Fig. 1 Emerald ash borer *Agrilus planipennis*

Fig. 2 Ash leaf-feeding bioassay plate

Host Preference of Emerald Ash Borer: Evaluation of Adult Feeding and Larval Development

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Fig. 3 Green and white ash plantation

Fig. 4 Emerald ash borer larvae and feeding galleries

INTRODUCTION

Emerald ash borer (*Agrilus planipennis* Fairmaire) has become one of the most devastating invasive pests in North America. Tens of millions of ash (*Fraxinus*) trees in forests and millions of landscape ash trees in urban settings have already been killed by this Asian pest. Populations of emerald ash borer (EAB) have been found in ten states and two provinces so far. These infestations continue to expand and additional infestations will undoubtedly be discovered. Determining and comparing North American, Asian and European ash species' susceptibility to EAB would be useful to municipal foresters, natural resource managers and regulatory officials. Evaluating whether tree vigor affects the ability of ash species to attract or resist EAB colonization or feeding could also enhance EAB control measures and lead to development of resistant ash cultivars. Such information would help to defray economic and ecological impacts associated with the widespread ash mortality observed to date in Michigan and Ohio.

OBJECTIVES

- Determine if adult EAB will feed on foliage from novel ash species & whether longevity of beetles varies among ash species.
- Determine whether female EAB will oviposit or novel ash species & evaluate larval survival & development.
- Compare effects of girdling & fertilization on larval density, survival, & development rate of wild & caged EAB on green & white ash plantation trees .

CONCLUSIONS

Adult EAB will feed on all species of ash tested, consuming twice as much leaf area on Carolina ash and velvet ash from AZ than on green ash. However, 2-7 times as many eggs and galleries were found on green ash logs than on Carolina and AZ velvet ash logs. Beetle longevity was greatly impacted when forced to feed exclusively on single-leaf ash and privet. In plantation trees exposed to wild EAB populations, larval density and mortality appear to be consistently highest on girdled trees and enhanced fertilization on white ash appears to slow EAB growth. In caged populations, girdled plantation trees have the highest proportion of larvae which will develop in one year.

CONTINUING RESEARCH

We are currently preparing to cut down and peel in full the remaining 5 blocks of green and white plantation trees from 2009 to identify larval variables as in 2008. Larval colonization data will be compared between years to identify trends.

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Study 1: Leaf-feeding & mortality on novel ash

Determine if adult EAB will feed on foliage from novel ash species & whether longevity of beetles varies among ash species.

METHODS

In spring 2008, we purchased seedlings or whips of North American ash, including single-leaf ash (*F. anomala*), green ash (*F. pennsylvanica*) & Oregon ash (*F. latifolia*), the Asian Manchurian ash (*F. mandshurica*), two European species including European ash (*F. excelsior*) & flowering ash (*F. ornus*), along with European privet (*Ligustrum vulgare*, a member of Oleaceae). Trees were maintained in a lathe house throughout the summer in 2008, then transplanted to an irrigated, pot-in-pot plantation in spring 2009.
In June 2009, foliage from 3 trees of each of 3 additional North American species were harvested from 3 US locations & shipped overnight to MSU: Carolina ash (*F. caroliniana*) from FL, velvet ash (*F. velutina*) from AZ, & velvet & single-leaf ash from UT.

Trial 1: Individual leaves were collected from 8-12 plants of each of the potted species & 3-4 leaves from each tree of the shipped species. Two male & 2 female EAB reared from infested ash logs were placed in a Petri dish with a single leaf (Fig 2). The petiole of the leaf was placed in a water pic to prevent wilting. Beetles were allowed to feed for 4 days. Total leaf area before & after feeding was quantified using leaf scanning software.
Trial 2: Four EAB were placed in a Petri dish with a single leaf & allowed to feed for up to 14 days (Fig 2). Leaves were collected from 10 plants of each of the following potted species: European, Oregon, green, Manchurian, & single-leaf ash & privet. Beetle mortality was recorded & leaves were replaced at 2-3 day intervals as needed.

