Forest Pest Management Cooperative

Accomplishments in 2015
and Research Projects for 2016

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FPMC Members

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International Society of Arboriculture – Texas Chapter
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August 2016

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FOREST PEST MANAGEMENT COOPERATIVE UPDATE

The Forest Pest Management Cooperative (FPMC) was initiated in March, 1996 and reached a milestone in 2016, celebrating its 20-year anniversary. During this period, the FPMC has had three coordinators: Dr. Donald Grosman (1996-2012), Dr. Melissa Fisher (2013-2014), and Dr. Ronald Billings (2015 to present).

The first two coordinators were headquartered at the Texas A&M Forest Service (TFS) Forest Health laboratory in Lufkin. In February 2015, when Dr. Billings (headquartered in College Station) took over leadership of the FPMC, TFS Regional Forest Health Specialist L. Allen Smith (headquartered in Longview) was assigned duties as temporary Research Supervisor (10%), to oversee the activities of the FPMC staff in Lufkin. The Lufkin staff currently consists of Staff Forester William “Bill” Upton, Research Specialist Larry Spivey, and Staff Assistant Patricia Faries. Charles Jackson also participated as a seasonal worker through May, 2016.

With this reduced field staff, the FPMC wrapped up most five-year growth studies on pine tip moth and continued treatment evaluations for conifer mites and southern pine beetle. New research studies were initiated in 2015 on evaluations of two insecticides (Sivanto™ and XX-Pire™) for cone and seed pests in southern pine seed orchards and evaluation of new Syngenta baits for leafcutting ant control.

In 2016, research studies continued with evaluations of emamectin benzoate (TREE-äge) treatments for SPB in Alabama, new studies to evaluate the duration of emamectin benzoate injections and effectiveness of winter injections for SPB prevention and control, evaluation of the duration of a commercially-available fungicide (BotaniGard™) for southern pine beetle prevention and control, a study to improve pheromone baits for SPB prediction, evaluations of attractiveness and control efficacy of a new BASF insecticide (Siesta™) against Texas leafcutting ants, and a new study to evaluate macro- and micro-infusion systems for oak wilt prevention, in conjunction with Dr. David Appel, Texas A&M University.

In 2015, the FPMC received a mandate from the Texas A&M Forest Service to reduce the financial support of the FPMC by TFS to 50% of total expenses by September 2016, 35% by September 1, 2017 and 25% by September 1, 2018. The FPMC also was required to expand research activities and membership to include urban forests and related forest health problems, given the fact that more than 80% of the citizens in the South are urban dwellers.

Three full members – The Campbell Group (member since 2007), Forest Investment Associates (member since 2003), and Rayonier (member since 2008) decided to drop their membership at the end of CY 2015. On the positive side, one new full member (US Forest Service/International Programs) and the Coop’s first supporting member (International Society of Arboriculture-Texas Chapter) joined at the beginning of CY 2016. Also, Plum Creek Timber Company was merged with Weyerhaeuser late in 2015, but the decision was made for both companies to pay their 2016 membership dues and maintain their members on the FPMC Executive and Contact teams. In 2016, full members consisted of Plum Creek Timber, Hancock Forest Management, Texas A&M Forest Service, USFS/Forest Health Protection, USFS/International Programs and Weyerhaeuser. Associate members are Anthony Forest products, Arborgen, Arborjet, International Forest Company. The International Society of Arboriculture, Texas Chapter is a supporting member.

Other activities of the FPMC for the 18-month period January 1, 2015 to June 30, 2016 include the following:

- Six issues of the quarterly FPMC newsletter *PEST* (Progress, Education, Science, Technology) were prepared and distributed to members as a means to keep them abreast of FPMC projects and accomplishments, as well as other forest pest related topics of interest.

- The annual southern pine beetle prediction survey with pheromone-baited traps was conducted in 19 East Texas counties; results of South-wide SPB prediction surveys carried out by Federal and State cooperators were compiled and displayed on the TFS Forest Health web page.
- In August 2015, a four-year financial plan for the FPMC (2015-2018) was prepared and distributed to the Executive Team.
- Billings provided two weeks of technical assistance to Honduras in September, 2015 and made recommendations to the Honduran Forest Service to address the worst southern pine beetle outbreak in 50 years.
- A survey of FPMC Executive and Contact team members was conducted to rank various research topics for 2016.
- A large three-panel poster describing the FPMC was made for display at the Texas Tree Conference, and future forestry venues.
- Articles on emerald ash borer and black twig borer were prepared and published in Texas Forestry Association's newsletter *Texas Forestry*.
- Billings attended the Southern Forest Insect Work Conference held in Fayetteville, AR in July, 2015, and gave a presentation on the Forest Pest Management Cooperative's first nineteen years.
- The FPMC webpage was resurrected using the TFS server and is available at https://fpmc.tamu.edu/.
- A poster describing the FPMC and its recent research accomplishments was prepared and presented at the North American Forest Insect Work Conference, held in Washington, D.C.
- FPMC staff members gave presentations on FPMC research projects at the East Texas Forest Entomology Seminar in 2015 and 2016.
- In 2015, the FPMC conducted a survey of urban foresters and arborists in Texas a means to identify the major forest health problems facing urban trees and forests within Texas and those issues in need of applied research. A poster discussing results of this survey was prepared to be displayed at the 2016 International Society of Arboriculture convention in Fort Worth in August, 2016.
- Research proposals in 2015 were prepared and submitted for a total of $243,995 to capture outside funding for the FPMC. Four of the proposal were funded in 2016 for a total of ca. $130,000.

The 2015 meeting of the FPMC Executive Team was held on August 26-27 at the TFS headquarters in College Station. The decision was made by those in attendance at this meeting not to increase FPMC annual dues for 2016. The FPMC dues have remained unchanged since 2009 at $10,000 per year for full members and $3,500 per year for both associate and supporting members. The 2016 meeting is scheduled for the same location on August 31-September 1. In preparation for this meeting, a summary of research projects and accomplishments for the period January 1, 2015 to December 31, 2015 is presented here. Also, new research projects underway in CY 2016 and preliminary results are described.

Executive Summary of Research Results 2015-2016

An executive summary of major findings of FPMC research projects for 2015-2016 is presented below:

Incorporating Emamectin Benzoate (EB) into a Control Strategy for SPB

- A series of studies conducted in Alabama and Mississippi since 2012 have tested the effectiveness of emamectin benzoate (TREE-äge) for controlling southern pine beetle (SPB).
- At a rate of 5 ml/in DBH, EB is effective for preventing SPB brood development in attacked trees, but most trees eventually die, presumably from blue-stain infection.
- Loblolly pines can be injected and baited the same day to induce attacks with similar results.
- Rates of 1.25ml/in and 2.50 ml/inch also prevented SPB brood development in most trials.
- Tree injected with EB in winter at 2.5 ml/inch and 5.0 ml/in and baited with pheromones 4 weeks late served as effective trap trees. Most trees eventually died from blue stain infection but produced little or no brood.
- Trees injected with EB at rates of 2.5ml/in or 5.0 ml/inch in November 2014 and baited 18 months later (April 2016) failed to produce SPB egg galleries or brood.

Emamectin Benzoate and Propiconazole for Protection of Black Walnut from Walnut Twig Beetle and Thousand Canker Disease

- Emamectin benzoate and the fungicide propiconazole were detected in the phloem at very low concentrations (< 1 part per million). Neither chemical was detected in nut meat.
- A single injection of emamectin benzoate (alone) reduced walnut twig beetle emergence from infested branches by 60.4%.
- None of the injection treatments significantly improved health parameters (overall crown condition, % dieback, number of died branches) compared to untreated check.
- Low beetle populations and abundant rainfall during the study period likely reduced insect/disease pressure on more resistant study trees.

Evaluation of Miticides for Control of Conifer Mites on Loblolly Pine: Phase II

- The effectiveness of three miticide treatments (TREE-äge, Ima-jet, and an experimental compound AJT085) and a check were tested on young loblolly pines in East Texas for control of conifer mites.
- After 6 and 12 months, only TREE-äge significantly reduced mite density on infested trees.

Executive Summary (Continued)

Pine Tip Moth Trials

- A number of Nantucket pine tip moth field trials were monitored for growth of treated and untreated seedlings in 2015 following various chemical treatments and dosage rates.
- In a comparison of PTM™ (fipronil) and SilvaShield™ (imidacloprid) tablets for tip moth control, after 6 growing seasons, there were no significant differences in height, diameter or volume growth among any of 14 different treatments compared to the check.
- After 5 growing seasons, significant increases in diameter and volume growth (but not height) prevailed for PTM™ nursery plug injection treatments and one soil treatment of containerized seedlings. For bare-root seedlings, only a low dilution rate of PTM™ applied after plantingshowed significant increases in diameter and volume growth.
- After three growing seasons, there were no significant differences in growth of containerized loblolly pine seedlings stored up to 4 weeks and/or treated with 1.4 ml of PTM™ insecticide when compared to untreated, unstored seedlings.

Efficacy of Sivanto™ and XXpire WG™ for Control of Cone and Seed Insects

- Tests of two new insecticides (Sivanto™ and XX-pire WG™) versus TREE-äge™ and a check treatment for control of seed orchard pests revealed no significant differences among treatments in numbers of healthy or green=infested cones.
- The specific clone had a significant impact on level of coneworm damage, regardless of treatment.
- Only the TREE-äge treatment provided a significant increase in full seeds per cone compared to the check.

Evaluation of BASF Bait Formulations for Attraction and Control of the Texas Leaf-cutting Ant

- Preference and efficacy tests of two bait sizes of the BASF insecticide Siesta™ were tested on colonies of Texas leafcutting ants. An observed preference for large pellets of Siesta compared to the commercial fire ant bait did not prove significant.
- Both the Siesta fire ant bait and a larger pellet formulation proved largely ineffective, reducing leafcutting ant colonies by less than 50%. Only the standard Amdro Ant Block™ was effective, reducing treated colonies by 95%.

Improving the Prediction System for the Southern Pine Beetle

- Field trials on 8 different sites in Louisiana, Mississippi and Alabama in the spring of 2016 of 6 different SPB pheromone baits showed that the combination of frontalin, *endo*-brevicomin and Caribbean pine turpentine deployed from a polyethylene bag was by far the most attractive lure, catching ca. 60% of all SPB in traps.
- The least attractive lure was frontalin and Sirex bait, used since 2007 as the standard lure used in pheromone traps for predicting SPB outbreaks.

PART I: 2015 ACCOMPLISHMENTS

INCORPORATING EMAMECTIN BENZOATE INTO A CONTROL STRATEGY FOR THE SOUTHERN PINE BEETLE

Initiated in 2012; On-going in 2015 and 2016

Justification

The Forest Pest Management Cooperative (FPMC) initiated trials in 2012 in AL and VA to evaluate the ability of emamectin benzoate-treated pines to serve as trap trees for maintaining southern pine beetle (SPB) populations at low levels. It was found that SPB was more likely to attack untreated trees surrounding a central-baited, treated tree compared to treated trees surrounding a central-baited, treated tree. In this study, treated trees were baited 4 weeks after injection of emamectin benzoate. The reduced attack density on injected trees suggests that SPB may have detected emamectin benzoate within the trees injected 4 weeks earlier and therefore preferred to attack nearby untreated trees rather than the baited, injected tree in the center of the plot. For this reason, it is of interest to assess the efficacy of emamectin benzoate for protection of southern yellow pines against SPB by applying injection and baiting treatments at different timings and dosage rates. Perhaps if a tree is baited at the same time it is injected or soon thereafter (two weeks after injection), beetles would not detect the chemical, as the emamectin benzoate will not have had time to move upward from the basal injection points. The bait may attract beetles that then attack the injected tree and may even produce brood, but the brood would not be expected to live.

Funding: FPMC and grants from Syngenta

Location: Talladega National Forest, Alabama AND Bienville National Forest in Mississippi

Objectives of 2014 Study:

1. Optimize the timing of tree baiting and injections to maximize mass attacks on target trees and minimize development and emergence of brood (trap tree effect)
2. Test for seasonal effects between spring and fall dispersal periods on treatment effectiveness

Methods:

Sites chosen for this study were selected based on low to moderate trap catch levels in early spring on the Talladega National Forest, AL. Trap catches of SPB in Virginia in 2014 were too low to justify treatments. Four paired Lindgren twelve-funnel trap sets, one trap in each pair baited with frontalin + Sirex lure (*alpha* and *beta*-pinene) only (standard) and the other baited with frontalin + Sirex lure + *endo*-brevicomin displaced by 4 m (enhanced), were deployed in locations 300 m away from study sites to monitor local beetle populations.

There were two trials (spring and fall) with five treatments (listed below) and six replicates of each treatment. Loblolly pines chosen for experimentation were located in closed-canopy, pine-hardwood stands and were isolated (no other pine within 8 m). When possible, poor quality (form, health, etc.) trees were selected. Treatment applications were timed to coincide with peak spring and fall SPB dispersal periods. TREE-äge™ containing emamectin benzoate was injected into the lower trunk of trees at 5 ml per inch of diameter at breast height (DBH) in trees 12 inches in diameter and 10 ml per inch DBH in trees 12 inches in diameter for three of the five treatments (1, 3, and 4) and at a half rate for one treatment (2). The Tree IV™ microinfusion system (Arborjet, Inc. Woburn, MA) was used to inject TREE-äge™ into 4 injection points (for trees ≤12 inches DBH) or 8 injection points (for trees >12 inches DBH) at a height of 0.3 m above the ground. For each seasonal trial, all trees were baited with species-specific lures (frontalin, Sirex lure, and *endo*-brevicomin). The spring trial was baited for two consecutive 6-week periods, first on April 15th, again on May 28th, and a third, fall baiting on September 23rd, 2014. The fall trial was baited twice, initially on September 2nd and again on October 14th, 2014, to coincide with peak SPB flight periods.

Treatments:

1. Inject tree with TREE-äge @ 5 ml/inch DBH and wait four weeks to bait
2. Inject tree with TREE-äge @ 2.5 ml/inch DBH and wait four weeks to bait
3. Inject tree with TREE-äge @ 5 ml/inch DBH and wait two weeks to bait
4. Inject tree with TREE-äge @ 5 ml/inch cm DBH and bait on same day
5. Control: Bait only, not injected

To evaluate the various treatments, the following protocol was followed:

- Monitor SPB and associated black turpentine beetle (BTB) attack level by visually estimating the number of pitch tubes on entire stem and observing the health of study trees at one to two week intervals following installation of baits and at four to five week intervals thereafter until final evaluation.
- At the end of the spring and fall field seasons (November and April), each study tree was sampled at heights of 1.5, 4 and 6.5 m by counting brood emergence holes in 20 X 25 cm (500 cm^2) sample windows on northern and southern aspects. Attack success or failure was determined on the basis of study tree survival or mortality.
- All dead study trees will be felled upon exhibiting complete whole crown needle fading (from green to yellow) and treatment evaluation methodology assessed as described in 2 above. In addition, SPB gallery length and percent cerambycid larval feeding will be measured on the corresponding bark plates (10 X 10 cm = 100 cm^2) to each of the six 20 X 25 cm (500 cm^2) sampling windows.

The average number of SPB and BTB attacks and emergence holes and percent tree mortality will be compared among treatments and between spring and fall seasons.

Results

The study plan initially called for conducting the study in Virginia and Alabama, but in 2014 there were insufficient SPB populations in the Virginia site to bring trees under sufficient attack, so only the Alabama results are presented here.

The overall mean catch of SPB adult beetles per trap per day (b/t/d) for the standard monitoring bait was 7.8; for the enhanced bait (with *endo*-brevicomin) trap catches averaged 12.9 b/t/d. The SPB trapping data was separated into three periods: Spring dispersal (Apr-May), during which the standard bait caught a mean of 18.9 b/t/d and traps baited with *endo*-brevicomin caught 27.7 b/t/d/; summer (June-Aug), in which traps with the standard bait caught a mean of 1.6 b/t/d and those enhanced with *endo*-brevicomin caught 5.9 b/t/d/; and fall dispersal (Sept-Oct), during which the standard bait attracted a mean of 1.0 b/t/d and the *endo*-brevicomin enhanced baits attracted a mean of 2.0 b/t/d (Figure 1). Of note is the significate decline in SPB flight activity from the spring to summer seasons as is typical; but there was a continued decline in fall flight activity, rather than the increase that usually occurs during this season.

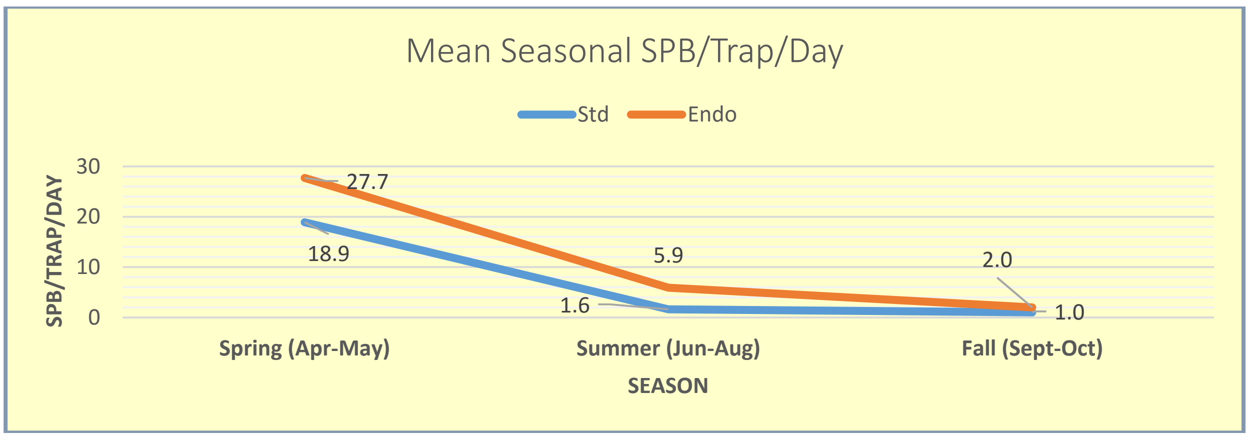

Figure 1. Average number of SPB per trap per day for standard and enhanced (with *endo*-brevicomin) baited traps by season on Oakmulgee Ranger District, AL, 2014.

An analysis of variance showed no significant differences among treatments in the average number of SPB or BTB attacks on the trees treated in the spring ($P = 0.325$; Figure 2). In contrast, the ANOVA revealed a significant difference at the 0.05 level among treatments initiated during the fall ($P = 0.048$, Figure 3). During this season, treatments 1 and 2 had SPB attack densities significantly lower than treatments 3, 4 or 5 (check). BTB attacks in both seasons were too low to show any significant differences.

The average numbers of SPB and BTB attacks per 500 cm2 bark samples also yielded no significant differences among treatments (Figures 4 and 5). By November 19th, 2014, six trees had died; two control trees, and one each of the four injection treatments.. Only the two control trees were successfully attacked and subsequently colonized by SPB and BTB as measured by the presence of adult egg gallery and brood development, confirmed by observation and evidenced by emergence holes. Similarly, only the two successfully-attacked control trees exhibited any cerambycid larval feeding (see Figure 8). By November 2015 (following rebaiting in 2015), all the check trees had died as well as 5 of 6 trees of each injection treatment, but essentially no SPB egg galleries or brood were produced in injected trees regardless of treatment or time delays (Figure 9A).

Discussion and Conclusion:

The 2012 FPMC study showed that loblolly pines treated with TREE-äge (emamectin benzoate) and baited after 4 weeks tended to have fewer southern pine beetle attacks than untreated, baited

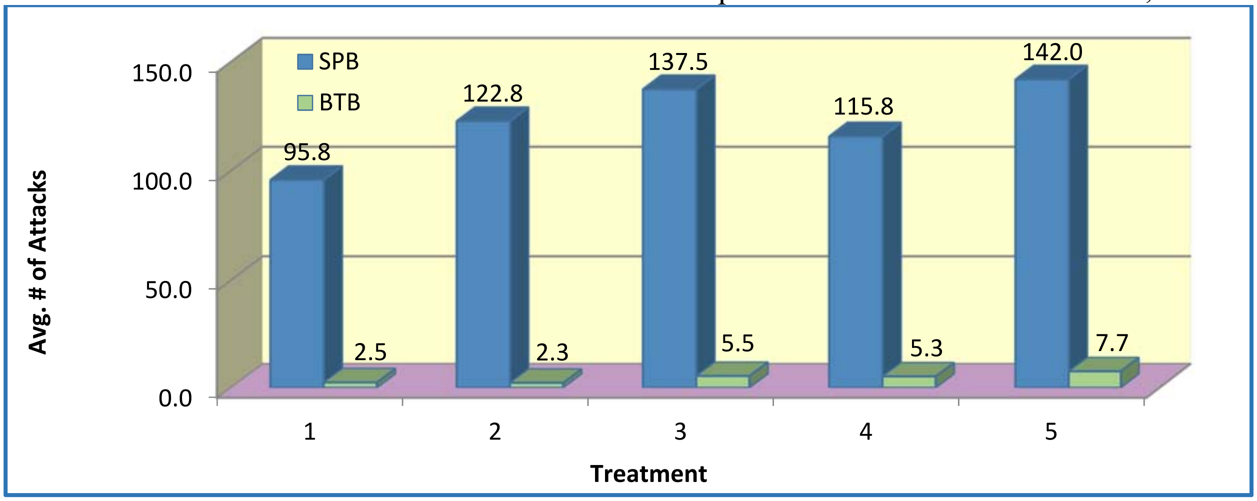

Figure 2. Average number of SPB and BTB attacks found on loblolly pine trees treated with: **1.** 5 ml/ inch DBH TREE-äge and wait four weeks to bait; **2.** 2.5 ml/ inch DBH TREE-äge and wait four weeks to bait; **3.** Inject tree with TREE-äge @ 5 ml/ inch DBH TREE-äge and wait two weeks to bait; **4.** 5 ml/ inch DBH TREE-äge and bait on same day; **5.** Control: Bait only, no injection, in spring 2014.

