As featured in American Nurseryman

Three industry experts discuss the current status of the emerald ash borer infestation and the program to eradicate it.

Under ATTACK

The emerald ash borer (EAB; *Agrilus planipennis*) is an exotic, invasive insect that has infested and killed an estimated 8 to 10 million ash trees since its accidental importation from Asia. The infestation is now established across more than 5,000 square miles in 13 counties in southeast Michigan, as well as in neighboring Essex County, Ontario, Canada. Isolated, localized infestations, termed "outliers," exist elsewhere in Michigan, northwest Ohio and northeast Indiana. While this EAB invasion is regional in scope, its impact on the nursery industry has been felt nationwide, as growers across the country report a sharp decline in the demand for ash trees.

All major eastern North American ash species have been killed by EAB, which infests trees ranging in size from one-half-inch caliper nursery stock to fully mature trees in forests. While most native borers colonize only weakened trees, EAB attacks healthy trees as well, making the problem especially devastating. If the pest is not contained and eradicated, the impact of EAB on ash in North America will be similar to that of chestnut blight and Dutch elm disease. These exotic pests devastated natural and urban forests in the 20th century. However, an aggressive, coordinated containment and eradication program undertaken by federal, state and Canadian agencies provides reason to be optimistic that North American ash can ultimately be spared the same fate of elm and chestnut trees.

by Dr. Daniel A. Herms, Dr. Deborah G. McCullough *and* Dr. David R. Smitley

Millions of ash trees in suburban Detroit have been killed by the emerald ash borer.

Our hope in writing this article is to provide some background on the current state of the EAB infestation, as well as an overview of the eradication program. We'd also like to clarify some misconceptions that appeared in Plant Health in the Aug. 1 issue of AMERICAN NURSERYMAN ("Michigan takes three-phase approach to fight EAB"). Two of us (Herms and McCullough) are members of the National Emerald Ash Borer Science Panel, and we're all heavily involved in EAB outreach and research, including projects directly relevant to the nursery and arboriculture industries.

A historical look. EAB was unknown in North America until June 2002, when it was determined to be the cause of unusually widespread ash mortality in southeast Michigan and discovered shortly thereafter just across the Detroit River in Windsor, Ontario. The insect is native to areas of Asia, including eastern Siberia, northeastern China, Mongolia, Japan and Korea, where it occurs on several species of ash. It was probably imported into Michigan about 10 to 15 years ago via infested ash crating or pallets.

The pest was first discovered in Ohio near Toledo in February 2003. Isolated infestations were subsequently found in four additional counties in northwest Ohio, as well as in suburban Columbus. In spring 2004, two additional outlier infestations were discovered in northeast Indiana. While the Aug. 1 Plant Health report stated, "EAB infestations have been reported in Wisconsin, … ," none has actually been detected in the Badger State.

Most of these outlier infestations have been linked to artificial spread of EAB from southeast Michigan through movement of infested ash nursery stock, logs and firewood. This largely occurred before the insect was identified and state and federal quarantines imposed. An infestation discovered in a Maryland nursery in August 2003, however, resulted when a Michigan grower violated the quarantine and shipped infested ash trees. This resulted in stiff penalties for the grower, including substantial fines, restitution and community service. Eradication programs were promptly implemented in Maryland and neighboring Virginia, which received some of the trees from Maryland. So far, no additional infestations have been discovered. Meanwhile, the infestations in Michigan, Ohio and Indiana already have, or soon will be, subject to the outlier eradication program described later.

Economic and ecological impact. The economic and ecological impacts of EAB have already been substantial and will be staggering if the infestation continues to spread. Ash species inhabit a variety of soils and ecosystems, and they are dominant throughout the forests of eastern North America.

According to USDA Forest Service statistics, there are at least 700 million white ash trees in Michigan forests and 3.8 billion in Ohio (including more than 70 million that exceed a 5-inch diameter at breast height), with standing timber valued at more than $1 billion. Furthermore, ash has been one of the most im-

PHOTOS: DANIEL A. HERMS, THE OHIO STATE UNIVERSITY/OARDC

portant nursery and landscape species. According to the USDA, wholesale value of ash trees sold in the US exceeded $31 million in 1998, a market that has been decimated since the discovery of EAB.