RESULTS

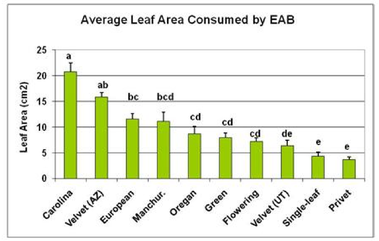

Fig. 5 Trial 1 Beetles fed significantly more on Carolina ash &velvet ash from AZ than they did on privet, Oregon, green, flowering, UT velvet or single-leaf ash. European & Manchurian ash were intermediate.

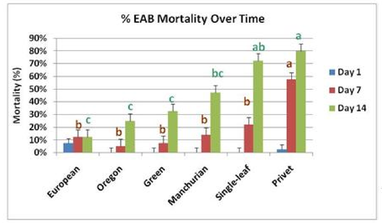

Fig. 6 Trial 2 EAB mortality after 7 days of feeding was significantly greater on privet than on any of the other species. After 14 days, EAB mortality was significantly greater on privet & single-leaf ash than on European, Oregon & green ash. Manchurian ash was intermediate.

Study 2: Egg & gallery densities on logs in ash trees

Determine whether female EAB will oviposit on novel ash species & if oviposition occurs, evaluate larval survival & development.

METHODS

Logs of 4 species, including uninfested green ash harvested from a site in MI, Carolina ash from FL, velvet ash from AZ, & velvet & single-leaf ash from UT, were harvested in June 2009 & sealed with Bailey's End Seal to slow desiccation. Logs from outside MI were shipped & arrived at MSU within 3 days of cutting. One log of each species, including a velvet ash log from each locale, each roughly 9 cm in diameter by 60 cm in length, were attached to the stem of large green ash trees, 3 to 4 m aboveground (Fig 7). Ash trees were located in two heavily infested sites & logs were suspended from 7-8 ash trees per site (15 logs per species, 75 logs total) from 29 June to 10 August 2009. Number of eggs located in 5 min of searching was recorded for each log (Fig. 8). Logs were dissected & number of EAB galleries was determined.

Fig. 7 Hanging ash logs in an EAB-infested ash tree.

Fig. 8 EAB egg found on a green ash log.

RESULTS

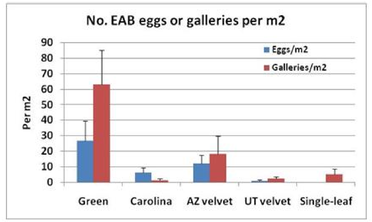

Fig. 9 We found a total of 105 eggs on 20 logs. 47% of eggs were found on 6 green ash logs, 33% on 6 AZ velvet ash, 18% on 6 Carolina ash, & 2% on 2 UT velvet ash. No eggs were found on single-leaf ash logs.

We found a total of 204 early instar EAB galleries on 24 logs. 66% of galleries were found on 11 green ash logs, 25% on 6 AZ velvet ash, 4% on 3 single-leaf ash, 3% on 3 UT velvet ash, & 2% on 1 Carolina ash log. More than 95% of the larvae found on all species survived only to the first instar before dying because of log desiccation.

Study 3: Larval Colonization on Trees

Compare the effects of girdling & fertilization on larval density, survival & development rate on green & white ash plantation trees exposed to wild EAB populations.

METHODS

A plantation of 80 ash trees (40 white, 40 green ash) was established in April 2007 at MSU's Tree Research Center (TRC) (Fig. 3). Average DBH was 5.53 ± 0.09 at time of planting. Trees were provided with drip irrigation & were sprayed with Tempo (pyrethroid) in 2007 to protect them from colonization by local EAB populations.

