

Materials and Methods

ASH: *Fraxinus pennsylvanica* Marsh. D. R. Smitley, K. F. Newhouse & T. W. Davis
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EMERALD ASH BORER (EAB) CONTROL ON STREET TREES, 2005-2008:

Ash street trees in a neighborhood in East Lansing, MI were used for this test (Ingham Co, MI T2N R1W Sec 1, 7, 8, 12, 17, 24). These trees were between 14 and 28 years old and ranged in size from 10-24 inches in diameter at breast height (DBH). The mean DBH was 14 inches. The trees used in the test were planted and maintained by the city of East Lansing and were located between the street and the sidewalk in seven different neighborhoods. Trees were spaced a minimum of 50 ft apart. The tree canopies ranged from 15 to 45 feet in diameter, and in no case did they overlap. Tree trunks were measured and marked with a metal tag during the first week of August 2005. Lawns where study trees were located were well maintained, but very few were irrigated. Each treatment was replicated 10 times with each replicate consisting of an individual tree. The following is a list of products tested, type of application, rate, and application date:

- 1) **TREE-äge (emamectin benzoate) trunk injection in fall 2005**, sponsored by Arborjet and Syngenta. Injections were made with the Arborjet Tree IV system by drilling 4 injection ports spaced equally around the trunk and at a height of 20 – 40 cm above the ground. Plastic septums (Arborjet #4 plug - 3/8”) were tapped into the drilled holes and the ports connected with plastic tubing to a single pressurized (45 psi) bottle containing TREE-äge diluted 1:1 with water. The TREE-äge solution was injected at a rate of 0.4 g ai/inch DBH on 27 Sep, 2005. No additional treatments were made for the duration of the test. Trees receiving this treatment: # 206, 331, 248, 242, 265, 320, 311, 275, 273, 270.
- 2) **TREE-äge (emamectin benzoate) trunk injection once every 2.5 years**, sponsored by Arborjet and Syngenta. Injections were made with the Arborjet Tree IV system by drilling 4 injection ports spaced equally around the trunk and at a height of 20 – 40 cm above the ground. Plastic septums (Arborjet #4 plug - 3/8”) were tapped into the drilled holes and the ports connected with plastic tubing to a single pressurized (45 psi) bottle containing TREE-äge diluted 1:5 with water. The TREE-äge solution was injected at a rate of 0.4 g ai/inch DBH on 28 Sep, 2005. A second treatment was made on 21 May, 2008, with the same apparatus and at the same rate but with a TREE-äge: water solution of 1:1 instead of 1:5. Trees receiving this treatment: # 201, 347, 229, 244, 263, 323, 322, 298, 284, 266.

- 3) **IMA-jet (5% imidacloprid) trunk injection by Arborjet once every 18 months** (fall 2005 and spring 2007). The injections were made with the Arborjet PRO-cap System. Each PRO-cap (4 per tree) was pressurized to 35 psi and is inserted into a 7/32" hole. IMA-jet was applied at 0.2 g ai/inch DBH in trees with less than a 12" DBH and at 0.4 g ai/inch DBH in trees with greater than a 12" DBH on 29 Sep, 2005. The trees were retreated on 21 May, 2007, at the same rate using the Arborjet Tree IV system (described in treatment 1) in 2007. Trees receiving this treatment: # 218, 338, 237, 221, 260, 314, 324, 268, 285, 216.
- 4) **Merit Tree Injection (200 SL, 200g imidacloprid/liter) in fall 2005.** Injections were made with the Arborjet VIPER (Air Hydraulic Device) injection system at a rate of 0.4 g ai/inch DBH. The number of plugs inserted into each tree was determined by the formula: trunk DBH²/2. Each injection was made through a plastic septum (Arborjet #3 Arborplug - 9/32") at 150-200 psi on 17 Oct, 2005. Trees receiving this treatment: # 219, 346, 223, 228, 257, 308, 303, 269, 293, 341.
- 5) **Merit Tree Injection (200 SL, 200g imidacloprid/liter) in fall of 2005, and Merit drench spring of 2008.** Injections were made with the Arborjet VIPER (Air Hydraulic Device) injection system at a rate of 0.4 g ai/inch DBH. The number of plugs inserted into each tree was determined by the formula: trunk DBH²/2. Each injection was made through a plastic septum (Arborjet #3 Arborplug - 9/32") at 150-200 psi on 17 Oct, 2005. Merit 75WP (imidacloprid) was applied as a basal drench at a rate of 1.42g ai/DBH inch. The appropriate amount of Merit was mixed in 1.5 gal of water and poured around the base of the tree within 2 feet of the trunk on 25 Jun, 2008. Trees receiving this treatment 217, 339, 230, 239, 258, 309, 312, 278, 282, 340.
- 6) **Untreated Control**
Control trees: # 208, 334, 251, 224, 256, 302, 304, 300, 267, 344
- 7) **Bayer Advanced Tree and Shrub (1.47% imidacloprid) as an annual fall basal soil drench.** 90ml of Bayer Advanced per inch of trunk DBH (1.38g ai/inch DBH) was mixed in a total of 1.5 gal of water and poured around the base of the tree within 2 feet of the trunk. Applications were made on 27 Oct, 2005, 14 Dec, 2006, 28 Nov, 2007 and 19 Nov, 2008. Trees receiving this treatment: # 215, 333, 250, 225, 235, 316, 305, 276, 295, 271.
- 8) **Bayer Advanced Tree and Shrub Granular as an annual fall treatment**
Bayer Advanced Tree and Shrub Granular (1.1% imidacloprid plus 2-1-1 fertilizer) was applied at a rate of 1.45 g ai/DBH inch. 132g product/inch DBH was applied around the base of each tree within 3 feet of the trunk. Applications were made on 27 Oct, 2005, 14 Dec, 2006, 28 Nov, 2007 and 19