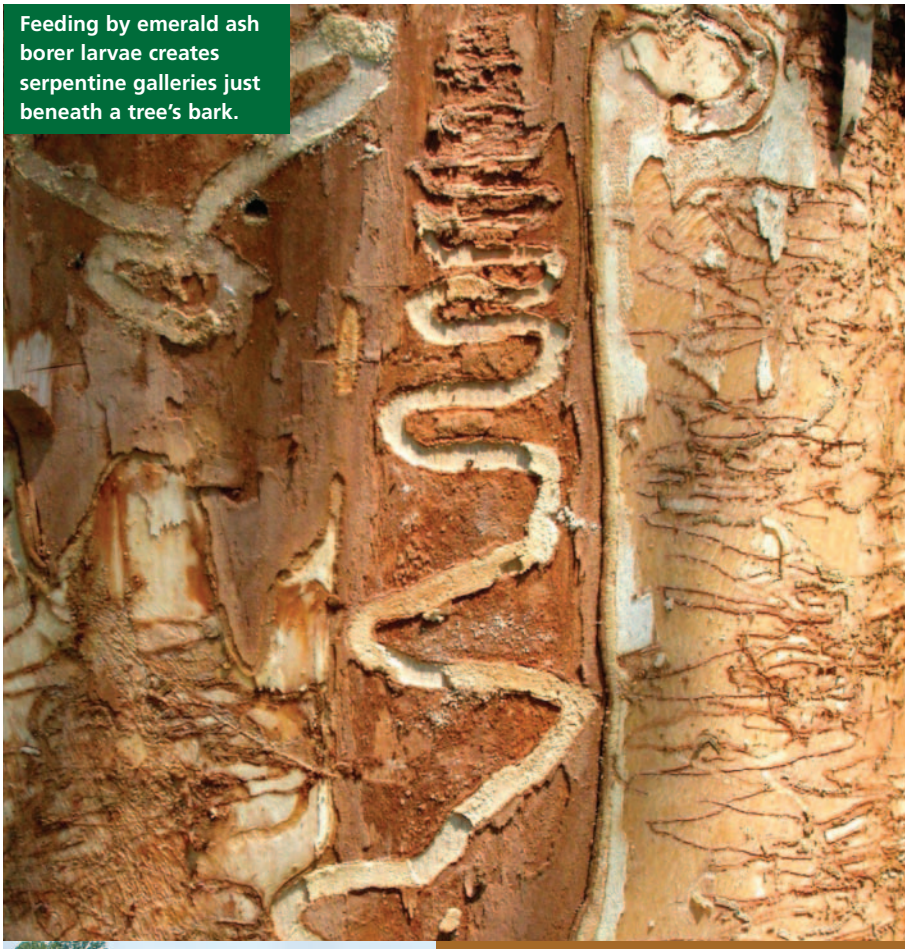
The pest has already caused tens of millions of dollars of damage to Michigan landscapes, urban forests and woodlots, and this cost is increasing at an exponential rate. The price of removing dead and dying ash has overwhelmed municipal budgets in affected counties. A quarantine on ash timber and firewood has also had negative economic impacts on sawmills, tool-handle factories and firewood dealers in Michigan and Ohio.

Taxonomy and biology. Taxonomically, EAB is a beetle (Coleoptera) belonging to the family known as metallic wood-borers (Buprestidae). Larvae of these insects are known as flatheaded borers, as during the larval stage the beetle appears to have a broadly flattened head. (It is actually the thorax that mostly conceals the much smaller head.) EAB larvae are white with a long (about 1 inch when mature), narrow, segmented abdomen that is also flattened, giving them the appearance of small tapeworms. Adults are elongate, half-inch-long beetles that are a striking metallic-green.