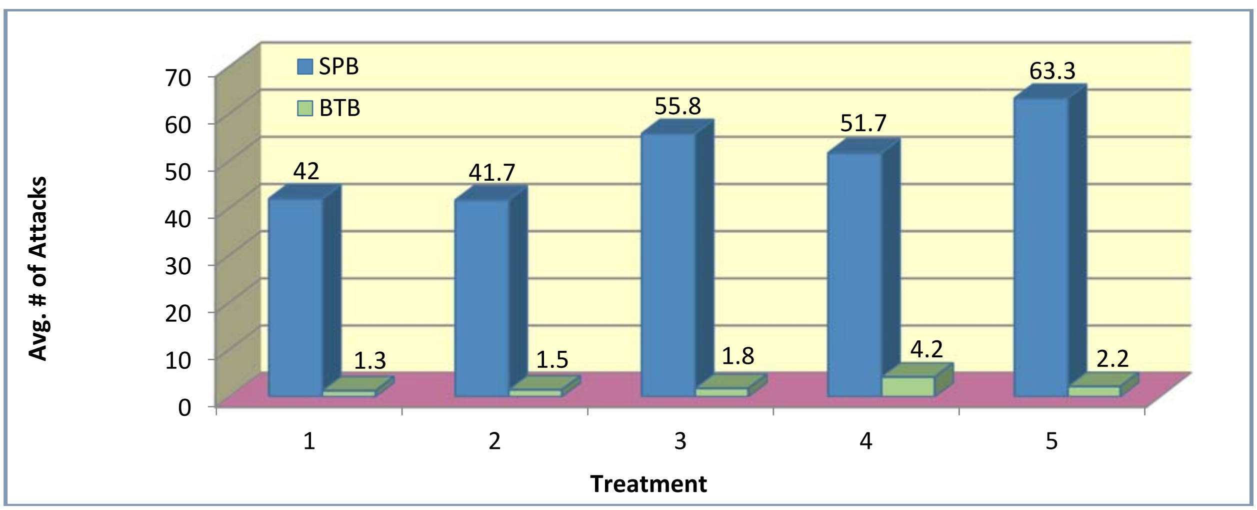

Figure 3. Average number of SPB and BTB attacks found on loblolly pine trees treated with: **1.** 5 ml/ inch DBH TREE-äge and wait four weeks to bait; **2.** 2.5 ml/ inch DBH TREE-äge and wait four weeks to bait; **3.** Inject tree with TREE-äge @ 5 ml/ inch DBH TREE-äge and wait two weeks to bait; **4.** 5 ml/ inch DBH TREE-äge and bait on same day; **5.** Control: Bait only, no injection, in fall 2014 Fall trial values: (P = 0.950 and P = 0.029 for SPB and BTB, respectively).

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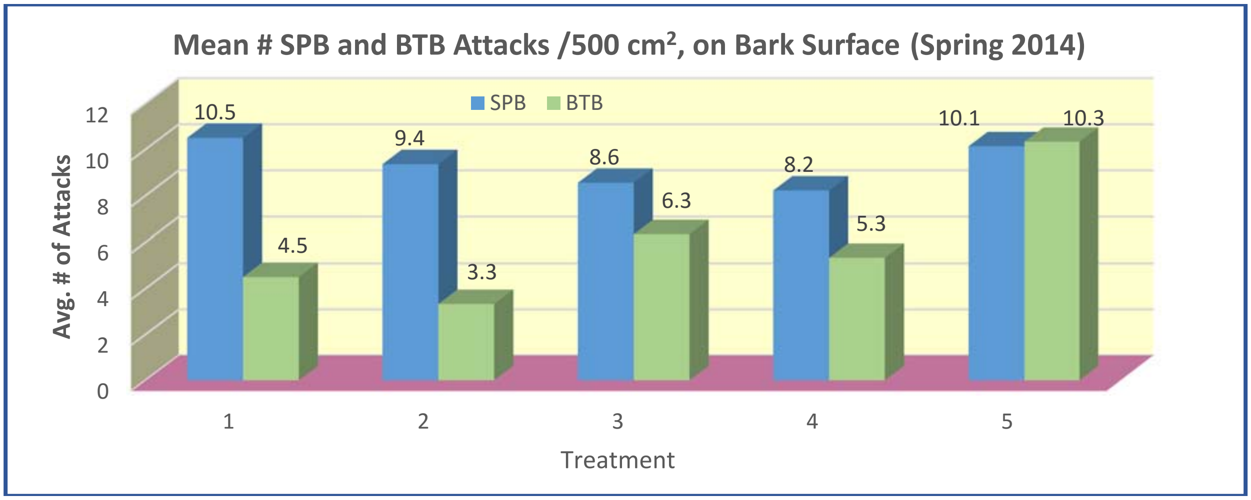


Figure 4. Average number of SPB and BTB attacks per 500 cm2 samples on loblolly pine trees treated with: **1.** 5 ml/ inch DBH TREE-äge and wait four weeks to bait; **2.** 2.5 ml/ inch DBH TREE-äge and wait four weeks to bait; **3.** Inject tree with TREE-äge @ 5 ml/ inch DBH TREE-äge and wait two weeks to bait; **4.** 5 ml/ inch DBH TREE-äge and bait on same day; **5.** Control: Bait only, no injection, in spring 2014.

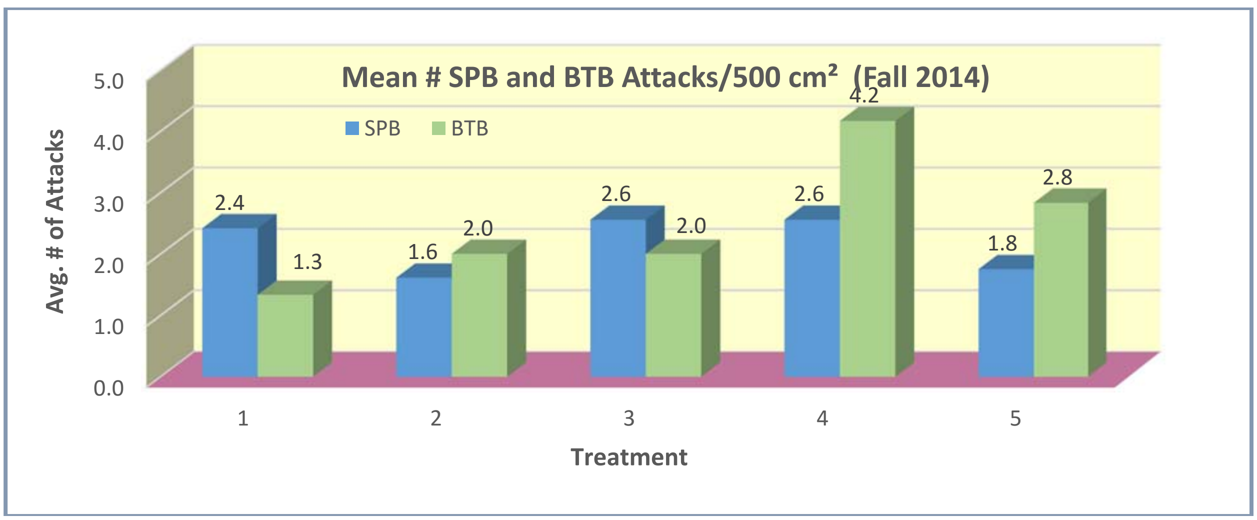


Figure 5. Average number of SPB and BTB attacks per 500 cm2 samples on loblolly pine trees treated with: **1.** 5 ml/ inch DBH TREE-äge and wait four weeks to bait; **2.** 2.5 ml/ inch DBH TREE-äge and wait four weeks to bait; **3.** Inject tree with TREE-äge @ 5 ml/ inch DBH TREE-äge and wait two weeks to bait; **4.** 5 ml/ inch DBH TREE-äge and bait on same day; **5.** Control: Bait only, no injection, in fall 2014.

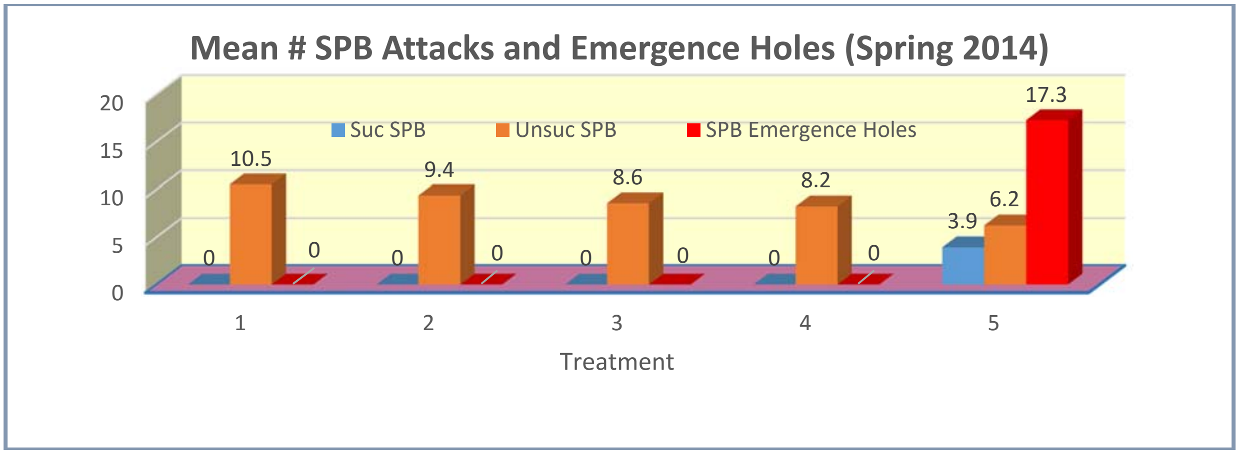


Figure 6. Average number of SPB attacks and emergence holes per 500 cm2 found on loblolly pine trees treated with: **1.** 5 mL/ inch DBH TREE-äge and wait four weeks to bait; **2.** 2.5 mL/ inch DBH TREE-äge and wait four weeks to bait; **3.** Inject tree with TREE-äge @ 5 mL/ inch DBH TREE-äge and wait two weeks to bait; **4.** 5 mL/ inch DBH TREE-äge and bait on same day; **5.** Control: Bait only, no injection, in spring 2014.

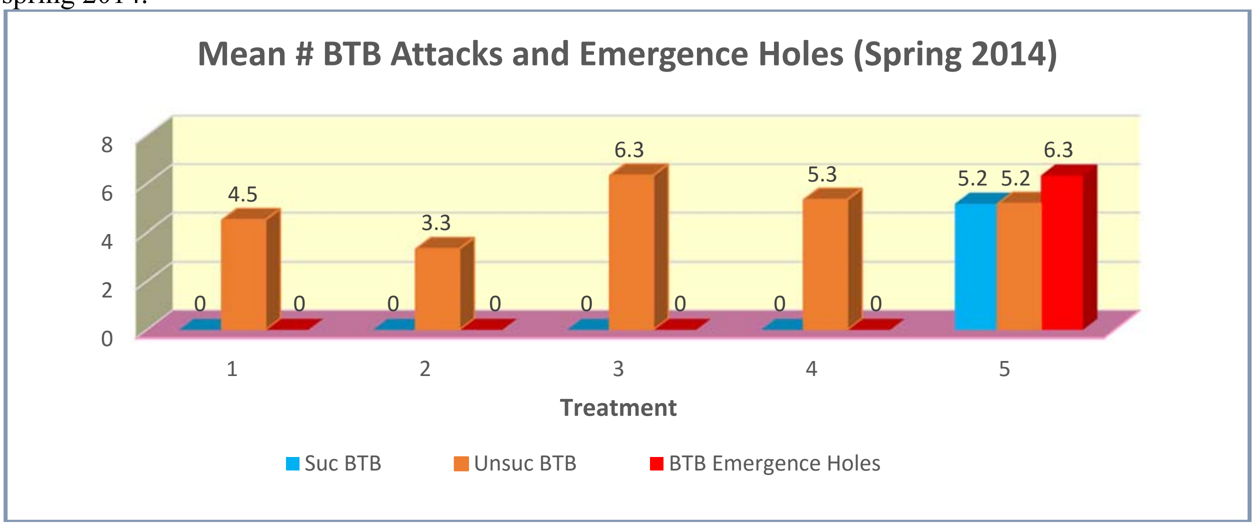


Figure 7. Average number of BTB attacks and emergence holes per 500 cm2 found on loblolly pine trees treated with: **1.** 5 mL/ inch DBH TREE-äge and wait four weeks to bait; **2.** 2.5 mL/ inch DBH TREE-äge and wait four weeks to bait; **3.** Inject tree with TREE-äge @ 5 mL/ inch DBH TREE-äge and wait two weeks to bait; **4.** 5 mL/ inch DBH TREE-äge and bait on same day; **5.** Control: Bait only, no injection, in spring 2014.

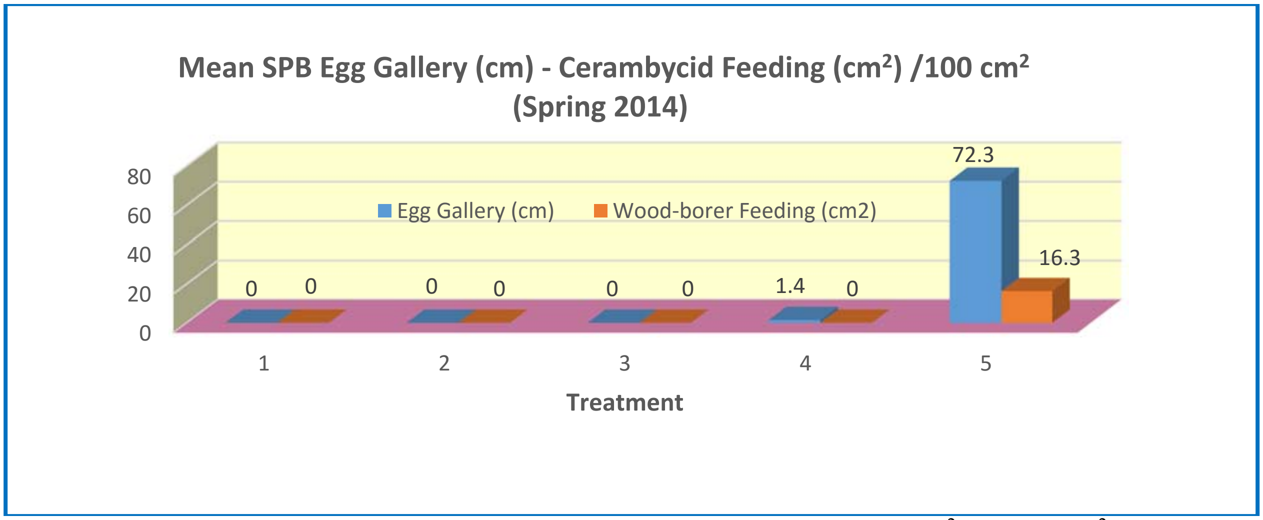
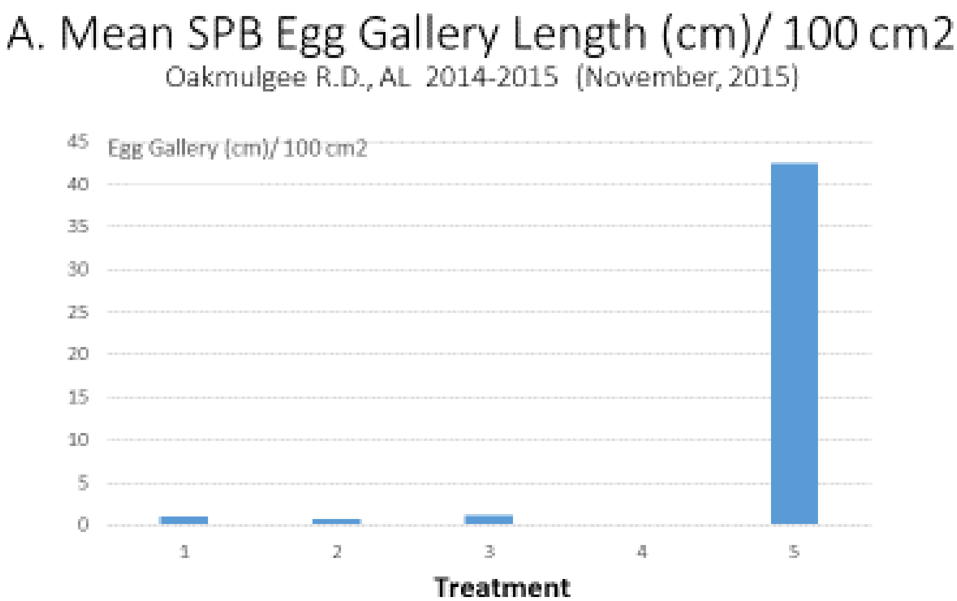


Figure 8. Average length (cm) of SPB egg gallery and cerambycid feeding (cm^2) per $100cm^2$ found on loblolly pine trees treated with: **1.** 5 ml/ inch DBH TREE-äge and wait four weeks to bait; **2.** 2.5 ml/ inch DBH TREE-äge and wait four weeks to bait; **3.** Inject tree with TREE-äge @ 5 ml/ inch DBH TREE-äge and wait two weeks to bait; **4.** 5 ml/ inch DBH TREE-äge and bait on same day; **5.** Control: Bait only, no injection, in spring 2014.



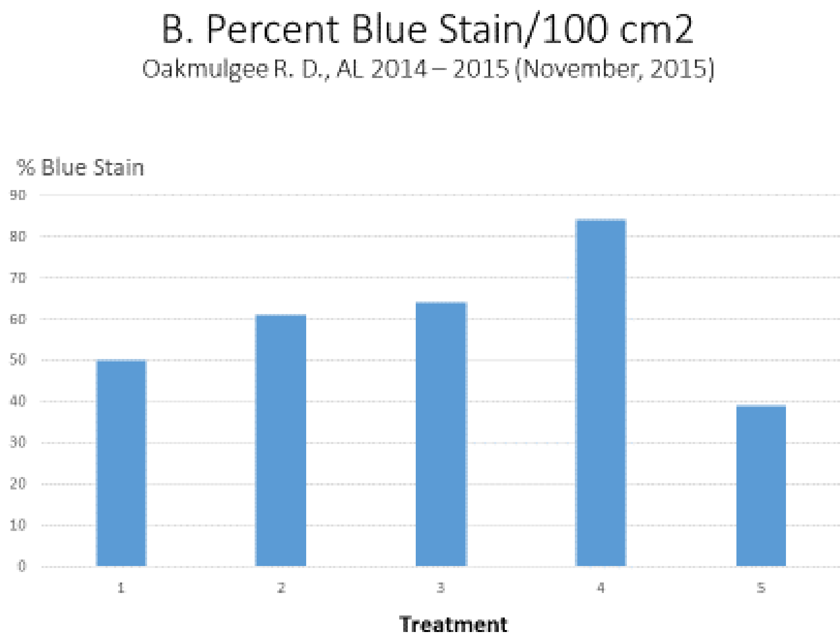


Figure 9. Average length (cm) of SPB egg gallery (A) and percent blue stain (B) per 100 cm^2 found on loblolly pine trees treated with: **1.** 5 ml/ inch DBH TREE-äge and wait four weeks to bait; **2.** 2.5 ml/ inch DBH TREE-äge and wait four weeks to bait; **3.** Inject tree with TREE-äge @ 5 ml/ inch DBH TREE-äge and wait two weeks to bait; **4.** 5 ml/ inch DBH TREE-äge and bait on same day; **5.** Control: Bait only, no injection, when trees faded or at end of 2015 season. Oakmulgee Ranger District, MS. November 2015.

trees. This may be because the attacking beetles quickly die upon contact with treated phloem tissue which prevents the release of pheromones and host volatiles that attract additional beetles, thus reducing the overall numbers of attacks. Why this has not been a result in these trials is unknown, but may be advantageous, since there was no survival of broods in treated trees, even those injected at a lower dosage (treatment 2) or on the same day as baiting (treatment 4). An effective trap tree technique should have an attack density similar to a baited, uninjected tree (as in treatments 2, 3 and 4 during the spring and fall trials). Furthermore, injected trees showed no successful egg gallery establishment, brood survival or emergence (Figure 8, 9A). Blue stain was more prevalent on the treated trees compared to the check, due to the lack of SPB galleries on the former (Figure 9B). Infection by beetle-vectored blue-stain fungi was considered the most probable cause of tree mortality for the one tree of each of the injection treatments which died during the course of this study. Blue stain was observed to be heavily present beneath the bark of these dead trees.

The success of treatment 2, in which trees were injected at half the dosage of the other injection treatments, suggests that a lower dose rate may be equally effective, reducing chemical and application costs considerably in operational treatments. Future studies should evaluate the effectiveness of even lower EB dosages (i.e., 1.0 and 2.0 ml/diameter inch). Also, trees baited the same day they were injected served as successful trap trees.

EVALUATION OF EMAMECTIN BENZOATE FOR SOUTHERN PINE BEETLE CONTROL IN 2015; BIENVILLE NATIONAL FOREST

Initiated in 2015; completed in 2016

Studies conducted in Alabama in 2013 and 2014 indicate that dosages of emamectin benzoate (EB) (TREE-äge) at 5 ml and 2.5 ml/diameter inch applied during the spring were effective in preventing brood production in treated trees. Trees treated with EB, as well as check trees, in the fall of 2014 received insufficient SPB attacks to evaluate treatments. Further studies are needed to replicate the 2014 spring results and to identify the lower dosage threshold at which EB will continue to prevent SPB brood production.

Objectives for CY 2015:

1. Evaluate the efficacy of trunk injections of emamectin benzoate for protection of southern yellow pines against SPB
2. Determine the duration of efficacy of emamectin benzoate for protection of southern yellow pines against SPB (in the second and third year following injection).
3. Develop and evaluate a new management strategy to monitor and respond to SPB populations to maintain them below the Allee threshold required for re-establishment and spread, using current knowledge of SPB seasonal behavior, available methods of SPB monitoring, and new technology for suppression.

Cooperators:

Ms. Cindy Ragland	Oakmulgee R.D, Talladega N.F., Brent, AL
Mr. Ron Fisher	Delta Ranger District, Bienville National Forest, MS
Dr. Christopher Asaro	VA Dept. of Forestry, Charlottesville, VA
Dr. Steve Clarke	USDA Forest Service – FHP R8, Lufkin, Texas
Mr. Joseph Doccola	Arborjet, Inc., Woburn, MA

Study Sites: The 2013 and 2014 study sites will continue to be monitored on the Talladega National Forest, Oakmulgee Ranger District in Bibbs and Perry Co., Alabama, with SPB attacking loblolly pine, *Pinus taeda*. Forest tracts (18-22) where loblolly pine predominate, of similar age (>20 years old) and low density (<90 square feet basal area), were (will be) selected as study sites. Pines selected for treatment or checks will be isolated from other pines to prevent the initiation of multiple-tree SPB infestations.

Insecticides:
Emamectin benzoate (TREE-äge™, Arborjet Inc.) – an avermectin derivative

Treatments in MS (2015) (Six replicates per treatment)**:**

1. Inject tree with TREE-äge @ 5 ml/inch DBH and wait two weeks to bait (Inject on April 1, bait on April 14)
2. Inject tree with TREE-äge @ 2.5 ml/inch DBH and wait two weeks to bait (Inject on April 1, bait on April 14)

3. Inject tree with TREE-äge @ 2.5 ml/inch DBH and bait simultaneously (Inject and bait on April 14)
4. Inject tree with TREE-äge @ 1.25 ml/inch DBH and wait 2 weeks to bait (Inject on April 1, bait on April 14)
5. Inject tree with TREE-äge @ 1.25 ml/inch DBH and bait simultaneously (Inject and bait on April 14)
6. Control: Bait only, not injected (Bait on April 14)

Treatment evaluation:

1. Monitor attack level (occurrence of pitch tubes) of SPB and health on study (baited, injected or untreated) trees at intervals of 5, 12 and 19 weeks after the installation of baits.
2. All dead study trees will be felled as soon as their crowns begin to fade. Bark plates (10 X 10 cm = 100 cm2) will be collected at approximately 1.5, 4.0 and 6.5 m height at northern and southern aspects. SPB gallery length, density of emergence holes, percent blue stain and amount of cerambycid galleries will be measured.