Nov, 2008. Trees receiving this treatment: #204, 343, 245, 240, 253, 313, 329, 297, 287, 342.

- 9) **Arena 50 WDG (clothianidin) as a basal drench in fall 2005** – was applied at a rate of 1.4 g ai/inch DBH. The appropriate amount of Arena was mixed in 1.5 gal of water and poured around the base of the tree within 2 feet of the trunk on 8 Nov, 2005.
Trees receiving this treatment: #202, 237, 247, 233, 226, 319, 326, 292, 280, 220.
- 11) **DinoCap (0.51 g dinotefuran per cap) Trunk Implants in Spring 2006.** Holes were drilled (3/8 inch diameter, 3/4 inch deep) every 4" around the base of the tree, the implants tapped into place, and sealed with a plastic cap on 16 May 2006. Trees receiving this treatment: #214, 345, 252, 241, 264, 318, 327, 277, 286, 203.
- 19) **Merit Tree Injection 200 SL (200gr imidacloprid/liter) once every 2 years.** Imidacloprid was injected into trees with the Arborjet VIPER injection system at a rate of 0.6 gr ai/inch DBH. The number of plugs inserted into each tree was determined by the formula: trunk DBH²/2. Each injection was made through a plastic septum (Arborjet #3 Arborplug - 9/32") at 150-200 psi on 29 Jun, 2006. The same trees were treated again with the same product and at the same rate on 30 Jun, 2008, using the Arborjet QUIK-jet micro-injector.
Trees receiving this treatment: #138, 402, 826, 363, 155, 375, 387, 166, 176, 197.
- 20) **Merit Tree Injection 200 SL (200gr imidacloprid/liter) summer 2006 and a Merit basal drench in spring 2008.** Merit was injected with Bartlett microinjectors at a rate of 0.6 gr ai/inch DBH. The number of microinjectors was determined by DBH²/2 on 6 Jul, 2006. On 2 June, 2008, 1.42g ai/DBH inch of Merit was mixed in 1.5 gal of water and poured around the base of each tree within 2 feet of the trunk. Trees receiving this treatment: #145, 495, 818, 356, 159, 371, 396, 397, 175, 198.
- 21) **Merit 75WP (imidacloprid) as an annual spring basal drench.** Merit was applied at a rate of 1.42g ai/DBH inch. The appropriate amount of Merit was mixed in 1.5 gal of water and poured around the base of the tree within 2 feet of the trunk on 2 Jun, 2006, 18 May, 2007 and 2 Jun, 2008. Trees receiving this treatment: #142, 817, 828, 358, 153, 380, 395, 171, 172, 194.
- 22) **Acetamiprid (92.5 g ai/L) trunk injection once every 18 months.** Cleary, Inc. evaluation of an experimental formulation of acetamiprid (NI-25) as a trunk injection. Acetamiprid was injected with the Arborjet VIPER system at a rate of 0.28 g ai/inch DBH. The number of plugs used was determined by the formula: DBH²/2. Each injection was made through a plastic septum (Arborjet #3 Arborplug - 9/32") at 150-200 psi on 13 Jun, 2006. Trees were

treated again on 9 Aug, 2007 using the Arborjet Tree IV system to inject acetamiprid at the rate of 1.11 g ai/inch DBH.