EAB belongs to the same genus as bronze birch borer (*A. anxius*) and twolined chestnut borer (*A. bilineatus*), both of which are native to North America. The biology of EAB is quite similar to its native relatives. Generally, there is one generation each year, although recent studies by Michigan State University (MSU), East Lansing, researchers suggest development may sometimes take longer in newly infested, healthy trees.

Adult beetles emerge from infested ash trees in late May through early August, with emergence peaking in mid- to late June. As adults emerge, they leave small (one-eighth-inch), distinctly D-shaped exit holes in the trunk and main branches. Adults may live three to six weeks and nibble on small patches of ash leaves during this period. Females generally produce about 50 to 80 reddish eggs, which are laid individually on the bark surface or within bark cracks and crevices.

When larvae hatch, they tunnel into the tree, where they feed on the phloem and outer sapwood, excavating S-shaped, serpentine galleries just under the bark, disrupting the flow of nutrients and water between the canopy and roots. This causes canopy thinning and branch dieback — and ultimately tree death. Larvae continue to feed through summer and into fall. They overwinter in the outer bark or within the outer inch of sapwood. Pupation occurs in mid- to late spring. Adults emerge soon thereafter to complete the typical one-year cycle.



Feeding by emerald ash borer larvae creates serpentine galleries just beneath a tree's bark.

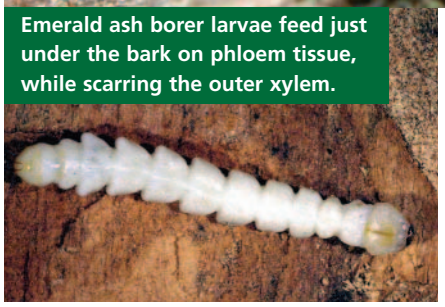
Ash trees killed by emerald ash borer are brought to marshalling yards for disposal.

Host plants and impact. Ash species known to be infested in Michigan include *Fraxinus americana* (white ash), *F. nigra* (black ash), *F. pennsylvanica* (green ash) and *F. quadrangulata* (blue ash), as well as cultivars of these species. Only living trees are colonized. In China, the insect colonizes the Asian ash species *F. mandshurica* (Manchurian ash) and *F. chinensis* (Chinese ash). In Japan, species of *Juglans* (walnut and bitternut), *Pterocarya* (wingnut) and *Ulmus* (elm) have also been recorded as hosts.

However, EAB has not been well-studied in Asia (a total of three published pages), and these host records may reflect the existence of subspecies or simply taxonomic confusion. Furthermore, host records for borers are notoriously unreliable and often include tree species from which adults were collected, even when larvae were not able to develop on those species.

Research on host range and host preference is underway, and preliminary results from MSU studies strongly

Adult emerald ash borer



Emerald ash borer larvae feed just under the bark on phloem tissue, while scarring the outer xylem.

suggest walnut and elm are not viable hosts for EAB in North America. Studies are also investigating the susceptibility of plants related to ash, such as lilac and privet. To date, infestations on these species have not been observed, even when growing in close proximity to infested ash trees.

Signs and symptoms. EAB infestations are usually difficult to detect until they become severe. Larvae are hidden under bark, and adults may spend most of their time in a tree's upper canopy. Research indicates EAB usually colonizes the upper trunk area of large trees first, making it difficult to see any diagnostic signs or symptoms. In addition, symptoms of EAB infestation often resemble other causes of tree decline.

Symptoms usually associated with ash borer infestation include small, vertical splits in the bark that can sometimes be observed on large branches or on the trunk. These splits occur when callus tissue that forms around a larval gallery pushes the outer bark away from the sapwood. To confirm the presence of EAB, one can widen the splits to reveal larvae and galleries under the bark. Usually larval galleries are distinctly S-shaped or serpentine, and they are packed tightly with frass (a mixture of sawdust and excrement). They are also visible on the inner surface of the outer bark when it is removed.

The presence of small, distinctly D-shaped exit holes in the trunk or scaffold branches is a good sign of infestation. As invasion progresses, the canopy starts to thin, and branch dieback may occur. Decline often accelerates rapidly at this point. When EAB populations are high, trees typically die within two to four years of infestation. Epicormic shoots often sprout from the main trunk of declining trees, and root sprouts sometimes occur at the base of dying trees.