Results of 2015 Studies:

All the infested trees baited with SPB pheromones on April 14, 2015 were mass attacked by SPB shortly after baiting and all but one tree (a check) died by September 30, 2015. Egg gallery length was significantly reduced in all injection treatments, even the two treatments in which trees were injected and baited on the same day (Figure 10). For reasons that are unclear, SPB egg gallery length among injected trees in the 2.5 ml/in treatment applied at the time of baiting while the same simultaneous injection and baiting treatment with 1.25ml/in had little gallery development. Also, as noted in previous studies, the amount of blue stain infection was consistently greater in all injection treatments, with the possible exception of the 2.5ml/inch treatment baited simultaneously. Injection treatments did not prevent the trees from being killed, due to the aggressive SPB population on the Bienville National forest in 2015. But brood production, as evidenced by the reduction in successful gallery construction, was minimized by all injection treatments. Additional replicates are needed to further test the efficacy of the lower dosage rates (1.25 and 2.50 ml/inch diameter).

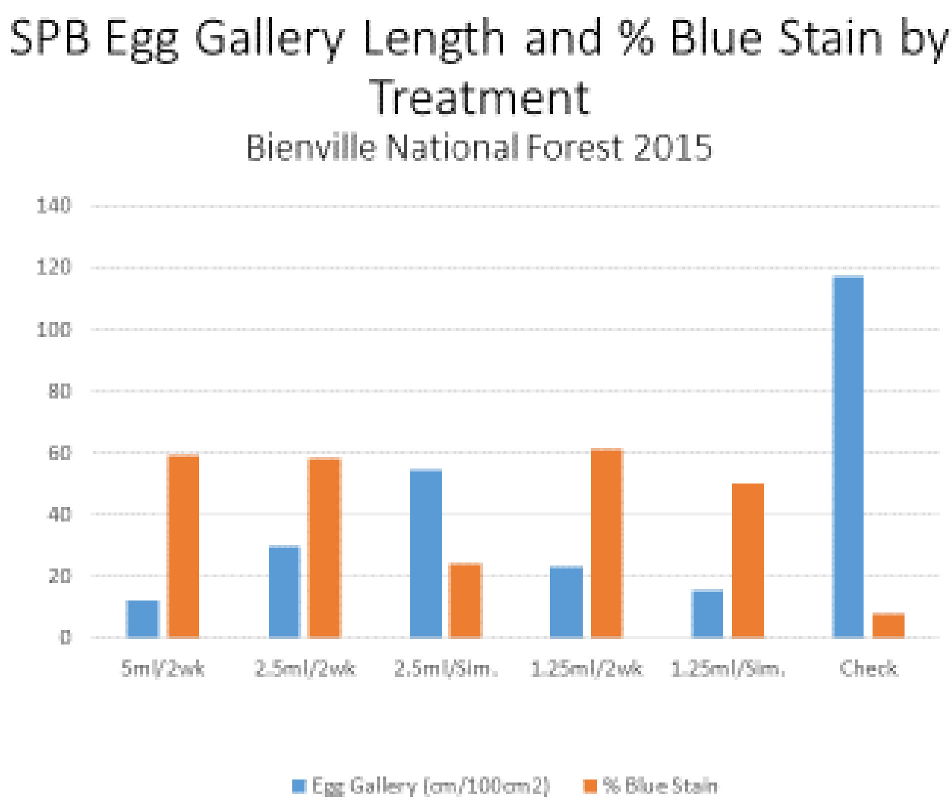


Figure 10: Southern pine beetle egg gallery length (cm/100 cm2) and % blue stain on treated and check trees. Bienville National Forest, Mississippi 2015.

EMAMECTIN BENZOTE AND PROPICONIZOLE FOR PROTECTION OF BLACK WALNUT FROM WALNUT TWIG BORER AND THOUSAND CANKERS DISEASE

Initiated 2012; completed 2015 (FS-PIAP #12-DG-11083148-005)

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Introduction: Thousand cankers disease was recently discovered in TN, VA and PA, within the native range of black walnut. Protection of individual, high-value walnut trees from insect attack has historically involved applications of liquid formulations of contact insecticides to the tree bole and/or foliage. Recently, an experimental formulation of an injected systemic insecticide, emamectin benzoate (TREE-äge ™; Arborjet Inc., Woburn, MA), was registered by Syngenta Crop Protection, LLC, Greensboro, NC, with the EPA, and may prove promising for protecting black walnut. In this study, the effectiveness of recommended rates of TREE-age™ alone and combined with the fungicide propiconazole (ALAMO®; Syngenta Crop Protection, LLC Greensboro, NC) was evaluated for reducing the attack success of walnut twig beetle (WTB) on individual black walnut trees and the progression of the thousand cankers disease fungus introduced during initial phases of tree colonization. Additionally, effects on other walnut pests were evaluated. The extent of disease infection and the distribution and concentration of emamectin benzoate and propiconazole in xylem, phloem, and nuts were determined.

5. Objectives:

1) To determine the efficacy of emamectin benzoate (TREE-äge™) and the fungicide propiconazole, alone or in combination, for protecting individual walnut trees from attack by walnut twig beetle and other insect pests.

2) To determine if emamectin benzoate, propiconazole or combination treatments can provide preventative and therapeutic control of thousand cankers disease.

3) To provide data on the distribution and concentration of emamectin benzoate in walnut xylem, phloem, and nuts at several points in time after injection.

6. Research approach:

Locations, Treatments, and Environmental Conditions

This study was established in 2012 while Dr. Grosman was coordinator of the FPMC at three locations: TCD-confirmed location in Sevier Co., TN (about 35°59 N, 83°45 W, elev. 1136 ft) and uninfested locations in Cherokee Co., TX (about 31°45 N, 95°11 W, elev. 429 ft) and Nacogdoches Co., TX (about 31°41 N, 94°26 W, elev. 309 ft). There were as many as four treatments: emamectin benzoate (TREE-äge™) alone injected into trees (treatment **1**); propiconazole (Alamo®) alone injected into trees (Treatment **2**); TREE-äge™+ Alamo® injected into tree (Treatment **3**); and an untreated control (treatments **4**).

Each treatment was applied to 10-40 randomly-assigned trees per site. Test trees were located in areas with known insect activity, spaced >10 m apart, 13 to 38 cm dbh, and within 100 m of access roads to facilitate the treatment. Each insecticide, fungicide or insecticide + fungicide treatment (treatments 1-3) was injected with the Arborjet Tree IV™ or QUIK-jet™ microinfusion system (Arborjet, Inc. Woburn, MA) into 4-8 evenly spaced points 0.3 m above the ground. Injections occurred in early- (TX) or late-April ((TN) 2012. The intent was to bait trees (treated and untreated) in TN with WTB pheromones (provided by Steve Seybold) beginning in June, 2012 and throughout the growing season. However, phytotoxic effects (burned leaves) caused by the treatments made it necessary to delay baiting. All treated trees in treatments 1-3 and the untreated control trees (treatment 4) were baited in June, 2013 and again in September, 2013. WTB populations were monitored throughout the season near the TN location with baited 4-unit Lindgren funnel traps placed at 10 feet on steel conduit poles. Trap catches were recovered every two weeks throughout the season.

In April, 2012 (at the time of treatment) and then four (August 2012), 16 (August 2013) and 40 (August 2015) months post-treatment the stem and crown of each tree were ranked as to the extent of insect damage. In addition, three small branches (12” length) were collected from the low, mid and upper crown of several study trees in 2012. The branches were evaluated for the presence of and ranked on the level of WTB (TN) and other insect damage (TX and TN).

Treatment Efficacy

A photograph of the crown of each study tree in TN was taken at the time of treatment. Trees were evaluated for crown condition in May and September 2012 and 2013. The date of appearance of TCD symptoms was recorded. Each walnut crown was given a rating of 0 (healthy), 1 (wilt symptoms comprising < 20% of the crown), 2 (wilt symptoms comprising 20-80% of the crown), 3 (wilt symptoms comprising >80% of the crown) (Mayfield et al. 2008), or 4 (dead tree).

At the planned termination of the experiment in August 2014 (about 28 months after treatment), the intent was to conduct a final crown ratings. However, an unusually cool summer resulted in premature leaf drop and final ratings were conducted in August 2015. An analysis of variance will be used to test for differences among injection treatments. A x^2 (Chi-square) test for homogeneity will be used to test the null hypothesis that the percentage of trees with a crown rating of 2 did not differ between the insecticide-, fungicide- or combination-treated trees and the untreated control group (Mayfield et al. 2008). The null hypothesis will be rejected if more than 20% of the treated trees reached a crown rating of 2. The test will be invalidated if fewer than 60% of the control trees reach a crown rating of 2.

Residue Analyses

Residue levels of emamectin benzoate and propiconazole have been determined in xylem (i.e., to ascertain whether the insecticide was moving within the tree), phloem (i.e., the target tissue where bark beetles feed, etc.) and nuts (that may be consumed). Branch and nut samples were collected June 26, 2012 (treatments 1 - 4), and nuts only September 16, 2012 (treatments 1 - 4) from 3-15 randomly selected trees per treatment (*see* below). Additional tissue samples were collected in September 2013 (treatments 1, 2 and 4).

Results:

Texas: Within one week of applications of TREE-äge alone and combined with Alamo in April 2012 nearly all trees experienced noticeable leaf burn. The combination treatment appeared to show greater phytotoxic symptoms than the insecticide alone.

Very little insect damage (psyliid and defoliator) was observed on any of the walnuts trees at the two Texas locations in 2012 and 2013 (Table 1 and 2). As a result of high variability, there was no difference among the treatments.

Tennessee: All products proved to be difficult to inject in April 2012 most likely because the new leaves were about 50% extended. Similar to Texas, all treatments caused phytotoxic symptoms (leaf deformity or burn) on nearly all trees (Table 3). However, the extent of leaf burn was 2x greater on trees treated with the combination treatment compared to those trees treated with either TREE-age or Alamo alone.

Many of the walnut study trees already exhibited signs of decline (flagging and dead branches, thin crown) in 2012. Subsequent branch samples collected in August 2012 (showed that 42 – 83% had walnut twig beetle attacks (Table 4) so trees were not baited to attract additional beetle.

Table 1: Occurrence and severity of damage caused by insects or injections of sytemic chemicals on Black Walnuts; Power's property, Rusk (Cherokee Co.), TX - 2012

		Psyllid	Tree Condition		
Treatment*	N	20-Jul	13-Apr	10-May	20-Jul
Emamectin benzoate	15	0.67	1.67	1.33	1.80
EB + Propiconizole	15	0.57	3.67	2.30	2.30
Check	14	1.46	1.00	1.00	1.18

Tree Condition: 1 = Excellent, 2 = Good, 3 = Fair, 4 = Poor, 5 = Near Death or Dead

Psyllid Rank: 1 = Isolated; 2 = light; 3 = moderate; 4 = heavy; 5 = extensive

Table 2: Occurrence and severity of damage caused by insects and/or injections of sytemic chemicals on Black Walnuts; Read's property, Martinsville (Nacogdoches Co.), TX - 2012

		Defoliator	Psyllid		Condition		
Treatment*	N	8-Jun	8-Jun	20-Jul	13-Apr	10-May	20-Jul
Emamectin benzoate	10	0.75	1.00	1.90	1.25	1.05	1.05
Check	10	1.90	1.95	2.80	1.00	0.37	0.37

Defoliator and Psyllid Rank: 1 = Isolated; 2 = light; 3 = moderate; 4 = heavy; 5 = extensive

Tree Condition: 1 = Excellent, 2 = Good, 3 = Fair, 4 = Poor, 5 = Near Death or Dead

Table 3: Occurrence and severity of damage caused by injections of sytemic chemicals on Black Walnuts; Bill France property, Seymour (Sevier Co.), TN - 2012

Treatment*	N	Phytotoxic Symptoms Ranking	Leaf Deformity	Bark Separation
Emamectin benzoate	40	1.09	0.40	0.13
Propiconazole	39	1.06	1.79	0.21
EB + Propiconizole	40	2.33	1.58	0.15
Check	19	0.00	0.37	0.00

Phytotoxicity ranking : 0= no signs; 1 = 20% of crown w burn; 2 = 40%; 3= 60%; 4 = 80%; 5 = 100%

Leaves affected by chemical: 0 = None; 1 =light, 2 = moderate; 3 = severe

Although some larval galleries and canker areas were observed, live WTB adults and larvae and brood emergence holes were not found on any of the branches.

As a result, all trees were baited in June 2013 and then again in August. Branches collected in August 2013 were improperly stored so no useable data could be collected. Those branches collected in November 2013, were autopsied and some useful data was collected. There were no differences among the treatments in the number of adult entrance holes, galleries, and adults found in those galleries, and adult gallery length (Table 5). Only the number of holes created by emerging brood adults differed among treatments. Branches from TREE-äge-treated trees had significantly fewer holes than untreated checks. Analysis of xylem, phloem and nut meat tissue indicated that both emamectin benzoate and propiconazole had been translocated into the crown, though at relatively low levels (Table 7 and 8)

The condition of untreated check trees remained stable over time while treated trees showed some improvement by 2013 indicating that the treatments may have had some beneficial effect and are allowing the trees to begin recovering from WTB attack and TCD infection (Table 6). However, only the emamectin benzoate plus propiconazole trees showed minor improvement by 2015. Unfortunately, the test was invalidated as fewer than 60% of the control trees reached a crown rating of 2.

Conclusions:
It was expected that TREE-äge would be very effective against WTB based on previous success with other bark beetle (southern pine beetle, western pine beetle, mountain pine beetle) and wood boring beetles. However, the concentration of emamectin benzoate was relatively low in phloem tissue and WTB are very small and do not appear to score the xylem tissue (that has high concentrations) as they construct their galleries. Therefore, the adult beetles may not be exposed to sufficient chemical to cause direct mortality. In contrast, it appears that brood larvae may be impacted given that there is a reduction in the number of exit holes on TREE-age-treated trees. Study trees were reinjected in September 2014 to increase concentration of chemical.

The condition of untreated check trees did not continue to decline over the 4 year study period. This suggests that environmental conditions (e.g. rainfall) were sufficient to maintain health of untreated trees (Figure 11). Perhaps because if this, trees were able to resist WTB attack, thus keeping WTB populations (based on trap catches) low. Because of low pest population pressure and favorable environmental conditions, it was not possible to see significant improvement in the condition of treated trees.

Newly emerging black walnut leaf tissue is highly sensitive to TREE-äge and Alamo. Trees injected later in the growing season (July), after tissue hardening, did not show any phytotoxic symptoms. Therefore, in the future, walnuts should be treated with TREE-äge and/or Alamo, after leaf hardening.

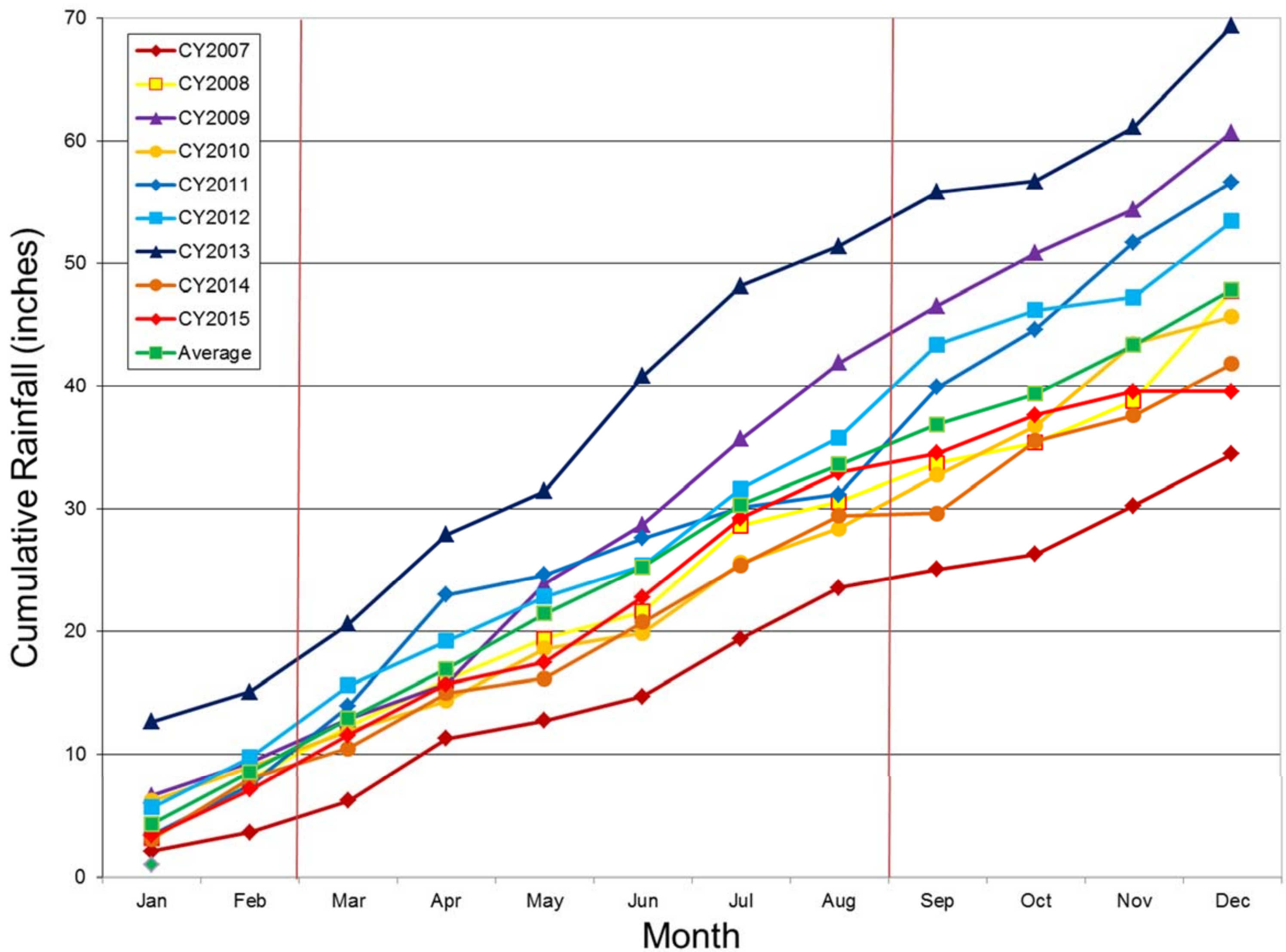

Figure 11: Cumulative annual rainfall pre- (2007 – 2012) and post-study initiation (2012 – 2015) for Seymour, TN area. The period between the vertical red lines (March – August) indicates the general growing season for black walnuts.

Table 4. Occurrence and severity of damage caused by Walnut Twig Beetle/ Thousand Cankers Disease on Black Walnut branches; Seymour(Sevier Co.), TN - 2012

				Number, Length or Area per 100 cm^2 of branch Surface Aea							
Treatment	N	% Branches with WTB	Branch Surface Area	# WTB Attacks	# Egg Galleries	Lgth of Egg Gal (cm)	Adults Present? (N=0, Y=1)	Brood Present? (N=0, Y=1)	Canker Present? (N=0, Y=1)	Canker Area (cm^2)	# Exit Holes
Emamectin benzoate	6	83.3	180.9	1.9	1.2	2.2	0.0	0.0	0.4	3.1	0.0
EB + Propiconizole	7	42.8	186.7	3.6	1.8	2.8	0.0	0.0	0.6	2.8	0.0
Check	8	62.5	178.3	1.1	0.6	0.8	0.0	0.0	0.2	1.4	0.0

Table 5. Occurrence and severity of damage caused by Walnut Twig Beetle/ Thousand Cankers Disease on Black Walnut branches; Seymour(Sevier Co.), TN - 2013

Trt	# of Reps	No. Entry Holes	No. Exit Holes *	No.Adult Galleries	Gallery Length (mm)	No. Adults	No. sporulating	Branch Length (cm)	Branch Width (cm)	Branch area (cm2)	No. Entry Holes/ 100sqcm	No. Exit Holes/ 100sqcm	No. Galleries/ 100sqcm	Gallary Length/ 100sqcm
EB	14	64.14	1.93 A	15.00	92.36	9.86	22.43	90.59	3.19	291.95	22.78	0.58	5.24	31.91
EBP	14	44.93	2.57 AB	10.43	67.36	7.36	10.64	87.45	2.58	228.87	19.54	1.45	4.68	28.95
Check	6	51.33	5.00 B	7.67	40.17	4.83	10.17	84.24	2.66	227.10	22.57	2.78	3.37	17.92

* Means with different letters are significantly different at P= 0.05, Tukeys.

Table 6: Condition of Black Walnuts 4, 16 and 40 months after treatment, Bill France property, Seymour, TN - August 2012, 2013 n& 2015

Treatment*	N	Branch Flagging (BF)	Thinning Crown (TC)	# Dead Branches < 1"	1-3"	> 3"	Total	% Dieback	Tree Condition *
2012									
Emamectin benzoate	40	0.58	1.25	3.63	1.78	0.38	5.78	11.25	2.00
Propiconazole	39	1.31	1.74	3.33	1.54	0.49	5.36	13.46	2.42
EB + Propiconizole	40	1.21	2.15	3.35	2.28	0.43	6.05	13.50	2.53
Check	19	0.58	0.89	2.58	1.79	0.32	4.68	8.95	1.92
2013									
Emamectin benzoate	38	0.26	1.84	2.00	1.92	0.45	4.37	11.58	1.71
Propiconazole	39	0.51	1.59	2.59	1.67	0.49	4.74	10.51	1.72
EB + Propiconizole	40	0.48	1.73	2.38	2.33	0.53	5.23	14.25	1.75
Check	19	0.05	2.05	2.11	1.32	0.47	3.90	11.05	1.90
2015									
Emamectin benzoate	40	0.43	1.15	2.87	2.05	1.58	6.50	8.93	1.94
Propiconazole	40	0.83	1.45	4.24	2.11	1.50	7.85	10.75	1.89
EB + Propiconizole	38	0.74	1.18	3.64	2.00	1.42	7.05	8.20	1.73
Check	19	0.26	1.53	3.06	2.08	2.40	7.54	14.00	2.08

BF & TC Rank: 1 = Isolated; 2 = light; 3 = moderate; 4 = heavy; 5 = extensive

Condition: 1 = Excellent, 2 = Good, 3 = Fair, 4 = Poor, 5 = Near Death or Dead

Treatment means within a year that have an asteriks are significantly different from untreated checks.