Trees receiving this treatment: #133, 401, 824, 361, 365, 378, 389, 167, 184, 187, 200.

- 23) **Acetamiprid trunk injection in spring of 2006 followed by a Tristar trunk spray in fall of 2007.** Cleary, Inc. evaluation of an experimental formulation of acetamiprid (NI-25, 92.5 g ai/L) applied as a trunk injection followed by Tristar as a trunk and limb spray 18 months later. Acetamiprid was injected with the Arborjet VIPER injection system at a rate of 0.56 gr ai/inch DBH. The number of plugs used was determined by the formula: $DBH^2/2$. Each injection was made through a plastic septum (Arborjet #3 Arborplug - 9/32") at 150-200 psi. on 13 Jun, 2006. A bark spray of Tristar 30SG was applied at a rate of 1.14 g ai/inch DBH.) The Tristar was mixed with 1.5 fl oz/inch DBH of Capsil (non-ionic spray adjuvant) and 60ml water/inch DBH, and was sprayed on the trunk and low scaffold branches (approximately 1 gallon/tree) with a R & D Sprayers[®] CO₂ sprayer at 50 psi through a single nozzle hand-held with an 8008 nozzle on 27 Aug, 2007. Trees receiving this treatment: 134, 406, 821, 362, 158, 369, 385, 161, 183, 195.
- 24) **Arena 50 WDG (clothianidin) in spring 2006 and Poncho (clothianidin) in fall 2007 and fall 2008 as a basal drench.** Clothianidin was applied at a rate of 1.4 g ai/inch DBH. On 2 June, 2006, the appropriate amount of Arena was mixed in 1.5 gal of water and poured around the base of each tree within 2 feet of the trunk. On 29 Nov, 2007 and 19 Nov, 2008, Poncho 600 FS (clothianidin 600 g ai/L) was applied at a rate of 0.85 g ai/inch DBH in the same way as described for Arena. Trees receiving this treatment: #141, 147, 825, 353, 367, 379, 391, 168, 174, 190.
- 25) **Arborjet IMA-jet (5% imidacloprid) trunk injection once every 18 months, starting in fall 2006.** Imidacloprid was injected with the Arborjet Tree IV System at a rate of 0.4 g ai/inch DBH through a plastic septum (Arborjet #4 Arborplug - 3/8") at 45psi on 3 Oct, 2006 and 21 May, 2008. Trees receiving this treatment: #137, 403, 827, 364, 368, 381, 386, 173, 192
- 26) **Safari 20SG (dinotefuran) as a basal drench in spring 2007 and spring 2008.** Safari was applied at a rate of 12 g prod/inch DBH (2.4 gr ai/inch DBH) as a basal soil drench. The appropriate amount of Safari was mixed in 1.5 gal of water and poured around the base of the tree within 2 feet of the trunk on 18 May, 2007 and 2 Jun, 2008. Trees receiving this treatment: #210, 349, 234, 246, 262, 330, 279, 283, 212 (Tree #307 was dropped because the homeowner also treated his tree with an insecticide).
- 27) **TREE-äge (emamectin benzoate) trunk injection in spring 2007 at 0.1 g ai/inch DBH,** sponsored by Arborjet and Syngenta. Injections were made with the Arborjet QUIK-jet micro-injector. The number of injection sites was

determined by the formula: trunk DBH²/2. The given rate of 0.1 g ai/inch DBH was injected through a plastic septum (Arborjet #4 Arborplug - 3/8") on 21 May, 2007. Trees receiving this treatment: #209, 243, 238, 328, 296, 211, 830, 160, 372, 163.