Woodpeckers are proving important predators of EAB. A noticeable increase in woodpecker activity on ash trees can provide an early indication of an infestation, especially during winter.

Industry research. In Asia, EAB does not devastate its native hosts. Rather, reports indicate outbreaks are relatively uncommon, isolated and associated with stress events such as drought. This suggests that Asian ashes may be generally resistant and that EAB preferentially colonizes stressed trees. Thus, EAB seems to behave in Asia much as its close native relatives do in North America, including bronze birch borer and twolined chestnut borer, which also preferentially colonize stressed trees. Native trees may be more resistant to their native pests due to natural defenses that have evolved over eons. Hence, Asian ash trees may be a source of resistance genes.

Researchers at The Ohio State University (OSU), Columbus and Wooster, are collaborating with colleagues at Wright State University, Dayton, and at MSU to investigate this possibility in a project funded in part by the Horticultural Research Institute and the USDA Agricultural Research Service (ARS) Floriculture and Nursery Research Initiative. An experimental ash planting was established in 2003 at the MSU Tollgate Education Center in Novi, MI, to compare resistance of North American, European and Asian ashes to EAB; identify mechanisms of resistance and susceptibility; and determine the effects of drought and other stress factors on borer susceptibility. (Trees were donated by Bailey Nurseries Inc., St. Paul, MN; J. Frank Schmidt & Son Co., Boring, OR; and Lake County Nursery Inc., Perry, OH.)

North American species that are being evaluated include important cultivars of white and green ash, as well as blue and black ash. *Fraxinus latifolia* (Oregon ash) is also being studied. European species include *F. excelsior* 'Aureafolia' (Golden Desert™ European ash), *F. ornus* (flowering ash) and *F. oxycarpa* 'Raywood' (Raywood ash), and Asian species include *F. mandshurica* 'Mancana' ('Mancana' Manchurian ash) and Chinese ash. The plantation also includes the hybrid ash *F. nigra* × *F. mandshurica* 'Northern Treasure'. First-year results are consistent with the hypothesis that Manchurian ash is more resistant to EAB than are North American species.

Scientists from MSU and the USDA Forest Service are also studying the relative preference of EAB for native species of ash, including green, white, black and blue ash. Several lab and field tests have been initiated to compare the rate of borer attack, feeding and development, as well as the response of these species to EAB. Preliminary data from these studies suggest green ash may be more preferred by the pest and attacked sooner or at higher densities than white ash, while blue ash may be least preferred. Black ash, which is especially common in wet, swampy areas in much of northern Michigan and Ontario, also appears to be quite suitable as a host. These studies, funded by the USDA ARS and USDA Forest Service, are also providing data that may be useful in developing lures and traps for adults.

Information regarding the relative resistance of North American ash species and identification of resistant ash genotypes is critical for reforestation, as well as restoring market demand for ash in the nursery industry. Identifying resistance mechanisms and their relationship to whole tree physiology will facilitate screening, selection and/or breeding of resistant trees, as well as cultural management of EAB in urban and natural forests.

In addition, we (and others) are involved in a number of studies focused on the role of insecticides for EAB control, both as an eradication tool and for

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Ash trees were removed from a residential property near Toledo as part of the EAB eradication program.

protecting landscape trees within the core infestation zone. These studies are designed to address the relative effectiveness of various insecticides for controlling EAB adults and larvae; optimal timing for application of soil injections, trunk injections and bark/foliage sprays; and residual effectiveness of insecticides over time.

We disagree that this research has the "green industry sidelined," as indicated in the Aug. 1 *American Nurseryman* report. While the professional quoted in the article was stating his opinion, results of insecticide research from 2003 were widely disseminated and used in 2004 by many tree-care professionals within the core infestation zone in southeastern Michigan to improve or enhance their ability to care for landscape trees.