Table 7. Mean Concentration (PPM) of emamectin benzoate (EB) in black walnut xylem, phloem and nut meat tissue 4 and 16 months folowing injection.

	Xylem		Phloem		Nut Meat	
	2012	2013	2012	2013	2012	2013
Emamectin benzoate	12.9710	1.7000	0.0575	0.0178	<0.001	<0.001
EB + Propiconazole	6.4611	1.1045	0.0995	0.0277	<0.001	<0.001
Check	<0.0059	0.0015	<0.0012	0.0013	<0.001	<0.001

Note: LOQ (Limit of qantitation) set at 1 ppb (0.001 ppm); 1 of 4 check samples from xylem and ploem had 0.002 ppm while others below LOQ

Table 8. Mean Concentration (PPM) of propiconazole (P) in black walnut xylem, phloem and nut meat tissue 4 and 16 months folowing injection.

	Xylem		Phloem		Nut Meat	
	2012	2013	2012	2013	2012	2013
Emamectin benzoate	n/a	n/a	n/a	n/a	n/a	n/a
EB + Propiconazole	-----	4.3129	-----	0.2373	<0.050	<0.050
Check	-----	<0.050	-----	<0.050	<0.050	<0.050

Note: LOQ (Limit of qantitation) set at 50 ppb (0.050 ppm); 1 of 4 check samples from xylem and ploem had 0.002 ppm while others below LOQ

EVALUATION OF MITICIDES FOR CONTROL OF CONIFER MITES ON LOBLOLLY PINE: PHASE II

Initiated 2014; completed in 2015

Introduction:

Conifer mites (family Tetranychidae) attack most species of trees (including conifers) and shrubs. Nursery seedlings and windbreak trees are particularly susceptible because they are often treated with insecticides that kill predators of conifermites (Cordell et al. 1989). Pine, hemlock, spruce, juniper, fir, and white-cedar are often heavily attacked.

Some trees species are attacked by more than one species of spider mites. The more important species on nursery seedlings are the spruce mite (*Oligonychus ununguis*), the conifer spider mite (*O. coniferarum*), and the southern red mite (*O. illicis*). These mites do best in cool spring and fall weather. Other mites, including the twospotted spider mite (*Tetranychus uriticae*) do best in dry, hot summer weather.

Heavy infestations of conifer mites cause reduced seedling and young tree growth, along with foliage yellowing or browning. Although most spider mite attacks do not cause mortality, they may predispose trees to attack by insects and disease or to damage by adverse environmental conditions. Spider mite populations can explode after use of insecticides to control other insects when mite predators are killed as well.

Several miticides (insecticidal/miticidal oils and soaps, Dicofol™, Kelthane™, Avid™, Floramite™, Hexagon™, Sanmite™, and Forbid™) are available for control, but resistance can develop if the applicator relies too heavily on one product. In Phase I, the FPMC evaluated effectiveness of TREE-äge and EcoMite Plus™ for control of conifer mites (see FPMC 2014 Accomplishment Report). Recently, Arborjet has developed several new formulations of miticides that merit field testing. In Phase II, the FPMC evaluated TREE-äge (emamectin benzoate) and two other treatments against conifer mites.

Objectives:

1) Evaluate the efficacy and duration of tree injection of TREE-age™ (emamectin benzoate), IMA-jet (imidacloprid) and a new chemical (Arborjet's AJT-085), for control of secondary conifer mites.

Methods:

<u>Locations, Treatments, and Environmental Conditions</u>
This study is being conducted at Campbell Global's Boyd Lake Seed Orchard, Jasper, TX (about 30º57 N, 94º09 W, elev. 105 ft). An initial survey was conducted in early September 2014 of the general health of four-year-old loblolly pines in a polymix trial containing several families. Each pine was evaluated for presence of conifer mites. Thirty (30) trees will be randomly selected for treatment. An additional ten trees will serve as untreated checks.

There were four treatments: TREE-äge (emamectin benzoate) tree injection (treatment **1**); IMA-jet (imidacloprid) tree injection (treatment **2**); Arborjet product AJT-085 tree injection (treatment **3**), and untreated control (treatment **4**).

Each treatment will be applied to 10 randomly-assigned trees. Test trees will be located in areas with abundant tip moth and mite activity, and spaced >4 m apart. Treatment 1 will be injected at the labeled rate (2.5 ml TREE-age per inch ground line diameter) after dilution in 1 part water (=5 ml dilution per inch) while treatments 2 and 3 will be injected undiluted (2ml IMA-jet per inch GLD, 1,25 ml AJT-085 per inch GLD) with the Arborjet Tree IV™ microinfusion system (Arborjet, Inc. Woburn, MA) into a three points (use #3 Arborplugs) at staggered heights up to 6 inches above the ground. Injections will occur in early September 2014 (Trt 1) or early December 2014 (Trt 2 & 3).

On December 8, 2014 (at the time of initial injection treatment) and then 1, 3, 6, 9, and 12 months after treatment application, two lower branches will be shaken over a white sheet of paper. The conifer mites found on the paper will be counted and identified. In addition, the top whorl of each tree will be evaluated for tip moth damage.

Precipitation and temperature data will be obtained from the nearest weather station during the course of this study from 1 September, 2014 to 1 December 2015. A sample of mites collected will be sent to Dr. Alex Mangini, US Forest Service, in Pineville, Louisiana, for identification.

Results:

A list of mites collected from study trees is shown in Table 9. The spider mite *Oligonychus milleri* was the most common mite found in all the treatments before and after tree injection. The mean abundance of mites prior to treatment (December 8, 2014) and at intervals following treatment through December 2, 2015 are shown in Table 10. Results show that spider mite numbers increased markedly by February 9, 2015 in the IMA-jet and AJT085-treated trees and the check, but not in the TREE-age treated trees. Even by June 23, the spider mite abundance on trees injected with TREE-age more than six months prior had mean numbers of spider mites that were half those of the other treatments. By December 2, 2015, mite populations had doubled on the check trees, were similar to pre-treatment levels on the Ima-jet and AJT-085 treated trees, but remained at half of pretreatment levels on TREE-äge-treated trees. Only the TREE-äge treatment proved to be significantly different ($P \leq 0.05$) from the check treatment.

Table 9: Collection information – mite specimens collected from December 8, 2014 – June 15, 2015 at Boyd Lake Seed Orchard by Bill Upton. Identifications by Alex Mangini, USDA FS.

Treat	Mites[1] – Major Taxa	Count	Species IDs – Slide Mounts of Selected Specimens
8 December 2014			
Pre-treatment	Tetranychidae(spider mite)	24	*Oligonychus milleri* (McGregor, 1950)
	Phytoseiidae(predator)	9	*Typlhodromips* sp. in *lugubris* sp. grp.
	Anystidae(predator)	1	*Anystis* sp.
	Bdellidae(predator)	1	*Spinibdella* sp.

15 January 2015			
TreeAge	Phytoseiidae	2	*Typlhodromips* sp. in *lugubris* sp. grp.
	Homoptera(scale insects)	2	no slide mounts
ImaJet	Tetranychidae	4	*Oligonychus milleri* (McGregor, 1950)
	Phytoseiidae	4	*Typlhodromips* sp. in *lugubris* sp. grp.
	Homoptera(scale insects)	2	no slide mounts
AJT085	Tetranychidae	7	*Oligonychus milleri* (McGregor, 1950)
	Phytoseiidae	4	*Typlhodromips* sp. in *lugubris* sp. grp.
	Anystidae	1	*Anystis* sp.
Check	Tetranychidae	5	*Oligonychus milleri* (McGregor, 1950)
	Phytoseiidae	4	*Typlhodromips* sp. in *lugubris* sp. grp.
19 February 2015			
TreeAge	Tetranychidae	11	*Oligonychus milleri* (McGregor, 1950)
	Phytoseiidae	1	no slide mounts
ImaJet	Tetranychidae	42	*Oligonychus milleri* (McGregor, 1950)
AJT085	Tetranychidae	32	*Oligonychus milleri* (McGregor, 1950)
	Phytoseiidae	1	*Typlhodromips* sp. in *lugubris* sp. grp.
Check	Tetranychidae	27	*Oligonychus milleri* (McGregor, 1950)
	Phytoseiidae	2	*Neoseiulus arenillus* (Denmark & Muma, 1967) + species to be determined
24 March 2015			
TreeAge	Tetranychidae	1	*Oligonychus milleri* (McGregor, 1950)
	Phytoseiidae	2	no slide mounts
ImaJet	Tetranychidae	23	*Oligonychus milleri* (McGregor, 1950)
	Phytoseiidae	2	no slide mounts
AJT085	Tetranychidae	12	*Oligonychus milleri* (McGregor, 1950)
Check	Tetranychidae	5	*Oligonychus milleri* (McGregor, 1950)
19 June 2015			
TreeAge	Tetranychidae	1	*Oligonychus milleri* (McGregor, 1950)
	Phytoseiidae	5	no slide mounts
	Cunaxidae (predator)	1	further identification not yet determined
	Tarsonemidae (scavenger)	2	further identification not yet determined
	Oribatida (scavenger)	1	further identification not yet determined
ImaJet	Tetranychidae	2	*Oligonychus milleri* (McGregor, 1950)
	Phytoseiidae	24	*Amblyseius obtusus* (Koch, 1839)
	Tarsonemidae	4	no slide mounts
AJT085	Tetranychidae	5	*Oligonychus milleri* (McGregor, 1950)
	Phytoseiidae	20	*Amblyseius obtusus* (Koch, 1839) + *Typlhodromips* sp. in *lugubris* grp.
	Tarsonemidae	2	no slide mounts
Check	Tetranychidae	6	*Oligonychus milleri* (McGregor, 1950)
	Phytoseiidae	9	no slide mounts

[1] Counts should not be considered precise; some specimens were lost in processing.

[2] Only one vial sent so there is no sorting by treatment.

Table 10: Mean numbers of spider mites on treated and check trees in 2015; Campbell Global's Boyd Lake Seed Orchard, Jasper, TX. Means followed by the same letter are not significantly different (P>0.05).

Treatment	Pre-treatment	Post Treatment			
	12/8/2014	1/15/2015	2/9/2015	3/24/2015	6/23/2015
TREE-age	6.2	1.9	2.3	5.2	9.8 A
Ima-jet	5.9	3.5	21.2	14	20.1 B
AJT085	3.9	4.1	17.8	27.5	30.2 B
Check	4.3	5.6	16.4	18.7	22.1 B

Treatment	Pre-treatment	Post Treatment	
	12/8/2014	10/02/2015	12/2/2015
TREE-age	6.2	1.8	2.8 A
Ima-jet	5.9	1.7	6.5 B
AJT085	3.9	3.0	5.4 B
Check	4.3	3.8	8.6 B

8. Literature cited:

Cordell, C.E., R.L. Anderson, W.H. Hoffard, T.D. Landis, R.S. Smith Jr., and H.V. Toko. 1987. Forest nursery pests. Agric. Handbook 680. U.S. Dept. Agriculture, Forest Service. 184 p.

PINE TIP MOTH TRIALS: COMPARISON OF PTM™AND SILVASHIELD™ FOR CONTROL

Initiated in 2010; Final growth measurements in January 2016.

Objectives:

1. Determine the efficacy of PTM™ and SilvaShield™ in reducing pine tip moth infestation levels on loblolly pine seedlings
2. Evaluate these products applied at different rates and timing
3. Determine the duration of protection provided by these insecticide applications

Study sites: In 2009, a recently-harvested tract, 121 acres in size and owned by The Campbell Group, was selected NW of Jasper, TX (Jasper Co.). The plot contained 15 treatments with 50 trees per treatment.

Insecticides:

- Imidacloprid [SilvaShield™ (SS) Forestry Tablet, Bayer]: highly systemic neonicotinoid with activity against Lepidoptera.
- Fipronil (PTM™ Insecticide, BASF) – a phenyl pyrazole with some systemic activity against Lepidoptera.

Research Approach:

Fifty seedlings for each treatment (A – O, see below) were hand planted (standard spacing 8' X 8') on a first-year plantation site. The site had received an intensive site preparation and the soil was disked. A randomized complete block design was used with beds or site areas serving as blocks, i.e., each treatment was randomly selected for placement along a bed. Ten seedlings from each treatment were planted on each of five beds. Treatments A, D, F, H, K, and M were applied as the seedling was planted. Just after seedling transplant, Treatments B, G, I, and N were applied (pushed into the soil 4" deep and 2 cm from each assigned seedling [SS] or poured into one 4" – deep probe hole near each seedling [PTM]). For treatments C, D, J, and K, one Tablet or solution was applied to each seedling in fall 2010. The remaining treatments (E, F, G, L, M, and N) were applied in February 2011.

Treatment Description:

A. PTM™ solution (1.4ml product in 13.6 ml water) applied into plant hole at planting (Dec. '09).
B. PTM™ solution (1.4ml product in 13.6 ml water) applied post plant at 1 point next to seedling (Dec. '09).

C. PTM™ solution (0.7ml product in 14.3 ml water) applied post plant at 2 points next to seedling (Sept. ’10).
D. PTM™ solution (1.4ml product in 13.6 ml water)applied to plant hole at planting (Dec. ’09) and (0.7ml product in 14.3 ml water) applied post plant at 2 points next to seedling (Sept. ’10).
E. PTM™ solution (0.7ml product in 14.3 ml water) applied post plant at 2 points next to seedling (Feb. ’11).
F. PTM™ solution (1.4ml product in 13.6 ml water) applied to plant hole at planting (Dec. ’09) and (0.7ml product in 14.3 ml water) applied post plant at 2 points next to seedling (Feb. ’11).
G. PTM™ solution (1.4ml product in 13.6 ml water) applied post plant at 1 point next to seedling (Dec. ’09) and (0.7ml product in 14.3 ml water) applied post plant at 2 points next to seedling (Feb. ’11).
H. SilvaShield™ (SS) (1 Tablet) applied into plant hole at planting (Dec. ’09).
I. SS (1 Tablet) applied post plant next to seedling (Dec. ’09).
J. SS (1 Tablet) applied post plant next to seedling (Sept. ’10).
K. SS (1 Tablet) applied into plant hole at planting (Dec. ’09) and SS (1 Tablet) applied post plant next to seedling (Sept. ’10).
L. SS (1 Tablet) applied post plant next to seedling (Feb. ’11).
M. SS (1 Tablet) applied to plant hole at planting (Dec. ’09) and SS (1 Tablet) applied post plant next to seedling (Feb. ’11).
N. SS (1 Tablet) applied post plant next to seedling (Dec. ’09) and SS (1 Tablet) applied post plant next to seedling (Feb. ’11).
O. Control: seedlings planted by hand without additional treatment.

Treatments and Layout

Code	Treatment	Color
A	PTM in plant hole at planting (Dec. '09)	red
B	PTM post plant at 1 pt next to seedling (Dec. '09)	blue
C	PTM post plant at 2 pt next to seedling (Sep. '10)	orange
D	PTM at planting + PTM post plant (2 pts, Sep. '10)	pink/blue
E	PTM post plant at 2 pt next to seedling (Feb. '11)	w hite
F	PTM at planting + PTM post plant (2 pts, Feb. '11)	red/w hite
G	PTM post plant (1 pt, Dec. '09) + PTM post plant (2 pts, Feb. '11)	yellow /blue
H	SS in plant hole at planting (Dec. '09)	yellow
I	SS post plant next to seedling (Dec. '09)	green
J	SS post plant next to seedling (Sep. '10)	pink
K	SS at planting + SS post plant (Sep. '10)	blue/w hite
L	SS post plant next to seedling (Feb. '10)	green/orange
M	SS at planting + SS post plant (Feb. '11)	yellow /green
N	SS post plant (Dec. '09) + SS post plant (Feb. '11)	blue/red
O	Check (lift and plant bare root seedlings)	green/w hite

Bed 1	Bed 2	Bed 3	Bed 4	Bed 5
J	G	L	I	K
E	H	E	O	E
F	J	C	H	I
L	E	H	G	O
A	C	J	E	H
N	B	M	M	A
K	L	B	B	F
O	F	F	K	M
B	M	A	A	N
D	I	K	C	C
G	A	D	N	G
C	N	I	F	J
I	D	G	L	D
M	K	O	D	B
H	O	N	J	L

Treatment Evaluation

Tip moth damage was evaluated after each tip moth generation (3-4 weeks after peak moth flight) by 1). Identifying if the tree was infested or not, 2). If infested, the proportion of tips infested on the top whorl and terminal was calculated; and 3). Separately, the terminal was identified as infested or not.

Times for Jasper Co., TX site:

- Generation 1: week of April 27
- Generation 2: week of June 22
- Generation 3: week of August 10
- Generation 4: week of September 21
- Generation 5: November 15 – December 31

Observations also were made as to the occurrence and extent of damage caused by other insects, i.e., aphids, weevils, coneworm, etc. Second-year trees were measured for ground-level diameter and height in the fall (November). Study trees were measured for growth (height, diameter at breast height, and volume) diameter (at DBH) and ranked for form at the end of the first, second, third and sixth growing season. To rank for form, each tree will be categorized as follows: 0 = no forks; 1 = one fork; 2 = two to four forks; 3 = five or more forks. A fork is defined as a node with one or more laterals larger than one half the diameter of the main stem (Berisford and Kulman 1967).

Results:

In 2010, tip moth populations were moderate to high through most of the year with damage levels ranging from 12% of the shoots infested on check trees after generation 1 to 54% after the 5th generation (Table 11). All PTM^{TM} and SS treatments with initial application made in December 2009 significantly reduced tip moth infestation of top whorl shoots compared to the check during all five generations. Overall reduction in damage compared to checks ranged from 79 – 97% for PTM^{TM} treatments and 94 – 100% for SS treatments. There was no difference between PTM^{TM} and SS treatments applied at planting. However, SS treatments applied post plant generally provided better protection compared to post plant PTM^{TM} treatments. Only SS treatments (3 of 5) significantly improved tree height growth compared to check trees (Table 14).

In 2011, tip moth populations were generally higher through most of the 2nd year with damage levels ranging from 18% of the shoots infested on check trees after generation 2 to 75% after the 5th generation (Table 12). All PTM^{TM} and SS treatments significantly reduced tip moth infestation of top whorl shoots compared to the check during all five generations. Overall reduction in damage compared to checks ranged from 31-87% for PTM^{TM} treatments and 78-99% for SS treatments. There was no difference between PTM^{TM} and SS treatments applied at planting. However, SS treatments applied post plant provided markedly better protection compared to post plant PTM^{TM} treatments. None of the treatments significantly improved tree height growth compared to check trees (Table 15). There were no differences in tree survival among the treatments.

In 2012, tip moth populations were high through most of the 3rd year, with damage levels ranging from 11% of the shoots infested after generation 1, to 90% after generation 5 (Table 9). Only the three SS treatments applied at planting showed a significant reduction in tip moth infestation of top whorl shoots compared to the control for all five generations (Table 13). Analysis of variance found that SS "at plant" and "post plant" provided significantly better protection than PTM^{TM} both "at plant" and "post plant" (SS AP vs. PTM AP: $p < .0001$; SS PP vs. PTM PP: $p < .0001$). Some of the treatments showed a significant improvement in tree height growth and diameter (measured as both GLD and DBH) compared to control trees, there was no difference in volume (Tables 16 [GLD] and 17 [DBH]).

In 2013, only growth was measured. Many treatments exhibited significant increases in height, while only two treatments exhibited significant increases in DBH compared with the control trees (Table 18). Treatments **C** [PTM^{TM} solution (0.7ml product in 14.3 ml water) applied post plant at

2 points next to seedling (Sept. ’10)], **D** [PTM^{TM} solution (1.4ml product in 13.6 ml water) applied to plant hole at planting (Dec. ’09) and (0.7ml product in 14.3 ml water) applied post plant at 2 points next to seedling (Sept. ’10)], **F** [PTM^{TM} solution (1.4ml product in 13.6 ml water) applied to plant hole at planting (Dec. ’09) and (0.7ml product in 14.3 ml water) applied post plant at 2 points next to seedling (Feb. ’11)], and **L** [SS (1 Tablet) applied post plant next to seedling (Feb. ’11)] showed significant increases in volume compared with the control trees (Table 18).

The study trees were revisited at the end of the sixth growing season (2015) and measured for growth for the final time. At that time, 66 trees had died and were not included in the 2015 analysis. As shown in Table 19, only height in one treatment (PTM 11 PP) showed a significant increase in height growth. Interestingly, there were no significant differences ($P>0.5$) in volume growth among any of the treatments compared to the check after 6 years of growth. Differences observed in earlier years had disappeared over time, suggesting that tip moth control in this study was not economically warranted, regardless of dosage or application method.

Acknowledgments:

Thanks go to Campbell Global for providing research site and seedlings. We also thank Jim Bean, BASF, and Bruce Monke, Bayer Environmental Science, for providing PTM^{TM} and SilvaShield^{TM} Tablets, respectively, for the project.

References:

Berisford, C.W. and H.M. Kulman. 1967. Infestation rate and damage by the Nantucket pine tip moth in six loblolly pine stand categories. For. Sci. 13: 428-438.

Table 11. Effect of PTM™ soil injection and SilvaShield™ tablet dose, timing and technique on pine tip moth infestation of loblolly pine shoots (top whorl) on one site (Campbell Group Nursery) in east Texas, 2010.