- 28) **TREE-äge (emamectin benzoate) trunk injection in spring 2007 at 0.2 g ai/inch DBH**, sponsored by Arborjet and Syngenta. Injections were made with the Arborjet QUIK-jet micro-injector. The number of injection sites was determined by the formula: trunk DBH²/2. The given rate of 0.1 g ai/inch DBH was injected through a plastic septum (Arborjet #4 Arborplug - 3/8") on 21 May, 2007. Trees receiving this treatment: #336, 255, 196, 289, 143, 149, 357, 390, 188, 315, (tree #193 was dropped because the homeowner treated this tree with insecticide).
- 29) **Imidacloprid 0.74% + Clothianidin 0.37 % + 2-1-1 Fertilizer in fall 2007 and fall 2008**, sponsored by Bayer Advanced. Imidacloprid + clothianidin was applied at a rate of 94.2 ml product/inch DBH. The appropriate amount of chemical was mixed in 1.0 gal of water and poured around the base of the tree within 2 feet of the trunk on 28 Nov, 2007 and 19 Nov, 2008. Trees receiving this treatment: #136, 496, 819, 360, 157, 374, 392, 165, 132, 494.
- 30) **TREE-äge (emamectin benzoate) trunk injection in spring 2008 at 0.2 g ai/inch DBH**, sponsored by Arborjet and Syngenta. Injections were made with the Arborjet QUIK-jet micro-injector. The number of injection sites was determined by the formula: trunk DBH²/2. The given rate of 0.2 g ai/inch DBH was injected through a plastic septum (Arborjet #4 Arborplug - 3/8") on 21 May, 2008. Trees receiving this treatment: #146, 152, 162, 170, 164, 822, 352, 370, 382, 393.
- 31) **Meridian 25WG (thiamethoxam) as a basal soil injection in spring 2008**, sponsored by Syngenta. Meridian was applied as a basal soil injection at a rate of 1.0 g ai/inch DBH (4 g prod/inch DBH). The appropriate amount of Meridian was mixed with 4 liter of water. A Model 102 Ross Root Feeder (15 psi), modified for use with an R & D Sprayers[®] CO₂ sprayer header, was used to inject 1.0 liters of solution into the ground about one foot from the base of the tree in each of the four cardinal compass directions around the trunk. The Ross Root Feeder was pushed approximately 4 inches into the soil for each injection. Applications were made on 25 Jun, 2008. Trees receiving this treatment: #139, 820, 467, 351, 359, 376, 388, 156, 169, 405.

Canopy thinning and die-back ratings were made for each tree on 6 Jul, 2006, 6 Jul 2007 and 16 July 2008, by comparing the canopy of each tree with photographs in various stages of decline going from 0% (healthy) to 100% (dead) in 10% increments. This canopy rating scale is attached (Smitley et al. 2008). Ratings were made by 2 or 3 individuals and the ratings were averaged.

For most treatments branches were collected in the fall and the bark removed to count EAB larvae and galleries. Because branch sampling and bark scraping is labor-intensive and costly compared with making visual canopy ratings, some of the sponsors chose not to include branch sampling in some or all years of the test. When branch sampling was included, the branches were pruned from the upper 1/3 of the tree canopy between 19 Sep and 26 Sep 2006, between 8 Oct and 12 Oct 2007, and between Nov 4 and 10, 2008. Three branches, at least 3 feet long and with a diameter between 1.5 and 5.0 inches were removed from each tree by the arborists of the City of East Lansing. Branches selected for pruning were spaced as far apart as possible to maintain canopy balance. The length and diameters of each branch were recorded and used to calculate the surface area sampled. EAB galleries and larvae were counted after removing the bark with a drawknife and chisel. The average area of bark sampled per tree ranged from 272 in² to 580 in² and averaged 420 in². Bark-scraping was done at Michigan State University's Entomology Field Research Station where scraping could be done in an indoor environment. Each of the branches was then examined to determine how many old galleries, new galleries and live larvae were present.

Results

Emerald ash borer was first detected in trees in East Lansing in spring of 2005 when trees in 2 different locations outside of the test area were found to have more than 50% canopy thinning and woodpecker activity. All of the ash trees in our test appeared relatively healthy in July 2006 when canopy thinning ratings averaged 7.3 to 20.3%. Trees continued to appear healthy in 2007 and remained within the normal range of canopy ratings for ash trees outside of the EAB infested area (8.8 to 29.4%). There were no significant differences among treatment means for canopy thinning ratings in 2006 or 2007. This is not surprising because canopy thinning and dieback ratings are mostly a reflection of tunneling damage from EAB larvae the previous fall, and branch samples indicate a low level of infestation in the control trees in fall 2006 (3.1 new galleries/m²). However, EAB activity increased rapidly after that, doubling to a density of 7.4 new galleries/m² in 2007, and exploding in 2008 to a density of 30.8 new galleries/m². Counts of live larvae, made at the same time as new galleries, closely parallel counts of new galleries. The increase in density of live larvae to 6.9/m² in fall of 2007 resulted in significant differences in canopy thinning and dieback ratings in July 2008. Trees in the control treatment averaged 51.3% canopy thinning and dieback, while trees in the most effective treatments averaged less than 20% canopy thinning (TREE-age once every 2.5 years, TREE-age once every 3.5 years, Arena basal soil drench in fall 2005, Merit basal soil drench each spring, Poncho basal soil drench each fall, and a single TREE-age injection treatment in spring of 2007). All treatments with an average canopy thinning rating of 20-30% in July, 2008 were also significantly different from the control treatment (IMA-jet every 18 months starting in fall 2005, Bayer Advanced imidacloprid basal granular treatment each fall, acetamiprid trunk injections in spring 2006 and fall 2007, acetamiprid trunk injection in spring 2006 followed by a Tristar trunk spray in fall 2007, IMA-jet every 18 months starting in fall of 2006, and Safari basal drench in fall 2007). The remaining treatments were not significantly different from the control treatment.