Although a number of trees were cut down and dissected after one year of treatment even though they were still alive, this was necessary to determine if the treatments actually killed enough insects to be useful as eradication treatments in a regulatory program. However, several research sites in Michigan also have been designated for long-term evaluation of the ability of soil- and trunk-injected insecticides to protect trees under landscape conditions. In addition, scientists at MSU are working with several arborists and landscapers, not only to document the success stories, but to learn as much as possible from treated trees that did not survive.

Due to the nature of the current program to eradicate outlier infestations, insecticide treatments for EAB are not recommended in Indiana, Ohio, Ontario and other areas outside the core infestation zone. In these eradication zones, all ash trees will be removed should an infestation be detected in their vicinity, even if they have been treated with an insecticide. (For the rationale behind this recommendation, see "Hold off on treating ash trees with insecticides — for now," in the Jan. 1 issue of American Nurseryman).

The cooperative EAB project. The USDA Animal and Plant Health Inspection Service (APHIS), the USDA Forest Service and the Canadian Food Inspection Agency, in cooperation with state Departments of Agriculture and Natural Resources, have joined forces to implement a long-term program to contain and eventually eradicate EAB from North America. The plan, which is in the early stages of implementation, is to locate and promptly eradicate outlier infestations; to prevent establishment of new outlier infestations through aggressive enforcement of state and federal quarantines; and to contain, suppress and ultimately eradicate the core infestation. A key component of the eradication plan is an intensive monitoring program to evaluate the success of outlier eradication efforts, identify existing, low-density infestations that have so far escaped detection and quickly detect new infestations.

Rapid elimination of outlier infestations before they expand and become entrenched is critical. To date, several outlier eradication programs have been implemented in Maryland, Michigan, Ohio and Virginia, resulting in the destruction of more than 100,000 ash trees. Eradication of outlier infestations involves removal of all visibly infested trees, as well as all other ash trees within one-half mile of the visibly infested trees.

Since infested trees do not show external signs or symptoms of attack during the first year, there is no way to determine which trees in the vicinity of infested trees were themselves infested. Consequently, it is necessary to cut even apparently healthy trees to destroy the insects lurking within before they can emerge, disperse and reproduce. Felled trees were chipped and incinerated at a co-generation power plant, and stumps were treated with herbicide to prevent sprouting.

Three major studies of Michigan outlier infestations in 2003 and 2004 provide a science-based rationale for the current eradication strategy. This research (conducted by scientists from MSU; USDA APHIS; the USDA Forest Service, along with volunteers from several state agencies; Purdue University, West Lafayette, IN; and OSU) involved felling and peeling bark from a large number of ash trees of all sizes occurring within one-half mile of a known point source — e.g. the infested firewood or nursery trees from which the infestation was known to originate.

Intensive sampling showed 80 percent of all larvae were in trees within 100 yards of the original point source. At one site, infested trees were found as far as nearly one-half mile from the point source. But at the other two sites, all larvae were found within 0.38 miles of the point source. Therefore, the cutting of all ash trees within a one-half mile radius of visibly infested trees should eliminate the vast majority of insects in outlier infestations, if not the entire infestation.

Treating infested trees with insecticides as an alternative to destroying them is not a viable option for eradication sites. While research has shown preventive insecticide applications can effectively protect shade trees from EAB in the core infestation in southeast Michigan, no insecticide program has been effective enough for eradication purposes.

To ensure success, these outlier eradication sites are being monitored for at least three years after cutting to determine if there is a need to "mop up" any beetles that may have slipped the dragnet. While some people have called for even more aggressive action at outlier sites, this strategy is a workable compromise. Eradication is expensive and disruptive, and increasing the radius of the area that is cut means an exponentially greater number of trees must be destroyed. For example, a circle with a

PHOTO: DANIEL A. HERMS, THE OHIO STATE UNIVERSITY/OARDC

Highway signs on the Michigan/Ohio border advise motorists not only of the emerald ash borer quarantine, but also of associated penalties for violations.

radius of 1 mile occupies four times the acreage of a circle with a one-half mile radius. Consequently, it is less expensive and less destructive to monitor eradication sites intensively, then implement a follow-up eradication program if necessary.