	Treatment				Mean Percent Top Whorl Shoots Infested by Tip Moth (**Pct. Reduction Compared to Check**)																	
Year	Product	Season	Tech.	N	Gen 1			Gen 2			Gen 3			Gen 4			Gen 5			Overall Mean		
2010	PTM	D '09	AP	50	0.4	**97**	*	1.5	**95**	*	0.0	**100**	*	0.0	**100**	*	2.4	**96**	*	0.9	**97**	*
	PTM	D '09 + S '10	AP	50	0.0	**100**	*	3.7	**89**	*	2.4	**88**	*	2.5	**95**	*	1.5	**97**	*	2.4	**93**	*
	PTM	D '09 + F '11	AP	50	1.3	**89**	*	2.7	**92**	*	0.7	**97**	*	1.1	**98**	*	0.0	**100**	*	0.9	**97**	*
	PTM	D '09	PP	50	3.4	**73**	*	5.8	**82**	*	5.7	**71**	*	5.4	**88**	*	5.6	**90**	*	5.2	**84**	*
	PTM	D '09 + F '11	PP	50	0.0	**100**	*	6.7	**79**	*	3.8	**81**	*	9.0	**81**	*	14.4	**73**	*	6.8	**79**	*
	PTM	S '10	PP	50	9.6	**23**		32.9	**-2**		12.4	**38**		15.0	**68**	*	41.4	**23**	*	23.1	**29**	*
	PTM	F '11	PP	50	7.4	**40**		42.4	**-32**		17.4	**12**		29.0	**39**	*	30.2	**44**	*	25.3	**22**	*
	SS	D '09	AP	50	0.0	**100**	*	0.4	**99**	*	1.4	**93**	*	8.2	**83**	*	4.3	**92**	*	2.9	**91**	*
	SS	D '09 + S '10	AP	50	0.0	**100**	*	0.7	**98**	*	0.0	**100**	*	0.0	**100**	*	0.0	**100**	*	0.1	**100**	*
	SS	D '09 + F '11	AP	50	0.0	**100**	*	0.0	**100**	*	0.0	**100**	*	1.0	**98**	*	0.0	**100**	*	0.2	**99**	*
	SS	D '09	PP	50	0.4	**97**	*	1.1	**97**	*	0.0	**100**	*	1.1	**98**	*	6.4	**88**	*	1.8	**94**	*
	SS	D '09 + F '11	PP	50	0.0	**100**	*	0.0	**100**	*	0.0	**100**	*	1.4	**97**	*	3.4	**94**	*	1.0	**97**	*
	SS	S '10	PP	50	7.6	**38**		33.7	**-5**		13.8	**30**		33.0	**30**	*	22.6	**58**	*	22.6	**31**	*
	SS	F '11	PP	50	7.3	**41**		34.6	**-8**		26.0	**-31**		39.8	**16**		47.0	**13**		30.9	**5**	
	Check			100	12.4			32.1			19.9			47.3			53.9			32.6		

PTM= fipronil; SS= SilvaShield, imidacloprid), D= December, S= September, F= February, AP= at plant, PP= post plant.
* Means followed by an asterisk are significantly different from checks at the 5% level based on Fisher's Protected LSD.
[shaded] = treatment reduced damage by 75% or better compared to check.

Table 12. Effect of PTM™ soil injection and SilvaShield™ tablet dose, timing and technique on pine tip moth infestation of loblolly pine shoots (top whorl) on one site (Campbell Group Nursery) in east Texas, 2011.

	Treatment				Mean Percent Top Whorl Shoots Infested by Tip Moth (**Pct. Reduction Compared to Check**)																	
Year	Product	Season	Tech.	N	Gen 1			Gen 2			Gen 3			Gen 4			Gen 5			Overall Mean		
2011	PTM	D '09	AP	47	11.1	**76**	*	3.3	**81**	*	6.6	**73**	*	4.6	**76**	*	20.0	**73**	*	9.2	**75**	*
	PTM	D '09 + S'10	AP	48	3.9	**91**	*	1.0	**94**	*	1.2	**95**	*	0.0	**100**	*	17.4	**77**	*	4.7	**87**	*
	PTM	D '09 +F '11	AP	48	7.9	**83**	*	2.6	**85**	*	2.1	**91**	*	2.5	**87**	*	8.0	**89**	*	4.7	**87**	*
	PTM	D '09	PP	42	37.2	**19**		6.4	**64**	*	11.2	**54**	*	9.1	**52**	*	45.8	**39**	*	22.0	**40**	*
	PTM	D '09 + F '11	PP	43	33.0	**28**	*	10.3	**42**	*	9.9	**59**	*	5.8	**69**	*	36.4	**51**	*	19.2	**47**	*
	PTM	S '10	PP	42	11.2	**76**	*	2.8	**84**	*	1.9	**92**	*	6.0	**68**	*	21.2	**72**	*	8.7	**76**	*
	PTM	F '11	PP	43	44.7	**3**		14.9	**16**		7.9	**67**	*	6.6	**65**	*	46.2	**38**	*	25.2	**31**	*
	SS	D '09	AP	47	7.0	**85**	*	1.8	**90**	*	0.7	**97**	*	0.0	**100**	*	4.7	**94**	*	2.8	**92**	*
	SS	D '09 + S'10	AP	46	4.0	**91**	*	0.0	**100**	*	0.0	**100**	*	0.5	**97**	*	0.0	**100**	*	0.9	**98**	*
	SS	D '09 +F '11	AP	47	0.7	**98**	*	0.0	**100**	*	0.7	**97**	*	0.0	**100**	*	0.4	**99**	*	0.4	**99**	*
	SS	D '09	PP	46	6.5	**86**	*	0.4	**98**	*	0.5	**98**	*	0.0	**100**	*	7.1	**91**	*	2.9	**92**	*
	SS	D '09 + F '11	PP	44	5.9	**87**	*	1.5	**92**	*	2.2	**91**	*	2.3	**88**	*	0.8	**99**	*	2.4	**93**	*
	SS	S '10	PP	43	7.7	**83**	*	2.3	**87**	*	0.0	**100**	*	0.0	**100**	*	6.2	**92**	*	3.2	**91**	*
	SS	F '11	PP	50	27.8	**39**	*	3.6	**80**	*	1.7	**93**	*	0.0	**100**	*	6.5	**91**	*	7.9	**78**	*
	Check			45	45.9			17.8			24.1			18.8			75.0			36.5		

PTM= fipronil; SS= SilvaShield, imidacloprid), D= December, S= September, F= February, AP= at plant, PP= post plant.
* Means followed by an asterisk are significantly different from checks at the 5% level based on Fisher's Protected LSD.
= treatment reduced damage by 75% or better compared to check.

Table 13. Effect of PTM™ soil injection and SilvaShield™ Tablet dose, timing, and technique on pine tip moth infestation of loblolly pine shoots (top whorl) on one site (Campbell Group Nursery) in east Texas, 2012.

	Treatment				Mean Percent Top Whorl Shoots Infested by Tip Moth (**Pct. Reduction Compared to Check**)																	
Year	Product	Season	Tech.	N	Gen 1			Gen 2			Gen 3			Gen 4			Gen 5			Overall Mean		
2012	PTM	W '09	AP	47	3.01	**73**	*	1.7	**62**		20.4	**29**	*	44.3	**26**	*	68.3	**24**	*	27.5	**27**	*
	PTM	W '09 + S'10	AP	48	3.3	**70**	*	4.1	**12**		13.3	**53**		22.8	**62**		43.8	**51**	*	17.5	**54**	*
	PTM	W '09 +F '11	AP	48	0.94	**91**	*	4.1	**11**		28.5	**0**		43.8	**27**		73.7	**18**	*	29	**23**	*
	PTM	W '09	PP	42	14.8	**-34**		3.7	**20**		28.5	**0**		61.2	**-3**		78.1	**13**		37.3	**1**	
	PTM	W '09 + F '11	PP	43	3.88	**65**	*	4.8	**-4**		30.7	**-8**		47.8	**20**		65.8	**27**	*	30.6	**19**	*
	PTM	S '10	PP	42	0.79	**93**	*	3.1	**32**		37.0	**-30**		59.1	**1**		75.2	**16**		36	**4**	
	PTM	F '11	PP	43	3.88	**65**	*	4.7	**-2**		25.5	**10**		46.6	**22**		68.3	**24**		28.9	**23**	*
	SS	W '09	AP	47	3.55	**68**	*	0.4	**92**	*	3.5	**88**	*	10.7	**82**	*	32.4	**64**	*	10.1	**73**	*
	SS	W '09 + S'10	AP	46	3.8	**65**	*	1.1	**77**		3.3	**89**	*	10.9	**82**	*	23.0	**74**	*	8.19	**78**	*
	SS	W '09 +F '11	AP	46	3.26	**70**	*	0.0	**100**	*	3.4	**88**	*	11.1	**81**	*	14.9	**83**	*	6.55	**83**	*
	SS	W '09	PP	46	3.33	**70**	*	4.3	**8**		27.0	**5**		34.1	**43**		58.2	**35**	*	25.4	**33**	*
	SS	W '09 + F '11	PP	44	6.86	**38**		0.6	**88**		8.5	**70**	*	19.9	**67**	*	36.1	**60**	*	14.4	**62**	*
	SS	S '10	PP	43	4.65	**58**	*	0.5	**90**		7.6	**73**	*	16.4	**73**	*	39.3	**56**	*	13.7	**64**	*
	SS	F '11	PP	50	4.83	**56**	*	2.4	**48**		9.7	**66**	*	12.2	**80**	*	48.1	**46**	*	15.4	**59**	*
	Check			45	11			4.63			28.5			59.6			89.8			37.7		

* Means followed by an asterisk are significantly different from checks at the 5% level based on Fisher's Protected LSD.

= treatment reduced damage by 75% or better compared to check.

Table 14. Effect of PTM™ soil injection and SilvaShield™ tablet dose, timing and technique on loblolly pine growth on one site (Campbell Group nursery) in east Texas, 2010.

	Treatment				Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm3) Compared to Check**)						Mean Percent Tree
Year	Product	Season	Tech.	N	Height (cm)		Diameter (cm) [a]		Volume (cm^3)		Survival
2010	PTM	D '09	AP	50	66.9	**8.2**	0.94	**0.02**	70.7	**11.8**	98
	PTM	D '09 + S '10	AP	50	65.1	**6.4**	0.93	**0.02**	68.5	**9.5**	96
	PTM	D '09 + F '11	AP	50	65.1	**6.4**	0.88	**-0.04**	62.5	**3.6**	96
	PTM	D '09	PP	50	61.0	**2.3**	0.86	**-0.05**	63.1	**4.2**	90
	PTM	D '09 + F '11	PP	50	62.6	**3.9**	0.94	**0.03**	71.5	**12.6**	90
	PTM	S '10	PP	50	58.7	**-0.1**	0.95	**0.04**	67.7	**8.8**	86
	PTM	F '11	PP	50	57.3	**-1.4**	0.88	**-0.04**	58.5	**-0.4**	88
	SS	D '09	AP	50	70.5 *	**11.7**	0.96	**0.05**	75.5	**16.5**	96
	SS	D '09 + S '10	AP	50	62.3	**3.6**	0.91	**0.00**	59.4	**0.4**	94
	SS	D '09 + F '11	AP	50	63.1	**4.4**	0.91	**-0.01**	60.9	**2.0**	96
	SS	D '09	PP	50	69.4 *	**10.6**	0.97	**0.06**	81.7	**22.8**	94
	SS	D '09 + F '11	PP	50	67.1 *	**8.3**	0.89	**-0.02**	69.2	**10.3**	88
	SS	S '10	PP	50	53.4	**-5.4**	0.83	**-0.08**	46.4	**-12.5**	88
	SS	F '11	PP	50	61.4	**2.7**	0.95	**0.03**	65.5	**6.6**	100
	Check			50	58.7		0.91		58.9		90

PTM= fipronil; SS= SilvaShield, imidacloprid), D= December, S= September, F= February, AP= at plant, PP= post plant.

[a] Ground Line Diameter.

* Means followed by an asterisk are significantly different from checks at the 5% level based on Fisher's Protected LSD.

Table 15. Effect of PTM™ soil injection and SilvaShield™ tablet dose, timing and technique on loblolly pine growth on one site (Campbell Group nursery) in east Texas, 2011.

	Treatment				Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm3) Compared to Check)**						Mean Percent Tree
Year	Product	Season	Tech.	N	Height (cm)		Diameter (cm) [a]		Volume (cm^3)		Survival
2011	PTM	D '09	AP	47	115.0	**4.4**	2.30	**0.1**	796.6	**135**	94
	PTM	D '09 + S '10	AP	48	114.5	**3.9**	2.17	**0.0**	754.7	**93**	96
	PTM	D '09 + F '11	AP	48	110.4	**-0.2**	2.10	**-0.1**	715.1	**53**	96
	PTM	D '09	PP	42	102.0	**-8.6**	2.10	**-0.1**	601.7	**-60**	84
	PTM	D '09 + F '11	PP	43	112.1	**1.5**	2.10	**-0.1**	696.1	**35**	86
	PTM	S '10	PP	43	103.1	**-7.5**	2.00	**-0.2**	603.2	**-58**	84
	PTM	F '11	PP	42	113.0	**2.4**	2.15	**0.0**	741.6	**80**	86
	SS	D '09	AP	47	123.1	**12.5**	2.27	**0.1**	778.4	**117**	94
	SS	D '09 + S'10	AP	47	123.1	**12.5**	1.94	**-0.2**	520.9	**-141**	94
	SS	D '09 + F '11	AP	46	123.1	**12.5**	1.93	**-0.2**	516.6	**-145**	92
	SS	D '09	PP	46	121.4	**10.8**	2.29	**0.1**	854.2	**193**	92
	SS	D '09 + F '11	PP	44	118.4	**7.8**	2.20	**0.0**	782.9	**121**	88
	SS	S '10	PP	43	99.3	**-11.3**	1.68	**-0.5**	437.9	**-224**	86
	SS	F '11	PP	50	123.7	**13.1**	2.33	**0.2**	845.4	**184**	100
	Check			45	110.6		2.17		661.6		90

PTM= fipronil; SS= SilvaShield, imidacloprid), D= December, S= September, F= February, AP= at plant, PP= post plant.

[a] Ground Line Diameter.

* Means followed by an asterisk are significantly different from checks at the 5% level based on Fisher's Protected LSD.

Table 16. Effect of PTM™ soil injection and SilvaShield™ Tablet dose, timing, and technique on loblolly pine growth (diameter measured at ground level [GLD]) on one site (Campbell Group nursery) in east Texas, 2012.

	Treatment				Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm³) Compared to Check)**							
Year	Product	Season	Tech.	N	Height (cm)			GLD (cm)			Volume (cm^3)	
2012	PTM	D '09	AP	47	282.7		**21.7**	5.85		**0.4**	10760.8	**2093**
	PTM	D '09 + S '10	AP	48	281.33	*	**20.3**	5.794		**0.3**	11727.1	**3060**
	PTM	D '09 +F '11	AP	48	290.84		**29.8**	5.80		**0.4**	10895.6	**2228**
	PTM	D '09	PP	42	258.3		**-2.8**	5.20	*	**-0.3**	8200.4	**-467**
	PTM	D '09 + F '11	PP	43	278.5		**17.5**	5.37		**-0.1**	9440.2	**773**
	PTM	S '10	PP	42	284.5		**23.5**	5.73		**0.3**	10945.0	**2278**
	PTM	F '11	PP	43	258.2		**-2.9**	5.12		**-0.3**	8392.0	**-276**
	SS	D '09	AP	47	288.5	*	**27.4**	5.45		**0.0**	9289.0	**621**
	SS	D '09 + S'10	AP	46	289.9	*	**28.8**	5.45		**0.0**	9408.7	**741**
	SS	D '09 +F '11	AP	46	275.7		**14.6**	5.14		**-0.3**	8194.0	**-473**
	SS	D '09	PP	46	286.1	*	**25.1**	5.60		**0.2**	9959.9	**1292**
	SS	D '09 + F '11	PP	44	283.1		**22.0**	5.51		**0.1**	9778.1	**1111**
	SS	S '10	PP	43	254.3		**-6.8**	4.65	*	**-0.8**	6676.8	**-1991**
	SS	F '11	PP	50	287.0	*	**26.0**	5.80		**0.4**	10753.9	**2086**
	Check			45	261.1			5.45			8667.5	

* Means followed by an asterisk are significantly different from checks at the 5% level based on Fisher's Protected LSD.

Table 17. Effect of PTM™ soil injection and SilvaShield™ Tablet dose, timing, and technique on loblolly pine growth (diameter measured at breast height [DBH]) on one site (Campbell Group nursery) in east Texas, 2012.

	Treatment				Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm³) Compared to Check)**								
Year	Product	Season	Tech.	N	Height (cm)			DBH (cm)			Volume (cm³)		
2012	PTM	D '09	AP	47	282.7		**21.7**	5.85		**0.4**	3395.3		**835**
	PTM	D '09 + S '10	AP	48	281.333	*	**20.3**	5.79		**0.3**	3787.4		**1227**
	PTM	D '09 +F '11	AP	48	290.84		**29.8**	5.80	*	**0.4**	3795.8		**1236**
	PTM	D '09	PP	42	258.3		**-2.8**	5.20		**-0.3**	2483.2		**-77**
	PTM	D '09 + F '11	PP	43	278.5		**17.5**	5.37		**-0.1**	3083.3		**523**
	PTM	S '10	PP	42	284.5		**23.5**	5.73	*	**0.3**	3963.9		**1404**
	PTM	F '11	PP	43	258.2		**-2.9**	5.12		**-0.3**	2426.0		**-134**
	SS	D '09	AP	47	288.5	*	**27.4**	5.45	*	**0.0**	3271.9		**712**
	SS	D '09 + S'10	AP	46	289.9	*	**28.8**	5.45		**0.0**	3064.8		**505**
	SS	D '09 +F '11	AP	46	275.7		**14.6**	5.14		**-0.3**	2446.2		**-114**
	SS	D '09	PP	46	286.1	*	**25.1**	5.60		**0.2**	3375.4		**815**
	SS	D '09 + F '11	PP	44	283.1		**22.0**	5.51		**0.1**	3674.9		**1115**
	SS	S '10	PP	43	254.3		**-6.8**	4.65		**-0.8**	2257.8		**-302**
	SS	F '11	PP	50	287.0	*	**26.0**	5.80	*	**0.4**	3556.8		**997**
	Check			45	261.1			5.45			2559.9		

* Means followed by an asterisk are significantly different from checks at the 5% level based on Fisher's Protected LSD.

Table 18. Effect of PTM™ soil injection and SilvaShield™ Tablet dose, timing, and technique on loblolly pine growth (diameter measured at breast height [DBH]) on one site (Campbell Group nursery) in east Texas, 2013.

	Treatment				Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm³) Compared to Check**)								
Year	Product	Season	Tech.	N	Height (cm)			DBH (cm)			Volume (cm³)		
2013 4th YR	PTM	D '09	AP	47	461.3	*	**29.2**	6.66		**0.3**	21,976.06		**3231**
	PTM	D '09 + S '10	AP	48	462.1	*	**30.0**	6.79		**0.5**	24,693.41	*	**5948**
	PTM	D '09 +F '11	AP	48	475.4	*	**43.3**	6.95	*	**0.6**	24,970.74	*	**6226**
	PTM	D '09	PP	43	430.7		**-1.4**	6.00		**0.3**	17,338.57		**-1406**
	PTM	D '09 + F '11	PP	43	445.5		**13.4**	6.31		**0.0**	19,768.15		**1023**
	PTM	S '10	PP	42	471.5	*	**39.4**	6.06		**-0.3**	25,282.59	*	**6538**
	PTM	F '11	PP	42	429.3		**-2.8**	6.93		**0.6**	18,258.59		**-486**
	SS	D '09	AP	47	467.2	*	**35.1**	6.78		**0.5**	22,850.26		**4105**
	SS	D '09 + S'10	AP	47	464.2	*	**32.1**	6.82		**0.5**	22,989.66		**4245**
	SS	D '09 +F '11	AP	46	453.5		**21.4**	6.32		**0.0**	19,139.11		**394**
	SS	D '09	PP	46	462.4	*	**30.3**	6.88		**0.6**	23,302.44		**4557**
	SS	D '09 + F '11	PP	44	459.4	*	**27.3**	6.63		**0.3**	22,450.83		**3706**
	SS	S '10	PP	43	427.0		**-5.1**	6.05		**-0.3**	18,345.79		**-399**
	SS	F '11	PP	50	471.7	*	**39.6**	6.99	*	**0.7**	25,028.44	*	**6283**
	Check			44	432.1			6.33			18,745.03		

* Means followed by an asterisk are significantly different from checks at the 5% level based on Fisher's Protected LSD.

Table 19. Effect of PTM™ soil injection and SilvaShield™ Tablet dose, timing, and technique on loblolly pine growth (diameter measured at breast height [DBH]) on one site (Campbell Group nursery) in east Texas, 2015.

	Treatment				Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm³) Compared to Check)**						
Year	Product	Season	Tech.	N	Height (cm)			DBH (cm)		Volume (cm³)	
2015 6th YR	PTM	D '09	AP	46	832.76		**0.74**	12.81	**0.46**	140,734.82	**9137.54**
	PTM	D '09 + S '10	AP	48	841.71		**9.69**	12.96	**0.61**	147,784.53	**16187.25**
	PTM	D '09 +F '11	AP	48	868.56	*	**36.54**	12.79	**0.44**	147,415.11	**15817.83**
	PTM	D '09	PP	43	818.05		**-13.97**	11.82	**-0.53**	119,169.00	**-12428.28**
	PTM	D '09 + F '11	PP	44	836.61		**4.59**	12.12	**-0.23**	129,063.94	**-2533.34**
	PTM	S '10	PP	43	838.95		**6.93**	12.63	**0.28**	141,531.18	**9933.90**
	PTM	F '11	PP	42	821.91		**-10.11**	12.10	**-0.25**	127,232.60	**-4364.68**
	SS	D '09	AP	47	838.85		**6.83**	12.31	**-0.04**	132,273.60	**676.32**
	SS	D '09 + S'10	AP	47	845.81		**13.79**	12.60	**0.25**	136,723.09	**5125.81**
	SS	D '09 +F '11	AP	46	841.30		**9.28**	12.22	**-0.13**	128,332.48	**-3264.80**
	SS	D '09	PP	47	846.64		**14.62**	12.86	**0.51**	143,340.10	**11742.82**
	SS	D '09 + F '11	PP	44	820.66		**-11.36**	12.38	**0.03**	130,245.90	**-1351.38**
	SS	S '10	PP	45	809.73		**-22.29**	11.95	**-0.4**	123,361.68	**-8235.60**
	SS	F '11	PP	50	838.38		**6.36**	12.88	**0.53**	142,626.69	**11029.41**
	Check			43	832.02			12.35		131,597.28	

* Means followed by an asterisk are significantly different from checks at the 5% level Fisher's Protected LSD.