For twelve of 23 treatments, branch samples were also collected and the bark scraped in 2007 and 2008. Canopy thinning and dieback in 2008 is strongly correlated with the density of EAB larvae found in fall of 2007 for treatment means ($n = 11$, $F = 9.6$, $P = 0.015$, $r^2 = 0.54$, Figure 1). In fall of 2008, no live larvae were found in any of the 30 branch samples collected from 10 ash trees injected with TREE-äge in fall of 2005, while control trees averaged 28.7 larvae per m^2 . Therefore, TREE-äge gave 100% control of emerald ash borer larvae for 3 years after a single treatment. Larval counts in fall 2008 were very low in the Merit basal drench treatment every spring (2.9 per m^2) when compared with the control (28.7 larvae per m^2). Larval counts were also low in the Merit Tree injection every 2 years (5.0), Meridian drench in spring 2008 (5.3) and Poncho annual fall drench (5.3) treatments. We won't know how much damage will be caused by 2.9 to 5.3 larvae per m^2 until July of 2009, but data from 2007-8 suggests that it is likely that we will see between 25 and 50% canopy thinning in those treatments next year. Branch sampling to count larvae has the advantage of providing research results 6 months earlier than the results from canopy thinning ratings. However, branch sampling is limited to a 3'-long section of 3 small (2-5" diam.) branches, and the data can vary considerably from branch to branch and tree to tree in the same treatment. Because canopy thinning ratings are based on the entire tree they may more accurately reflect the infestation of the entire tree.

Any insecticide treatment plan that controls EAB well enough to keep the larval density below 5.0 larvae per m^2 and canopy ratings below an average of 40% thinning and dieback, during the 4-year period of most severe pressure from EAB, can be considered to provide good protection against EAB. At that level of protection, homeowners will be satisfied with the appearance of their ash trees even during the peak of the outbreak, and very few trees will be lost. This test in East Lansing, Michigan, has been conducted under severe pressure from emerald ash borer. We expect to see one more year of heavy emergence of EAB adults in 2009. After that, beginning in 2010, most of the ash trees in the area will be dead, causing the population of emerald ash borer to decline substantially in 2010 and 2011. At that time it will be much easier to keep EAB below damaging levels, and all of the treatments in this test that gave 70% control of EAB larvae or better should provide adequate protection.

Although some of the trunk injection treatments gave the highest level of control of any treatment in the test, and have already been adopted as the treatments of choice by many arborists, the most effective basal soil drench or basal soil injection treatments are also a good choice for homeowners and city foresters managing smaller ash trees (<15" dbh), because these treatments may be less expensive (for homeowners in particular) or much faster to make than trunk injections. Fall drenches of imidacloprid (05, 06, 07, 08) were compared with spring drenches (06, 07, 08) in treatments #7 and #21. Although treatment #7 is the Bayer Advanced formulation and treatment # 21 is Merit, the amount of imidacloprid a.i. applied is almost identical. When these two treatments are compared, trees receiving the annual fall drench averaged a canopy thinning rating of 32.8% and a larval density of 10.8/ m^2 in 2008, compared with a rating of 18.0% and a larval density of 2.9/ m^2 for trees receiving the spring drench. Although the canopy thinning and larval density means were almost twice as high for trees receiving the fall drench, the means are not significantly different at this point. These trees will be rated again in 2009.

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Literature Cited

Smitley, David, Terrance Davis and Eric Rebek. 2008. Progression of ash canopy thinning and dieback outward from the initial infestation of emerald ash borer (Coleoptera: Buprestidae) in Southeast Michigan. *J. Econ. Entomol.* 101: 1643 – 1650.