In April 2008, we selected 5 blocks, each with four green & four white ash trees (N=40). A green & a white ash in each block were randomly assigned to one of four treatments: girdling (Gir), fertilization (Fert), enhanced fertilization (FA) & untreated controls (Con). Girdled trees had a 20-cm wide ring of phloem removed 1 m aboveground (Fig. 14). Trees requiring fertilization received Harrell's Pro-Blend with Micros 19-5-10 controlled-release fertilizer at a rate of 40g N per tree. Trees assigned the enhanced fertilization treatment were also sprayed on the lower 1.5 m of the stem with the phosphite fungicide Agri-Fos® plus Pentra-bark™, a bark-penetrating surfactant, at a rate of 1.8 oz Agri-Fos per tree. Wild EAB were allowed to colonize these blocks over the summer. From September to November 2008 trees were felled & dissected. Number, mortality & instar of EAB larvae was recorded (Fig. 12).

RESULTS

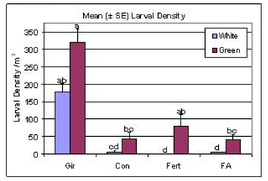

Fig. 10 There was a significant species by treatment interaction for larval density. In general, green ash had higher larval densities than white ash & girdled trees had higher larval densities than trees of other treatments (Fig.17). However, within green ash there was no significant difference in larval density between girdled & fertilized trees. Green ash larval densities were also not significantly higher than white ash on girdled & control trees.

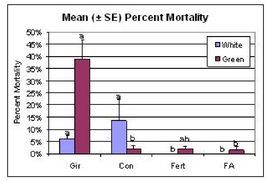

Fig. 11 Within green ash, a significantly higher percent of larvae were found dead on girdled trees than on trees of any other treatment due to intraspecific competition.

Fig. 12 Peeling trees & marking larvae

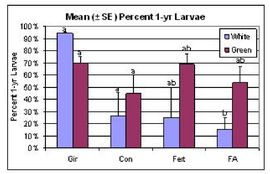

Fig. 13 Within white ash, a significantly higher percent of larvae were considered to be 1-yr larvae (will overwinter as 4th instars or prepupae) on girdled trees than on trees treated with the Fertilizer + Agri-Fos combination.

Study 4: Oviposition & Larval Response on Trees

Compare the effects of girdling & fertilization on larval response using no-choice oviposition cages on green & white ash plantation trees.

METHODS

In 2009, the remaining 40 plantation trees described in Study 3 were separated into 5 blocks & treatments were assigned as in the previous year. In July 2009, two cup cages were attached to the north & south aspects of the bole of each tree with silicone caulk (Fig. 16). One male & one female adult EAB were placed into each cage with foliage to feed on. One cage per tree contained EAB fed on foliage from that tree (same tree-fed), while the other contained EAB fed on *Fraxinus uhdei* , a common rearing ash species (*F. uhdei*-fed). The foliage type the adult fed on was randomly assigned to an aspect (either north or south) for each block. Females were allowed to oviposit through mid August & larvae allowed to develop through mid September. Cages were removed & bark immediately under & surrounding the cage was peeled. Number & instar of EAB larvae was recorded (Fig. 15)

Fig. 14 Girdled trees at TRC Plantation

Fig. 15 Peeling under cages.

Fig. 16 Cup cages

Fig. 17 High larval density on a girdled tree.

RESULTS

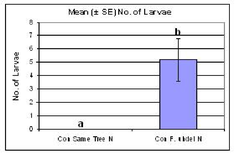

Fig. 18 Significantly more 1 and 2-yr larvae were found on north aspect control trees with *F. uhdei*-fed adults than with same-tree fed adults, which had no larvae. There were no other significant differences among number of larvae by treatment, species, aspect, or foliage type.

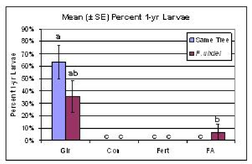

Fig. 19 A significantly higher percent of 1-yr larvae were found on girdled trees with same tree-fed adults than on trees of any other treatment. Within girdled trees, however, there was no effect of foliage type. No 1-yr larvae were found on control or fertilized trees, & only one FA tree had any 1-yr larvae.