PINE TIP MOTH TRIALS: EVALUATION OF PTM™ TREATMENTS FOR CONTAINERIZED PINE SEEDLINGS

Initiated in 2011; Final growth measurements in December 2015

Objectives

1. Evaluate techniques for application of PTM™ (fipronil) to containerized seedlings in the nursery or planting site
2. Evaluate efficacy of PTM™ (fipronil) applied to containerized and bareroot seedlings for reducing pine tip moth infestation levels
3. Determine the duration of chemical activity

Methods

One family of loblolly pine containerized seedlings was selected by Cellfor

Treatments:

1. PTM™: High concentration/ undiluted plug injection [5.6mL PTM undiluted/ seedling (110 TPA rate)]: Injection into container seedling plug just prior to shipping
2. PTM™: High concentration/ diluted soil injection [5.6mL PTM in 9.4mL water (15mL total volume)/seedling]: Soil injection next to transplanted container plug just after planting
3. PTM™: High concentration/ diluted soil injection [5.6mL PTM in 9.4mL water (15mL total volume)/ seedling]: Soil injection next to transplanted bareroot just after planting
4. PTM™: Mid-concentration/ undiluted plug injection [1.4mL PTM undiluted/ seedling (435 TPA rate)]: Injection into container seedling plug just prior to shipping
5. PTM™: Mid-Concentration/ diluted plug injection [1.4mL PTM in 1.7mL water (3mL total volume)/seedling]: Injection into container seedling plug just prior to shipping
6. PTM™: Mid-concentration/ diluted soil injection [1.4mL PTM in 13.6mL water (15mL total volume)/seedling]: Soil injection next to transplanted container plug just after planting
7. PTM™: Mid-concentration/ diluted soil injection [1.4mL PTM in 13.6mL water (15mL total volume)/seedling]: (Standard 1) Soil injection next to transplanted bareroot just after planting.
8. PTM™: Low-concentration/undiluted plug injection [1mL PTM undiluted/seedling (600 TPA rate)]: Injection into container seedling plug just prior to shipping
9. PTM™: Low-concentration/ diluted plug injection [1mL PTM in 2mL water (3mL total volume/seedling)]: Injection into container seedling plug just prior to shipping
10. PTM™: Low-concentration/ diluted soil injection [1mL PTM in 14mL water (15mL total volume)/seedling]: Soil injection next to transplanted container plug just after planting
11. PTM™: Low-concentration/diluted soil injection [1mL PTM in 14mL water (15mL total volume)/seedling]: (Standard 2) Soil injection next to transplanted bareroot just after planting
12. Containerized Control (untreated)
13. Bareroot Control (untreated)

Containerized seedlings were individually treated using a small syringe on site just prior to planting. The seedlings were treated at different rates based on the restricted rate of 59g AI/acre/year and the number of trees planted per acre (TPA). At 110 TPA = 0.537g AI/seedling (a rate being considered by some forest industries for treatment of high-valued "crop" trees); at 435 TPA = 0.136g AI/seedling (a tree density currently being used by Weyerhaeuser Co.); and 600 TPA = 0.1g AI/seedling (a tree density used by several forest industries).

Ten recently harvested tracts were selected in fall 2010 across the southeastern U.S. (TX, LA, AR, MS, GA, FL, and NC) based on uniformity of soil, drainage, and topography.

- TX: Rayonier (Leach), Weyerhaeuser (Fontenot), Hancock (Bounds)
- LA: Campbell Group (Stansfield)
- AR: ArborGen (Bryant)
- MS: Cellfor (Muir)
- GA: Rayonier (Wilson, Petre)
- FL: Rayonier (Wilson, Petre)
- NC: NC Forest Service (West), Weyerhaeuser (Edwards)

All study sites had been intensively site prepared, i.e., subsoil, bedding and/or herbicide. A 1-acre (approximate) area within each site was selected. A triple Latin square design was established with single tree plots (13 rows X 13 treatments) serving as blocks, i.e., each treatment was randomly selected for placement along each row (bed). Thirty-nine (39) rows were established on each site. Seedlings were planted at 8-foot spacing along each row. Individual tree locations were marked with different colored pin flags prior to tree planting. Herbicide to control broadleaf competitors was applied over the area in the spring to ensure that the seedlings remained exposed to tip moth attack throughout the year.

Damage and Tree Measurements

Tip moth damage was evaluated after each tip moth generation (3-4 weeks after peak moth flight) by 1). Identifying if the tree is infested or not, 2). If infested, the proportion of tips infested on the top whorl and terminal was/will be calculated; and 3). Separately, the terminal was identified as infested or not. Observations also were be made as to the occurrence and extent of damage caused by other insects, i.e., coneworm, aphids, sawfly, etc. All study trees were measured for height & diameter (at ground level) at the beginning of the study (when seedlings were planted). Measurements also were be taken when tree growth has stopped in mid- to late November for at least the first 2 years of the study. Tree form will be evaluated at the end of year 3. Form ranking of the seedling or tree will be categorized as follows: 0 = no forks; 1 = one fork; 2 = two to four forks; 3 = five or more forks. A fork is defined as a node with one or more laterals larger than one half the diameter of the main stem (Berisford and Kulman 1967).

Results:

In 2011, tip moth populations were variable across the South; with relatively low damage levels on checks in TX (5% on container & 11% on bareroot) to ~30% on all seedlings in GA (Figure 12, Table 20). PTM injected into container seedling plugs before planting reduced overall tip moth damage by 92% compared to untreated checks. This was 4% and 13% better than protection provided by PTM applied to container and bareroot seedlings, respectively, after planting (Figure 13). Nearly all PTM treatments (9 of 11) significantly improved height, diameter, and volume of seedlings, compared to the check (Table 21). Mean volume improvement for plugs treated prior to planting was 42% compared to checks. This was 12% higher than volume increase observed on post-plant treated seedlings. In addition, most PTM treatments (8 of 11) significantly improved survival compared to untreated checks. Mean survival of pre-plant treated seedlings was 6.7% better than checks. This was double the improvement (3.4%) in survival observed on post-plant treated seedlings.

In 2012, tip moth populations were again variable, with low damage levels on checks in FL (5% on container & 10% on bareroot) to 58% on bareroot seedlings in LA (Figure 14, Table 22). PTM applied to containers after planting reduced overall tip moth damage by 43% compared to untreated checks. This was only 5% and 7% better than protection provided by PTM injected into container seedling plugs before planting and PTM applied to bareroot seedlings after planting, respectively (Figure 15). Almost all PTM treatments significantly improved height, diameter, and volume (Table 23). Only the containerized high-dilution and bareroot high-dilution treatments applied to the soil after planting did not show significant improvement in diameter growth. The bareroot high dilution treatment applied to the soil after planting did not show significant improvement in volume either (Table 23). Mean volume improvement for plugs treated prior to planting was increased by 39% compared to checks. This was 16% higher than volume increase observed on post-plant treated seedlings. None of the PTM treatments significantly improved survival compared to untreated checks. Mean survival of pre-plant treated seedlings was 9.2% better than checks, and that of post-plant treated seedlings; 5.2%.

In 2013, only tree growth was measured. All treatments resulted in significant growth increases compared to the controls except treatments **3** (Bareroot; high concentration, dilute, soil injection) and **10** (Containerized; low concentration, dilute, soil injection) (Table 24). Mean percent improvement in volume compared to the control for containerized, plug injected treatments was 31%, for containerized soil injected treatments; 25%, and for bareroot treatments; 38%. No measurements were taken in 2014.

The study trees were remeasured for growth for the final time at the end of the 2015 growing season. Results after 5 years show significant increases ($P<0.05$) in containerized seedling diameter and volume growth (but not height) for all plug injection treatments and one soil treatment (medium dilution of PTM).For bare root seedlings, significant increases in diameter and volume growth were exhibited by only the low dilution rate of PTM (Table 25)

Acknowledgments

Thanks go to Arborgen, The Campbell Group, Hancock, NC Forest Service, Rayonier, and Weyerhaeuser for providing research sites and Cellfor and Plum Creek for providing seedlings. We also thank Jim Bean, BASF, for providing financial support and PTM^{TM} product for the project.

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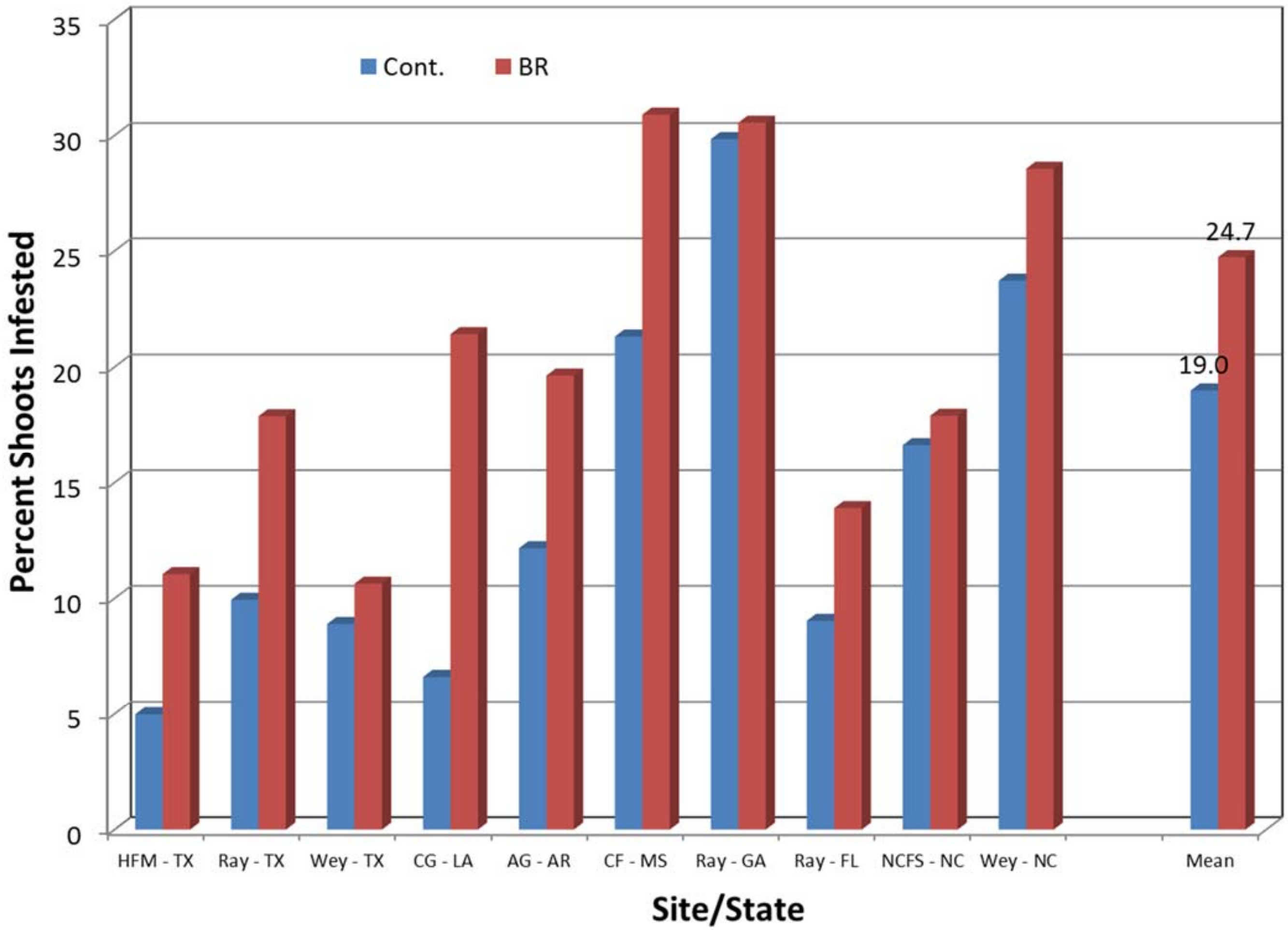


Figure 12. Mean tip moth infestation levels on first year containerized and bareroot loblolly pine on ten sites across the southeastern United States, 2011.

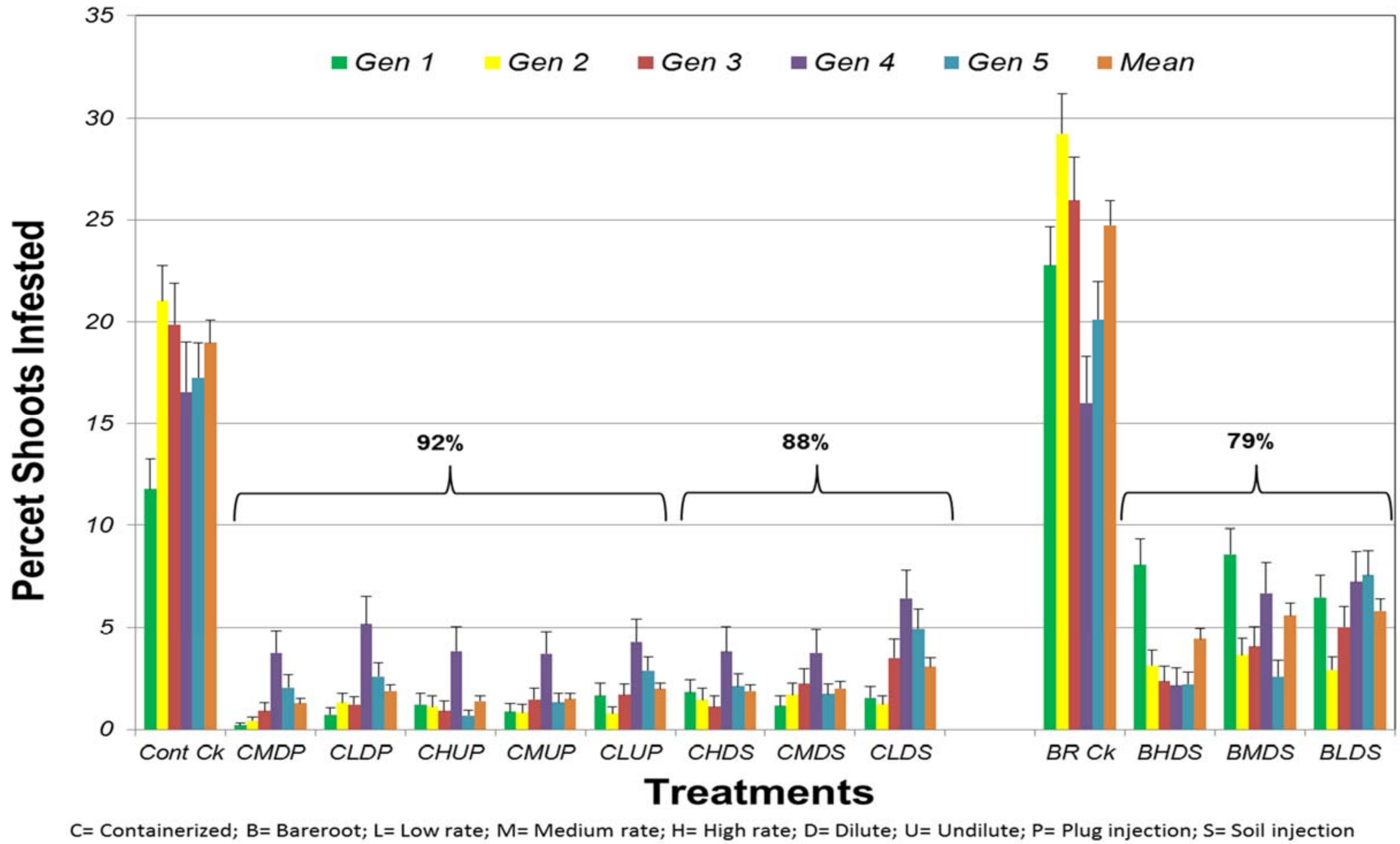


Figure 13. Effect of PTM™ plug and soil injection dose on tip moth infestation of containerized or bareroot loblolly pine on ten sites across the southeastern United States, 2011.

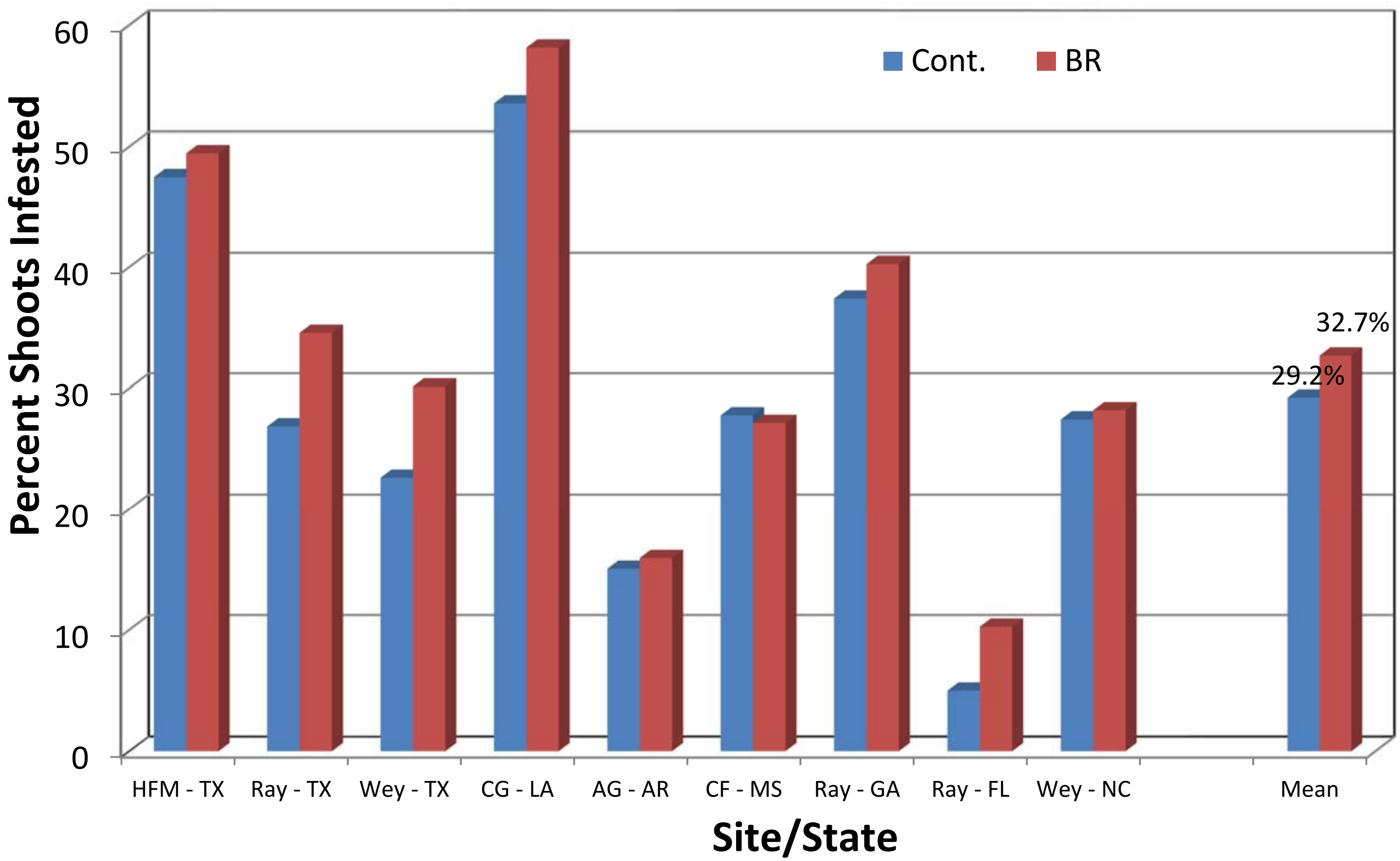


Figure 14. Mean tip moth infestation levels on first year containerized and bareroot loblolly pine on ten sites across the southeastern United States, 2012.

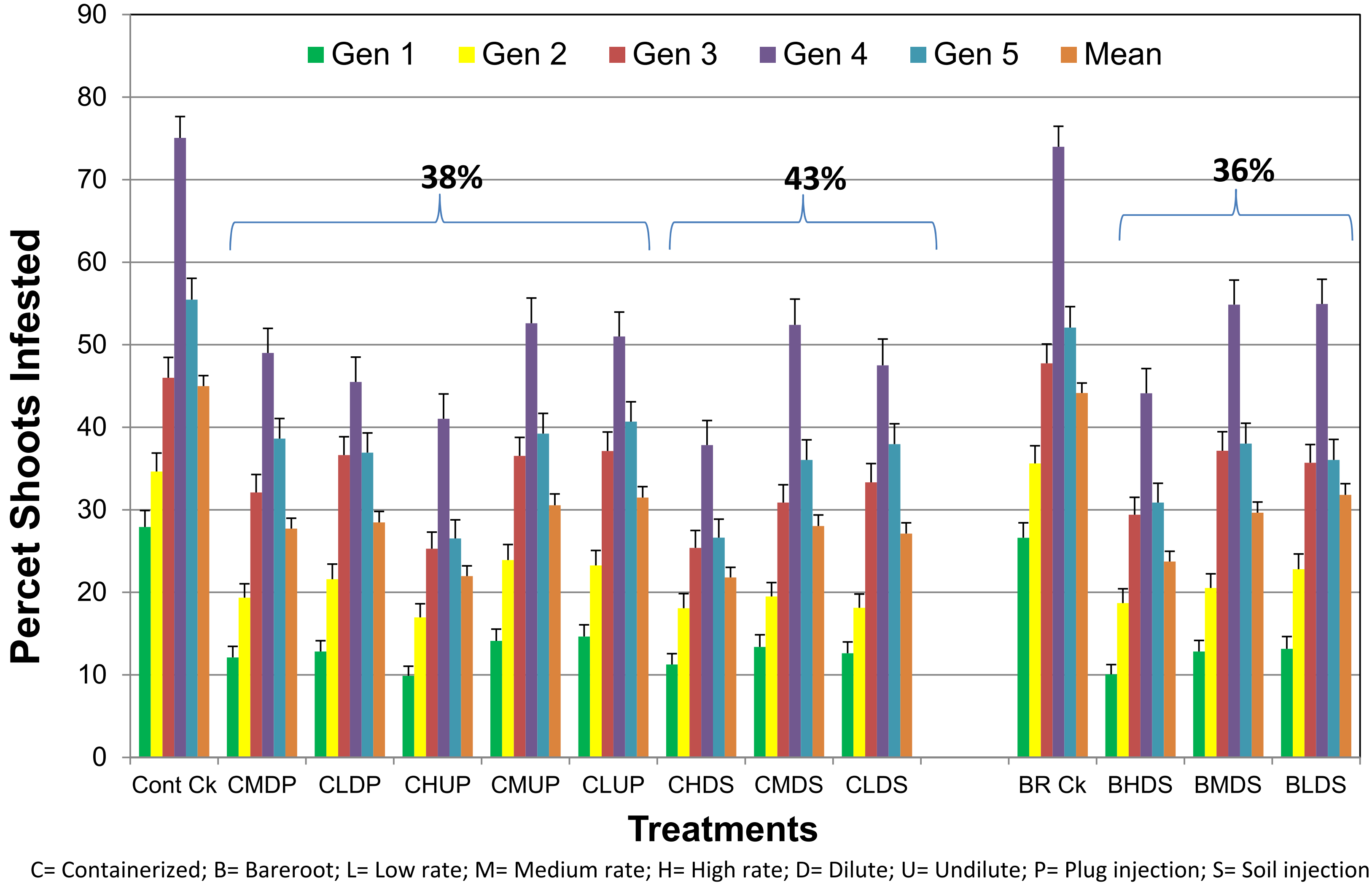


Figure 15. Effect of PTM™ plug and soil injection dose on tip moth infestation of containerized or bareroot loblolly pine on ten sites across the southeastern United States, 2012.

Table 20. Effect of PTM dose and technique on pine tip moth infestation of containerized and bareroot loblolly pine shoots (top whorl) on ten sites across the sotheastern United States, 2011.