However, monitoring efforts have been complicated by research that indicates EAB apparently does not produce the long-range pheromones that have been so useful in trapping other insect pests such as gypsy moth. Rather, monitoring currently is being conducted in Indiana, Michigan and Ohio by means of an extensive grid of "trap trees," which consist of a girdled green ash tree wrapped with a band of sticky Tanglefoot or similar substance.

Research conducted by MSU and USDA Forest Service scientists in 2003 showed adult beetles were more strongly attracted to girdled trees than to unwounded trees, possibly due to host plant volatiles released into the air by the girdled trees. It should be emphasized that the extensive grid of trap trees is strictly a monitoring tool to assess the distribution of EAB and aid in detection of outlier populations, and it is not intended as a control measure.

There are so many infested trees in the core infestation zone in southeast Michigan and neighboring Essex County, it is physically and economically impossible to remove them all or treat them with insecticides. Scientists and regulatory officials have developed a plan to surround and contain the core infestation with a Reduced Ash Zone (RAZ), which will likely extend through central and southwest Michigan and across northeastern Indiana and northwestern Ohio.

The optimal location of the RAZ currently is being determined by analyzing a combination of aerial photos, land-use data and ground surveys to estimate ash density and EAB distribution. The RAZ will be routed as much as possible through areas with naturally low densities of ash such as agricultural land, industrialized areas and large bodies of water. Incentive-based programs and ash markets will be developed to encourage property owners to remove and sell ash trees of all sizes before the species are killed by EAB or removed in an eradication action.

An aggressive EAB suppression program will occur just inside the RAZ to relieve pressure on the leading edge and minimize EAB breakouts. An intensive monitoring program within and beyond the periphery of the RAZ also will be implemented to rapidly detect spot infestations that will inevitably breach the RAZ so they can be quickly extinguished. It's important to note that ash trees in the RAZ inevitably will be killed by EAB, as will billions more, if EAB is allowed to spread unchecked across North America.

Preventing the artificial spread of EAB is another major component of the eradication plan. Accordingly, federal, state and Canadian quarantines have been enacted to prohibit movement of firewood, ash nursery stock, logs, wood chips and untreated lumber. In the Aug. 1 Plant Health report, Dr. David Roberts of the MSU Extension Southeast, Novi, was quoted as saying, "The quarantine program … is really ineffective in my opinion." He went on to say, "It's basically voluntary; there is no enforcement of it." On the other hand, Tom Harrison, the head of the Plant Pest Control section of the Ohio Department of Agriculture paints a different picture, referring to the quarantines as "the most far-reaching and heavily enforced to date."

Preventing the movement of firewood presents a particularly tough challenge that has been recognized by regulatory officials since day one. Many federal, state and provincial agencies, along with extension personnel at MSU, OSU and Purdue University, are assisting regulatory officials by actively spreading the word about EAB and particularly the dangers posed by transporting firewood.

A multimedia publicity campaign featuring television, radio and newspaper ads, billboards, press releases, fliers, posters and bulletins has been launched to inform people about the firewood quarantine. Highway signs warn motorists of substantial fines for moving firewood outside the quarantine zone. A stepped-up inspection and enforcement program is targeting rest areas, highways and campgrounds at critical times of year such as major holidays and during hunting season. Officials in Ohio have stopped and inspected vehicles for firewood as they enter the state from quarantined areas of Michigan, and Canadian officials have ticketed violators at campsites. These and related outreach and enforcement efforts will continue and expand to minimize the artificial spread of this invading pest.

EAB has the potential to decimate ash throughout North America, but efforts to eradicate this invasive insect are now underway. Eradication is possible, but it requires considerable resources and political will. Even if these efforts are not successful, as some critics suggest, the Cooperative Eradication Project will dramatically slow the spread of the infestation, buying time needed for research advances on effective traps, biological controls, host plant resistance and other management tactics. The eradication program requires a long-term commitment of funds and effort. But these costs are miniscule compared with the devastating economic and ecological impacts of EAB if the pest is allowed to spread unchecked throughout North America.

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