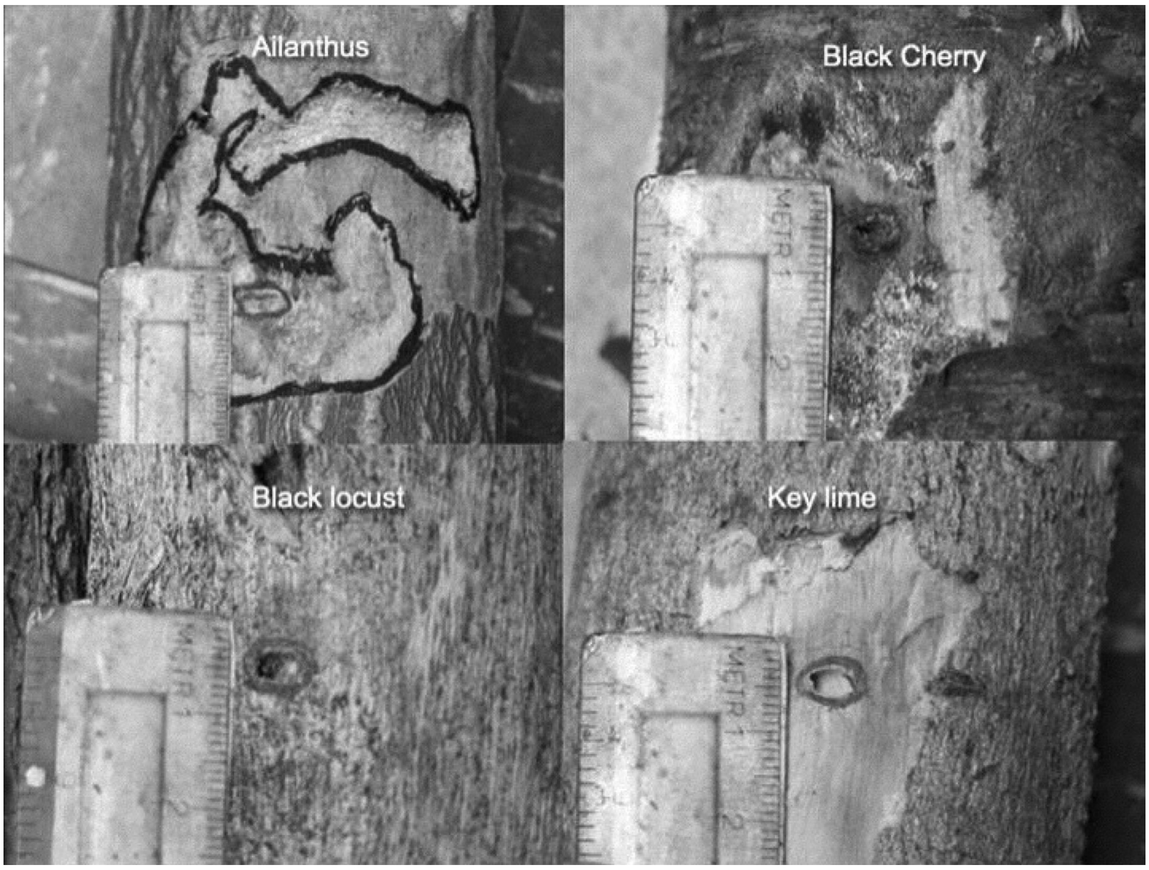

Figure 2. Example of *Eucryptorrhynchus brandti* (Harold) larval galleries in each of 4 species tested. Note that galleries were created only in *Ailanthus altissima* (Mill.) Swingle (photo credit, N. Herrick).

colony of *E. brandti* is possible. The use of billets with one end sealed with paraffin and the other sitting in water may be an adequate bioassay for larval survival tests. Preliminary results from the quarantine studies showed that the risk of this beetle attacking non-target trees is minimal. Continued testing is ongoing.

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