	Treatment					Mean Percent Top Whorl Shoots Infested by Tip Moth																	
Year	Cont. or BR	Conc.	Dilute or Undilute	Inj. Loc.	N	Gen 1 (10 sites)			Gen 2 (10 Sites)			Gen 3 (8 Sites)			Gen 4 (6 Sites)			Gen 5 or Last (10 Sites)			Overall Mean		
2011	Cont.	Med	Dilute	Plug	390	0.2	**98**	*	0.4	**98**	*	0.9	**95**	*	3.8	**77**	*	2.1	**88**	*	1.3	**93**	*
	Cont.	Low	Dilute	Plug	390	0.7	**94**	*	1.3	**94**	*	1.2	**94**	*	5.2	**69**	*	2.6	**85**	*	1.9	**90**	*
	Cont.	High	Undilute	Plug	390	1.2	**89**	*	1.1	**95**	*	0.9	**95**	*	3.8	**77**	*	0.7	**96**	*	1.4	**93**	*
	Cont.	Med	Undilute	Plug	390	1.3	**89**	*	0.8	**96**	*	1.5	**93**	*	3.7	**78**	*	1.3	**92**	*	1.5	**92**	*
	Cont.	Low	Undilute	Plug	390	1.6	**86**	*	0.8	**96**	*	1.7	**92**	*	4.3	**74**	*	2.9	**83**	*	2.0	**90**	*
	Cont.	High	Dilute	Soil	390	1.8	**84**	*	1.5	**93**	*	1.1	**94**	*	3.8	**77**	*	2.1	**88**	*	1.9	**90**	*
	Cont.	Med	Dilute	Soil	390	1.2	**90**	*	1.7	**92**	*	2.2	**89**	*	3.8	**77**	*	1.7	**90**	*	2.0	**89**	*
	Cont.	Low	Dilute	Soil	390	1.6	**87**	*	1.2	**94**	*	3.5	**83**	*	6.4	**61**	*	5.0	**71**	*	3.0	**84**	*
	Cont.				390	11.6			21.1			19.9			16.5			17.3			19.0		
	BR	High	Dilute	Soil	390	8.5	**63**	*	2.9	**90**	*	2.4	**91**	*	2.2	**87**	*	2.2	**89**	*	4.4	**82**	*
	BR	Med	Dilute	Soil	390	8.6	**63**	*	3.6	**87**	*	4.0	**84**	*	6.7	**58**	*	3.3	**84**	*	5.6	**77**	*
	BR	Low	Dilute	Soil	390	6.5	**72**	*	3.0	**90**	*	5.0	**81**	*	7.2	**55**	*	7.6	**62**	*	5.8	**76**	*
	BR				390	22.8			29.0			25.9			16.0			20.1			24.7		

* Means followed by an asterik are significantly different from checks at the 5% level based on Fisher's Protected LSD.

= treatment reduced damage by 75% or better compared to check.

Table 21. Effect of PTM dose and technique on containerized and bareroot loblolly pine growth on ten sites across the southeastern United States, 2011.

	Treatment					Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm3) Compared to Check)**						Mean Percent Tree Survival (**Percent Improvement Compared to Check**)	
Year	Cont. or BR	Conc.	Dilute or Undilute	Inj. Loc.	N	Height (cm)		Diameter (cm) [a]		Volume (cm^3)			
2011	Cont.	Med	Dilute	Plug	369	52.2 *	**7.0**	1.04 *	**0.12**	91.9 *	**28.2**	94 *	**7**
	Cont.	Low	Dilute	Plug	367	50.7 *	**5.5**	1.00 *	**0.09**	88.6 *	**24.9**	94 *	**6**
	Cont.	High	Undilute	Plug	371	50.0 *	**4.8**	0.98 *	**0.07**	86.1 *	**22.4**	95 *	**7**
	Cont.	Med	Undilute	Plug	360	52.8 *	**7.6**	1.03 *	**0.12**	95.5 *	**31.8**	92 *	**5**
	Cont.	Low	Undilute	Plug	374	51.9 *	**6.7**	1.02 *	**0.11**	91.7 *	**28.0**	96 *	**8**
	Cont.	High	Dilute	Soil	356	47.3	**2.1**	0.95	**0.03**	77.9	**14.2**	91 *	**4**
	Cont.	Med	Dilute	Soil	352	49.6 *	**4.4**	0.98 *	**0.07**	83.5 *	**19.8**	90	**2**
	Cont.	Low	Dilute	Soil	353	49.8 *	**4.6**	0.98 *	**0.06**	87.6 *	**23.9**	91	**3**
	Cont.				342	45.2		0.91		63.7		88	
	BR	High	Dilute	Soil	362	53.6	**3.2**	1.01	**0.04**	95.7	**24.1**	93	**3**
	BR	Med	Dilute	Soil	371	57.2 *	**6.8**	1.07 *	**0.10**	112.1 *	**40.4**	96 *	**5**
	BR	Low	Dilute	Soil	367	58.2 *	**7.8**	1.08 *	**0.11**	118.4 *	**46.7**	94 *	**4**
	BR				352	50.4		0.97		71.7		90	

[a] Ground Line Diameter.

* Means followed by an asterisk are significantly different from checks at the 5% level based on Fisher's Protected LSD.

Table 22. Effect of PTM dose and technique on pine tip moth infestation of containerized and bareroot loblolly pine shoots (top whorl) on nine sites across the southeastern United States, 2012 (Est. 2011).

	Treatment					Mean Percent Top Whorl Shoots Infested by Tip Moth (**Pct. Reduction Compared to Check**)																	
Year	Cont. or BR	Conc.	or Undilute	Inj. Loc.	N	Gen 1 (10 sites)			Gen 2 (9 Sites)			Gen 3 (8 Sites)			Gen 4 (6 Sites)			Gen 5 or Last (9 Sites)			Overall Mean		
2012	Cont.	Med	Dilute	Plug	390	12.0	**57**	*	19.4	**44**	*	32.1	**30**	*	49.0	**35**	*	38.6	**30**	*	27.7	**38**	*
	Cont.	Low	Dilute	Plug	390	12.5	**55**	*	21.6	**38**	*	36.6	**20**	*	45.5	**39**	*	36.9	**33**	*	28.5	**37**	*
	Cont.	High	Undilute	Plug	390	10.4	**62**	*	17.0	**51**	*	25.3	**45**	*	41.0	**45**	*	26.5	**52**	*	22.0	**51**	*
	Cont.	Med	Undilute	Plug	390	14.2	**49**	*	23.9	**31**	*	36.5	**21**	*	52.6	**30**	*	39.2	**29**	*	30.6	**32**	*
	Cont.	Low	Undilute	Plug	390	11.0	**60**	*	23.3	**33**	*	39.1	**15**	*	51.0	**32**	*	40.7	**27**	*	31.5	**30**	*
	Cont.	High	Dilute	Soil	390	11.0	**60**	*	18.0	**48**	*	25.4	**45**	*	37.8	**50**	*	26.6	**52**	*	21.8	**52**	*
	Cont.	Med	Dilute	Soil	390	13.8	**50**	*	19.4	**44**	*	30.9	**33**	*	52.4	**30**	*	36.0	**35**	*	28.0	**38**	*
	Cont.	Low	Dilute	Soil	390	13.6	**51**	*	18.1	**48**	*	33.3	**28**	*	47.5	**37**	*	38.0	**32**	*	27.1	**40**	*
	Cont.				390	27.7			34.7			46.0			75.1			55.5			45.0		
	BR	High	Dilute	Soil	390	10.0	**61**	*	18.7	**48**	*	29.4	**38**	*	44.1	**40**	*	30.9	**41**	*	23.7	**46**	*
	BR	Med	Dilute	Soil	390	13.5	**48**	*	20.5	**42**	*	37.2	**22**	*	54.8	**26**	*	38.0	**27**	*	29.7	**33**	*
	BR	Low	Dilute	Soil	390	16.2	**37**	*	22.8	**36**	*	35.7	**25**	*	54.9	**26**	*	41.4	**21**	*	31.8	**28**	*
	BR				390	25.9			35.6			47.7			74.0			52.1			44.2		

* Means followed by an asterisk are significantly different from checks at the 5% level based on Fisher's Protected LSD.

= treatment reduced damage by 75% or better compared to check.

Table 23. Effect of PTM dose and technique on containerized and bareroot loblolly pine growth on nine sites across the southeastern United States, 2012 (Est 2011). GLD = ground line diameter

	Treatment					Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm3) Compared to Check)**										Mean Percent Tree Survival (**Percent Improvement Compared to Check**)	
Year	Cont. or BR	Conc.	Dilute or Undilute	Inj. Loc.	N	Height (cm)			GLD (cm)			Volume (cm^3)					
2012	Cont.	Med	Dilute	Plug	327	128.3	*	**19.8**	2.96	*	**0.44**	1882.9		**544.0**	*	93	**9**
	Cont.	Low	Dilute	Plug	327	125.0	*	**16.5**	2.86	*	**0.34**	1843.3		**504.4**	*	93	**9**
	Cont.	High	Undilute	Plug	326	127.7	*	**19.3**	2.88	*	**0.36**	1884.0		**545.1**	*	93	**9**
	Cont.	Med	Undilute	Plug	321	127.6	*	**19.1**	2.95	*	**0.43**	2015.4		**676.5**	*	91	**7**
	Cont.	Low	Undilute	Plug	335	124.3	*	**15.8**	2.84	*	**0.32**	1694.9		**355.9**	*	95	**11**
	Cont.	High	Dilute	Soil	314	117.7	*	**9.2**	2.70		**0.18**	1634.6		**295.6**	*	89	**5**
	Cont.	Med	Dilute	Soil	311	120.8	*	**12.3**	2.70	*	**0.18**	1631.4		**292.4**	*	89	**5**
	Cont.	Low	Dilute	Soil	309	119.7	*	**11.2**	2.71	*	**0.19**	1669.3		**330.3**	*	88	**4**
	Cont.				295	108.5			2.52			1339.0				84	
	BR	High	Dilute	Soil	321	129.3	*	**7.9**	2.86		**0.12**	1882.9		**261.0**		91	**4**
	BR	Med	Dilute	Soil	327	136.4	*	**15.0**	3.05	*	**0.31**	2266.5	*	**644.6**	*	93	**6**
	BR	Low	Dilute	Soil	330	136.6	*	**15.2**	3.06	*	**0.32**	2246.8	*	**624.9**	*	94	**7**
	BR				306	121.4			2.74			1621.9				87	

* Means followed by an asterisk are significantly different from checks at the 5% level based on Fisher's Protected LSD.

Table 24. Effect of PTM dose and technique on containerized and bareroot loblolly pine growth on six (6) sites across the southeastern United States, 2013 (Est 2011). GLD = ground line diameter

	Treatment					Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm3) Compared to Check)**									Mean Percent Tree Survival (**Percent Improvement Compared to Check**)	
Year	Cont. or BR	Conc.	Dilute or Undilute	Inj. Loc.	N	Height (cm)			GLD (cm)			Volume (cm^3)				
2013	Cont.	Med	Dilute	Plug	216	238.6	*	**29.0**	4.92	*	**0.61**	7278.8	*	**1562.1**	62	**8**
3rd Yr	Cont.	Low	Dilute	Plug	215	235.9	*	**26.3**	4.84	*	**0.53**	7350.0	*	**1633.4**	61	**7**
	Cont.	High	Undilute	Plug	212	240.4	*	**30.8**	4.97	*	**0.66**	7858.9	*	**2142.3**	60	**7**
	Cont.	Med	Undilute	Plug	208	239.7	*	**30.1**	5.00	*	**0.69**	7997.7	*	**2281.1**	59	**5**
	Cont.	Low	Undilute	Plug	223	232.4	*	**22.8**	4.82	*	**0.51**	6944.8	*	**1228.2**	64	**10**
	Cont.	High	Dilute	Soil	206	229.6	*	**20.0**	4.73	*	**0.42**	7153.8	*	**1437.2**	59	**5**
	Cont.	Med	Dilute	Soil	200	229.8	*	**20.2**	4.76	*	**0.45**	7206.5	*	**1489.9**	57	**3**
	Cont.	Low	Dilute	Soil	201	222.4		**12.8**	4.60		**0.29**	7027.9		**1311.2**	57	**3**
	Cont.				189	209.6			4.31			5716.6			54	
	BR	High	Dilute	Soil	208	245.1		**16.3**	4.94		**0.30**	8011.3		**1552.3**	59	**4**
	BR	Med	Dilute	Soil	212	253.1	*	**24.3**	5.20	*	**0.56**	9180.4	*	**2721.3**	60	**5**
	BR	Low	Dilute	Soil	211	256.2	*	**27.4**	5.22	*	**0.58**	9428.8	*	**2969.8**	60	**5**
	BR				194	228.8			4.64			6459.0			55	

Table 25. Effect of PTM dose and technique on containerized and bareroot loblolly pine growth on six (6) sites across the southeastern United States, 2015 (Est 2011). DBH = diameter breast height

	Treatment					Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm3) Compared to Check)**								Mean Percent Tree Survival (**Percent Improvement Compared to Check**)	
Year	Cont. or BR	Conc.	Dilute or Undilute	Inj. Loc.	N	Height (cm)		DBH (cm)			Volume (cm^3)				
2015	Cont.	Med	Dilute	Plug	243	550.0	**42**	8.50	*	**1.02**	46160.5	*	**8378.2**	89	**10**
5th Yr	Cont.	Low	Dilute	Plug	246	543.6	**35.6**	8.34	*	**0.86**	46095.6	*	**8313.3**	90	**11**
	Cont.	High	Undilute	Plug	249	544.5	**36.5**	8.28	*	**0.80**	46795.6	*	**9013.3**	92	**13**
	Cont.	Med	Undilute	Plug	234	554.7	**46.7**	8.55	*	**1.07**	49116.2	*	**11333.9**	86	**7**
	Cont.	Low	Undilute	Plug	251	544.0	**36.0**	8.23	*	**0.75**	44548.1	*	**6765.8**	92	**13**
	Cont.	High	Dilute	Soil	232	527.5	**19.5**	7.97		**0.49**	42509.1		**4726.8**	85	**6**
	Cont.	Med	Dilute	Soil	223	537.0	**29.0**	8.15	*	**0.67**	44699.0	*	**6916.7**	82	**3**
	Cont.	Low	Dilute	Soil	246	536.1	**28.1**	7.66		**0.18**	42410.9		**4628.6**	90	**11**
	Cont.				215	508.0		7.48			37782.3			79	
	BR	High	Dilute	Soil	246	561.9	**5.9**	8.48		**0.14**	48512.1		**3643.5**	90	**5**
	BR	Med	Dilute	Soil	246	571.8	**15.8**	8.80		**0.46**	52462.0	*	**7593.4**	90	**5**
	BR	Low	Dilute	Soil	249	571.0	**15.0**	8.91	*	**0.57**	53575.2	*	**8706.6**	92	**7**
	BR				231	556.0		8.34			44868.6			85	

***** Means followed by an asterisk are significantly different from checks at the 5% level based on Fisher's Protected LSD.

PINE TIP MOTH TRIALS; EFFECTS OF COLD STORAGE TIME ON EFFICACY OF FIPRONIL INJECTION TREATMENTS ON CONTAINERIZED LOBLOLLY PINE SEEDLINGS

Initiated in Winter 2012; Final growth measurements in 2017

Cooperators:
Wayne Bell, International Forest Company (No data received from GA)
Jim Bean, BASF, Research Triangle Park, NC

Objectives: 1) Evaluate the effects of cold storage times on containerized seedling survival and 2) efficacy of PTM (fipronil) for reducing pine tip moth infestation levels.

Justification:

Several trials (2003 - 2011) have shown that fipronil applied to bare root and containerized seedlings before or after planting is highly effective in reducing tip moth damage for 2+ years. EPA approved the registration and use of PTM insecticide for tip moth control only as a soil injection treatment at or post plant. Recently, a plug injection system was developed that would allow treatment of container seedlings in the nursery prior to shipment to the field. Container seedlings, once package in shipping boxes, are often stored temporarily in coolers. A trial will be established to determine if cold storage of PTM-treated seedlings will affect survival and/or treatment efficacy against tip moth.

Methods:
One family of loblolly pine bareroot seedlings will be selected (from IFCo).

Treatments**:**

A = PTM + Storage (4wk) - Injected with PTM (1.4 ml) and placed in cold storage 4 weeks prior to planting.
B = PTM + Storage (2 wk) - Injected with PTM (1.4 ml) and placed in cold storage 2 weeks prior to planting.
C = PTM + Storage (1 wk) – Injected with PTM (1.4 ml) and placed in cold storage 1 week prior to planting.
D = PTM only – Injected w PTM and no storage
E = Storage (4 wk) only – Seedlings placed in cold storage 4 weeks prior to planting
F = Storage (2 wk) only – Seedlings placed in cold storage 2 weeks prior to planting
G = Storage (1 wk) only – Seedlings placed in cold storage 1 week prior to planting
H = Check- no PTM & no storage

Note: If possible, Trt **A** seedlings (150 for each site; 300 total) should be treated first (Nov. 12) and Trt **A** & **E** seedlings placed in cold storage; Trt **B** seedlings would be treated on Nov. 26 and Trt **B** & **F** seedlings placed in cold storage; Trt **C** seedlings would be treated on Dec. 3 and Trts **C** & **G** seedlings placed in cold storage; and Trt **D** seedlings would be treated on Dec. 10 and Trt **A, B, C, E, F,** and **G** seedlings would be taken out of cold storage. All seedlings, including checks (**D** & **H**), could be planted on Dec. 10 or 11. The TX seedlings would be shipped immediately. Containerized seedlings will be individually treated at the IFCo nursery prior to planting using the plug injection system developed by

Stewart Boots, S&K Designs. The seedlings will be treated with PTM™ at 1.4 ml per seedling (435 tpa) based on the restricted rate of 59 g AI/acre/year (PTM™).

Two recently harvested tracts will be selected; one in east Texas and one near Moultrie, GA (No growth data have been received from GA for this study for the end of the 2014 growing season.)
A 1 acre (approximate) area within each site will be selected. A quadruple Latin square design will be established with single tree plots (8 rows X 8 treatments) serving as blocks, i.e., each treatment will be randomly selected for placement along each row (bed). Thirty-two (32) rows will be established on each site. Seedlings will be planted at 8 foot spacing along each row. Individual tree locations will be marked with different color pin flags prior to tree planting.

The plot corners should be marked with PVC pipe and the individual trees with different color pin flags and tags. It may be necessary to apply herbicide over the area in the spring to ensure that the seedlings remain exposed to tip moth attack throughout the year.

Tip moth damage was evaluated by determining percent of trees infested, percent of infested shoots in the top whorl and percent terminals infested about 4 weeks after peak moth flight at each generation. All study trees were measured (height & diameter @ 6 inches) at the beginning of the study (just after seedlings were planted) and in mid- to late November after growth had stopped.

Results:

Standard least squares analysis was conducted on the tip moth infestation and growth data. Three effects were tested: 1. Treatment (PTM-treated or untreated), 2. Storage time, and 3. Treatment x Storage time (crossed). Treatment x Storage time combinations showed a significant effect on percent tip moth infestation in generations 2 and 3. PTM-treated seedlings were found to have significantly ($p < 0.0001$) decreased tip moth infestations compared with untreated seedlings in all four generations. Storage time only showed a significant difference in tip moth infestation among treatments in generation 2.

A Student's T test was conducted to determine how the treatment x storage time combinations differed. Although not significant, treatment A (PTM-treated/ 4 week storage time) resulted in lower percent tip moth infestation than the other treatment x storage combinations (Table 26). The greatest difference in percent tip moth infestation was found between PTM-treated and untreated seedlings. Very little difference in percent tip moth infestation was found among the storage time treatments.

After the first growing season, there was no significant difference in diameter or volume for any of the effects tested using standard least squares analysis. Height was significantly different for the PTM-treated vs. untreated trees ($p < 0.0001$). A student's T test was conducted on the treatment x storage combinations to determine how the treatments differed. Treatment B (PTM treated/ 2 week storage time) had the greatest growth increase compared with all other treatments, although

Square 1

row/column	1	2	3	4	5	6	7	8
A	B	A	G	H	C	F	E	D
B	G	H	C	F	D	A	B	E
C	A	E	B	C	F	H	D	G
D	D	C	F	G	E	B	H	A
E	C	F	D	A	H	E	G	B
F	F	D	H	E	B	G	A	C
G	E	B	A	D	G	C	F	H
H	H	G	E	B	A	D	C	F

Square 2

	1	2	3	4	5	6	7	8
A	G	E	C	H	B	D	F	A
B	H	F	E	D	A	B	G	C
C	E	G	H	B	D	A	C	F
D	F	A	D	G	C	H	B	E
E	B	C	G	A	H	F	E	D
F	A	D	B	C	F	E	H	G
G	C	B	A	F	E	G	D	H
H	D	H	F	E	G	C	A	B

Square 3

	1	2	3	4	5	6	7	8
A	A	B	C	D	H	E	G	F
B	D	F	H	C	B	A	E	G
C	F	A	B	E	G	H	C	D
D	H	E	G	A	F	D	B	C
E	B	H	E	G	C	F	D	A
F	G	C	D	H	A	B	F	E
G	C	D	A	F	E	G	H	B
H	E	G	F	B	D	C	A	H

Square 4

	1	2	3	4	5	6	7	8
A	B	A	G	C	D	E	H	F
B	H	F	A	D	E	B	C	G
C	G	B	C	A	F	D	E	H
D	A	G	E	F	H	C	D	B
E	F	D	B	E	C	H	G	A
F	E	H	D	G	B	A	F	C
G	C	E	F	H	A	G	B	E
H	D	C	H	B	G	F	A	D

A = PTM + 4 week storage
B = PTM + 2 week storage
C = PTM + 1 week storage
D = PTM only (no storage)
E = 4 week storage only
F = 2 week storage only
G = 1 week storage only
H = Check (untreated)

this was not significant (Table 27). At the end of the third growing season (2015), there were no significant differences in height, diameter, volume or growth among any of the treatments versus the check trees. (Table 28).

Conclusions:

First year and third year data show that storage time does not have an overall significant effect on percent tip moth infestation or seedling growth. Trees treated with PTM showed significantly reduced tip moth infestation in all generations in year one and also showed a significant increase in height growth compared with the untreated trees. In this study, after the third growing season, cold storage period or treatment with PTM insecticide had no long lasting effects on tree survival or growth. No further monitoring of trees in this study is planned.

Table 26. Mean percent top whorl shoots infested by tip moth per treatment in 2013 at two sites (GA & TX). Levels not connected by the same letter in each generation are significantly different**.**

				Mean Percent Top Whorl Shoots Infested by Tip Moth														
Year	Treatment	PTM Rate (ml)	Storage Period (weeks)	n	Gen 1 (GA & TX)		n	Gen 2 (GA only)		n	Gen 3 (GA only)		n	Gen 4 or Last (GA & TX)		n	Overall Mean	
	A	1.4 ml	4	64	1.26	**C**	32	0	**D**	32	0.78	**C**	53	0.79	**B**	64	0.71	**C**
2013	B	1.4 ml	2	64	0	**C**	32	2.34	**D**	32	1.04	**C**	57	4.3	**B**	64	2.34	**C**
YR1	C	1.4 ml	1	65	2.31	**C**	32	1.04	**D**	32	0	**C**	56	8.93	**B**	65	5.13	**C**
	D	1.4 ml	0	64	0.52	**C**	32	1.56	**D**	32	0	**C**	57	6.29	**B**	64	3.13	**C**
	E	None	4	61	32.70	**AB**	32	90.89	**A**	32	55.75	**B**	51	62.84	**A**	61	48.79	**A**
	F	None	2	62	21.42	**B**	32	78.59	**B**	32	58.92	**B**	50	59.91	**A**	62	40.12	**B**
	G	None	1	62	31.75	**B**	31	74.66	**B**	31	60.99	**B**	57	56.08	**A**	62	48.64	**A**
	H	None	0	63	31.93	**A**	32	63.49	**C**	32	79.22	**A**	58	63.98	**A**	63	49.03	**A**

Table 27. Mean height, diameter (GLD), volume, and growth (difference in volume from 2012-2013) of loblolly pine trees per treatment at two sites (GA & TX) in 2013. Means connected by the same letter are not significantly different (P>0.05)**.**

					Growth Measurements							
Year	Treatment	PTM Rate (ml)	Storage Period (weeks)	n	Height (cm)		GLD (cm)		Volume (cm^3)		Growth (cm^3)	
	A	1.4 ml	4	53	60.92	**A**	1.45	**A**	208.21	**AB**	183.42	**B**
2013	B	1.4 ml	2	57	61.39	**A**	1.77	**A**	587.77	**A**	567.42	**A**
YR 1	C	1.4 ml	1	56	59.66	**A**	1.45	**A**	206.7	**AB**	182.66	**B**
	D	1.4 ml	0	57	64.84	**A**	1.46	**A**	251.73	**AB**	229.05	**AB**
	E	None	4	51	50.90	**C**	1.51	**A**	188.86	**B**	162.94	**B**
	F	None	2	50	52.72	**BC**	1.58	**A**	259.63	**AB**	236.12	**AB**
	G	None	1	57	52.70	**BC**	1.54	**A**	241.43	**AB**	219.73	**AB**
	H	None	0	58	58.26	**AB**	1.43	**A**	180.36	**B**	146.76	**B**

Table 28. Mean height, diameter (GLD), volume, and growth (difference in volume from 2014-2015) of loblolly pine trees per treatment at Boyd Lake, Texas in 2015. Levels connected by the same letter are not significantly different (P>0.05)**.**

					Growth Measurements							
Year	Treatment	PTM Rate (ml)	Storage Period (weeks)	n	Height (cm)		GLD (cm)		Volume (cm^3)		Growth (cm^3)	
	A	1.4 ml	4	21	315.71	**A**	6.35	**A**	13682.31	**A**	12264.38	**A**
2015	B	1.4 ml	2	24	327.17	**A**	6.16	**A**	13548.66	**A**	12118.22	**A**
YR 3	C	1.4 ml	1	24	311.75	**A**	6.35	**A**	13833.59	**A**	12578.39	**A**
	D	1.4 ml	0	25	317.8	**A**	6.45	**A**	14161.91	**A**	12794.69	**A**
	E	None	4	18	295.94	**A**	5.86	**A**	10598.12	**A**	9596.61	**A**
	F	None	2	18	310.67	**A**	5.74	**A**	11376.5	**A**	10332.18	**A**
	G	None	1	26	325.5	**A**	6.35	**A**	13816.38	**A**	12521.56	**A**
	H	None	0	24	295.88	**A**	5.86	**A**	11154.44	**A**	10071.27	**A**

EFFICACY OF SIVANTO™AND XX-PIRE WG™FOR CONTROL OF SOUTHERN PINE CONE AND SEED INSECTS

Initiated in 2015; completed in 2016

Cooperator: Donald M. Grosman, Arborjet, Inc., Woburn, MA 01801

Abstract:

In the southeastern United States, pine seed orchards provide the commercial forestry industry with genetically improved seed needed for extensive annual plantation establishment. Cone and seed insects commonly destroy 50% of the potential seed crop and losses up to 90% are not uncommon. For this reason, effective pest management is an essential part of seed orchard management. Currently, the use of insecticides is the only known measure for effectively avoiding heavy seed losses. The purpose of this project is to assess two new insecticides Sivanto™ and XXpire WG™ for control of cone and seed insects in loblolly pine seed orchards. Although focusing on southeastern plantation management, this study is national in scope, as coneworms and seedbugs are also pests in northern California, the Pacific Northwest, and the Midwest.

Objective:

The objective of this study is to determine the efficacy of Sivanto™ and XXpire WG™ for control of southern cone and seed insects in pine seed orchards.

Background/Justification Statement:

In the southeastern United States, commercial forestry is based on plantation management with approximately 32 million acres in production, containing 23.9 billion ft^3 of timber, of which close to 1,000 ft^3 ac^{-1} yr^{-1} is composed of seedlings that are newly planted each year (Byram et al., 2003; Fox et al., 2004). Pine seed orchards provide the seed needed for annual plantation establishment. These seeds are genetically improved, with greater than fifty years of investment put into breeding and progeny testing (Byram et al., 2003). Cone and seed insects severely reduce potential yield in southern pine seed orchards that produce genetically-improved seed for regeneration programs. Cone and seed insects commonly destroy 50% of the potential seed crop and losses up to 90% are not uncommon (Fatzinger et al., 1980). For this reason, effective pest management is an essential part of seed orchard management (Byram et al., 2003).

Because economic thresholds are low and alternative non-insecticide based methods have yet to be proven effective, the use of insecticides is the only known measure for effectively avoiding heavy losses of seeds (Byram et al., 2003; Grosman et al., 2002). When choosing insecticides to evaluate, it is most productive to choose those that are effective on similar groups of insect pests. Two of the most important insect pest groups found in seed orchards include Lepidoptera (coneworms) and Hemiptera (seedbugs) (Grosman et al., 2002).

Screening insecticides that are already registered for other crops increases the likelihood of obtaining an additional registration for conifer seed orchards. Fortunately, the EPA classifies seed orchards as terrestrial nonfood crops rather than forest sites. This enables seed orchards to screen insecticides registered for crops such as cotton, rather than the just the few registered for forestry (Byram et al., 2003).

Bayer CropScience recently developed the insecticide Sivanto ™ (a.i. flupyradifurone) which Sivanto™ targets piercing-sucking insects (Hemiptera). It has been tested and found to control all life stages (eggs, nymphs and adults) of aphids, psyllids, soft scales, leaf hoppers, whiteflies, and thrips. Sivanto™ is considered “bee friendly”, has no spray restrictions, and can be applied to the soil or used as a foliar treatment.

Dow AgroSciences’ product XXpire WG™ is a combination insecticide for control of chewing and sucking insects (Lepidoptera and Hemiptera). When applied just to the point of spray run-off at 2.0 – 3.5 oz/100 gallons of water, XXpire WG™ has been found to provide excellent control of aphids, lepidopterous larvae, lacebug, certain scales, mealybug, whitefly, and thrips. XXpireWG™ is a water dispersible granule consisting of a 1:1 ratio of spinetoram to isoclast (sulfoxaflor). Spinetoram is derived by chemically modifying naturally-occurring spinosyns J and L and is a group 5 insecticide like spinosad. Isoclast was discovered by and is proprietary to Dow AgroSciences (Alexander et al., 2014).

The purpose of this project is to assess Sivanto ™ and XXpire WG™ for control of cone and seed insects in loblolly pine seed orchards. This study is national in scope, as coneworms and seedbugs are also pests in northern California, the Pacific Northwest, and the Midwest. Consequently, if efficacy is shown, the new pesticides can be useful in orchards throughout the country.

The methods and procedures employed for this study emulated protocols described in previously published research. The experimental design was modeled after the protocol described in DeBarr et al. (1978). Data collection and analysis were modeled after protocols described in DeBarr (1970; 1978) and Grosman et al. (2002). Data collection included counts and evaluation of cones and conelets to assess damage by coneworm and seedbug, respectively. Radiographed seeds were analyzed for seed bug damage.

Methods:

This study was conducted in 2015 in a loblolly pine seed orchard located in eastern Texas in cooperation with Arborgen Inc. Blocks selected had not been sprayed with insecticide for one or more years prior to initiation of the experiment. Ten ramets from each of 6-8 loblolly clones were selected at each site (two ramets/clone/treatment). This was a randomized complete block design with clones as blocks.

The treatments included:

1. Sivanto™ (flupyradifurone): sprayed @ 102-205 g ai/acre
2. Sivanto™: soil drench @ 307-410 g ai/acre
3. XXpire WG™ (spinetoram and sulfoxaflor): 5.5 oz/acre
4. Positive Control: TREE-äge (emamectin benzoate): labeled rate
5. Negative Control: untreated

The Tree-äge injection treatment was applied in November 2014, the Sivanto soil drench was applied one month prior to pollen flight (March 2015), while sprays were applied in early April, approximately 10 days after peak pollen flight to coincide with the presence of early-instar larvae of *Dioryctria amatella* and *D. clarioralis* on the male and female flowers of the pines using a hydraulic sprayer. Sprays were applied again in early June and early August.

To assess for coneworm and seed bug damage, conelet and cone survival were evaluated. In early April, 2015, 18 branches on each tree (50 conelets, 50 cones if possible) were tagged. The branches chosen were distributed from the top of the tree to the lowest producing branch and there was a single cluster, or several clusters per tag. Counts of surviving conelets and cones from these branches were made in July and October, 2015. The July counts gave a better estimate of early-season loss including conelet abortion and early-season coneworm damage (Mangini et al. unpublished report). Conelet and cone survival generally reflect protection from seed bugs and coneworms, respectively.

A sample of 10 conelets per tree were collected in October and evaluated for seedbug damage. Coneworm attacks were evaluated by collecting all cones from each ramet if the trees are small or half of the cones from each ramet if the trees are large (Mangini et al. unpublished report).

A subsample of 10 healthy cones/ tree were selected; seed lots from these cones were radiographed following procedures reported by (DeBarr, 1970) to determine seed yield/cone and filled seed yield/cone to measure the extent of seed bug damage.

Data were analyzed using standard least squares regression in JMP Pro 11. If significant, this test was followed by Tukey's HSD to detect significant differences among treatments.

Research timetable

September-October 2014

- Select test orchards, clones and ramets

November-December 2014

- Inject study trees selected to be treated with TREE-äge
- Flag 18 branches/tree and record number of conelets and cones on all treatment and check trees

March 2015

- Apply Sivanto™ soil drench

April 2015

- Spray trees with Sivanto™ and XXpire WG™

June-August 2015

- Treat trees with Sivanto™ and XXpire WG™ (early June)
- Evaluate conelet and cone survival on flagged branches (July)
- Treat trees with Sivanto™ and XXpire WG™ (early August)

September-November 2015

- Evaluate conelet and cone survival on flagged branches (early September)
- Collect cones from sample trees for evaluation of coneworm and seedbug damage levels (late September, early October)
- Send 10 cones per ramet per treatment for analysis to Lufkin (early October)
- Clean, radiograph, and analyze X-rays of seed lots (October – December)

January – June 2016

- Conduct statistical analysis of data
- Prepare report

Results:

As shown in Table 29, there were no significant differences (P>0.05) among treatments in number of healthy cones (P = 0.71), green infested cones (P= 0.33), and other cones (P= 0.14). Significant differences based on treatment were found in small dead cones, with the fewest small dead cones attributed to the Tree-age treatment (Mean = 3.3 versus 16.7 for the check). The number of small dead cones did not vary significantly from the check for the Sivanto spray (mean = 18.9), the Sivanto soild drench (mean = 10.6) or the XX-pire spray (mean = 9.8) treatments.

The TREE-äge treatment also had significantly fewer large dead cones (Mean = 5.4) than did the check trees (mean = 39.7), but this treatment did not vary significantly (P>0.05) from the XXpire spray treatment (mean = 16.8), the Sivanto soil drench (mean = 16.9) or the Sivanto spray (mean = 27.5) with regard to large dead cones.

The specific clone of the seed tree had a significant effect (P= 0.0001) on the impact of cone worms (*Dioryctria* spp.). Clone G407 produced significantly more healthy cones (214.7) than did clones G476 (133.4), H97 (117.0), and G394 (89.2) for all treatment combined (Table 30, Fig. 16).

An X-ray analysis of seeds from treated and check cones revealed no significant differences (P=0.4178) among the mean number of seeds in the 5 treatments (Sivanto Spray, Sivanto Soil Drench, XXpire Spray, TREE-äge Injection and Control). However, the mean number of full seeds was found to be significant among treatments (P = 0.0085) (Table 31). The injection of Tree-Age into the study trees resulted in a significantly higher mean number of full seeds per cone (73.6) than the control trees (46.5) which received no pesticide application. Tree-Age was not significantly better than any of the other insecticide treatments but all other treatments were not significantly better than the untreated control trees. Mean numbers of seedbug-damaged seed did not vary significantly among the five treatments (P=0.2698).

Table 29. Mean number of cones and conelets evaluated over 5 treatments as healthy, damaged, dead, or infested with seedbugs and coneworms in loblolly pines at Arborgen Orchard, Woodville, Texas in 2015. Levels not connected by the same letter in each generation are significantly different.

Study			Treatment				
			Sivanto Spray	Sivanto Soil Drench	XXpire Spray	Tree-Age Injection	Control
		N	13	14	14	14	14
2015 5th Year	Cone Evaluation	Healthy	141.92 **A**	170.21 **A**	166.07 **A**	164.21 **A**	147.07 **A**
		Small Dead	18.92 **A**	10.64 **AB**	9.79 **AB**	3.29 **B**	16.71 **A**
		Large Dead	27.54 **AB**	16.86 **AB**	16.79 **AB**	5.36 **B**	39.71 **A**
		Green Infested	12.00 **A**	11.79 **A**	12.36 **A**	5.14 **A**	11.50 **A**
		Other	17.46 **A**	33.43 **A**	21.86 **A**	24.14 **A**	48.71 **A**
	Seedbug	Seedbug	392.21 **A**	388.21 **A**	420.79 **A**	336.43 **A**	400.57 **A**
		Seedworm	97.64 **B**	116.93 **AB**	114.21 **AB**	84.57 **B**	169.71 **A**
		Full	611.79 **AB**	594.07 **AB**	630.86 **AB**	736.43 **A**	464.79 **B**
	Branch Count Cone	Healthy	35.08 **A**	45.86 **A**	39.86 **A**	48.43 **A**	39.64 **A**
		Damaged	6.15 **A**	5.43 **A**	5.71 **A**	2.64 **A**	6.93 **A**
		Dead	14.38 **A**	9.21 **AB**	6.71 **AB**	3.71 **B**	8.93 **AB**
	Branch Conelet	Healthy	33.00 **B**	36.57 **AB**	32.00 **B**	49.36 **A**	28.92 **B**
		Damaged	0.00 **A**	0.00 **A**	0.00 **A**	0.00 **A**	0.15 **A**
		Dead	11.54 **AB**	12.36 **AB**	17.36 **A**	2.50 **B**	17.38 **A**

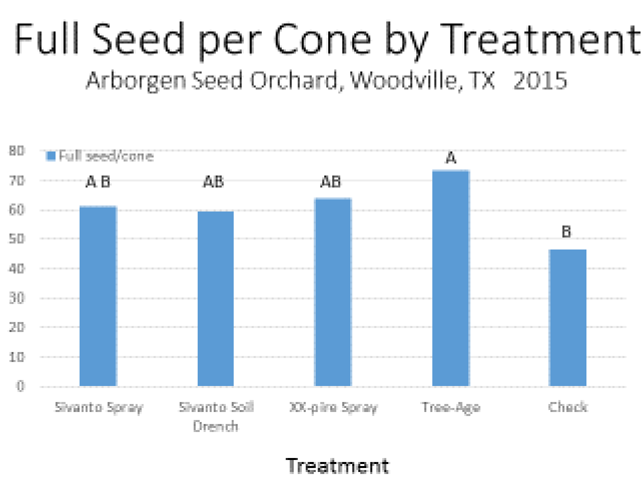
Table 30: Number of healthy cones per clone. Means with the same letter are not significantly different (P>0.05). Arborgen Seed Orchard, Woodville, TX.

Clone					Mean healthy cones
G407	A				214.7
G303	A	B			193.6
G434	A	B			191.0
S46	A	B	C		171.3
G476		B	C	D	133.4
H97			C	D	177.0
G394				D	89.2

Table 31: Mean number of full seeds per cone in treated and check trees in 2015; Means followed by the same letter are not significantly different (P>0.05). Arborgen Seed Orchard, Woodville, TX.

Treatment			**Mean**
TreeAge	A		73.6
XXpire Spray	A	B	63.1
Sivanto Spray	A	B	61.2
Sivanto Soil Drench	A	B	59.4
Control		B	46.5

Figure 16



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Part II: Research Projects in 2016

EVALUATION OF BASF BAIT FORMULATIONS OF SIESTA™FOR ATTARACTION AND CONTROL OF THE TEXAS LEAFCUTTING ANT

Initiated and Completed in 2016

Cooperator: BASF

Background

Siesta™ Insecticide Fire Ant Bait, with the active ingredient metaflumizone, delivers fast and long lasting control of native and imported fire ants. Metaflumizone is formulated on corn grit, along with soybean oil, a proven attractant bait for native and imported fire ants. Siesta Insecticide Fire Ant Bait is the only sodium blocker insecticide (SCBI) that does not require metabolism for bioactivation. The specific site of the insecticidal action is not currently known, but it does act on the insect's nervous system, where it blocks the voltage-dependent sodium neuron channel. As a result, these neurons are inactivated, causing the ant to enter a state described by researchers as "relaxed paralysis." The direct effects are that Siesta Insecticide Fire Ant Bait causes the cessation of feeding, increasing levels of immobility, and ultimately ant death. BASF provided a quantity of Siesta™ to be tested in preference and efficacy trails in 2016 as a potential method to control Texas leafcutting ants (TLCA) (*Atta texana*).

Objectives: 1) To determine the attractiveness of the Texas leaf-cutting ant to Siesta™ baits.
2) To determine the efficacy of Siesta™ baits for control of Texas leaf-cutting ants.

Methods

Two types of bait were tested in preference and efficacy trials: 1) the commercial Siesta™ fire ant bait and 2) Siesta bait passed throught the FPMC pelletizer to make a larger pellet, known to be preferred by TLCA (Grosman et al. 2002).

Preference Trial

Trials were conducted near Jasper and Colmesneil in East Texas in February, 2016, by placing 5 g portions of different baits (Siesta commercial fire ant bait and Siesta bait modified into larger-sized pellets) into Petri dishes. Each treatment was replicated ten times per trial period. For each trial replicate, one dish of each treatment was distributed at random within the central nest area (but near areas of high activity) or along foraging trails. All dishes within each replicate were retrieved when the dish, containing the most attractive bait, was nearly empty or at the end of the test period (approximately 3 hours). The amount (weight) of bait removed by ants from each Petri dish was noted and means calculated for each treatment. Petri dishes with each of the baits also were placed near imported fire ant mounds to test for differences in preference, based on pellet size.

Efficacy Trial

Experiments were conducted in east Texas; within 100 miles of Lufkin. In this area, 40 Texas leaf-cutting ant colonies were selected. Those colonies larger than 30 m by 30 m, smaller than 3m by

3 m, adjacent to each other (within 100 m), and/or lacking a distinct central nest area were excluded from this study. Treatments were randomly assigned to the selected ant nests with 10 replicates per treatment.

The central nest area (CNA) is defined as the above-ground portion of the nest, characterized by a concentration of entrance/exit mounds, surrounded by loose soil excavated by the ants (Cameron 1989). Scattered, peripheral entrance/exit and foraging mounds will not be included in the central nest area. Application rates will be based on the area (length X width) of the central nest. The treatments may include:

Application rates were based on the area (length X width) of the central nest. The treatments included:

1) Treatment 1: 12 oz/m^2 of Siesta fire ant bait
2) Treatment 2: 12 oz/m^2 of Siesta fire ant bait in large-sized pellets
3) Treatment 3: 8 – 12 oz/m^2 of Amdro™ Ant Block
4) Treatment 4: untreated colonies

Procedures used to evaluate the effect of treatments on Texas leaf-cutting ant colonies followed those described by Cameron (1990). The number of active entrance/exit mounds was counted prior to treatment and periodically following treatment at 1, 2, 8, and 16 weeks. Ten untreated colonies will be included as controls and monitored to account for possible seasonal changes in ant activity. For each colony, the percent of initial activity will be calculated as the current number of active mounds at each post-treatment control divided by the initial number of active mounds. Differences in mean percent of initial activity among treatments will be tested for significance. Also, the percent of colonies totally inactive will be calculated for each treatment at each post-treatment evaluation. Data will be analyzed with ANOVA and Student's T test using JMP Pro 11.

Results

Preference Trial
The Texas leafcutting ants removed 2.7 times more Siesta large-pellet baits (mean = 1.67 g.) from Petri dishes on average compared to the commercial Siesta fire ant bait (mean = 0.62) bait (mean = 0.80g) (Table 39). However, differences were not significant ($P>0.05$). Four of ten large-pellet bait dishes were taken over by fire ants, which discourage further removal of pellets by leafcutting ants. In preference tests with fire ants, there were no significant differences in weight of baits removed between treatments (mean = 0.57 gm of fire ant bait removed verses 0.38 gm of pelletized baits).

Efficacy Trial
Niether of the Siesta treatments reduced the number of active leafcutting ant mounds significantly, compared to the check after 8 week (Figure 40). At the end of week 8, only the Amdro AntBlock significantly affected ant survival, reducing mean town ant activity by 95%. This reduction was significantly greater than that of the check and the two Siesta baits.

Overall, results of this field trial were disappointing with regard to Siesta. Ant activity was reduced by 40% after 16 weeks by the Siesta pelletized bait and only 31% by the unpelletized, standard Siesta bait. Amdro AntBlock spread across active colonies and PTM injected into the feeder holes remain the best commercially available options for Texas leafcutting ant control.

Table 32: Results of preference tests of Siesta commercial fire ant bait and Siesta bait offered as large pellets to Texas leafcutting ants, East Texas February, 2016.

Trt	Rep	Initial Wt (g)	Post Wt (g)	Diff. Wt (g)	Notes
A Siesta standard	1	5.00	3.49	1.51	
A for TLCA	2	5.00	3.67	1.33	
A	3	5.00	4.68	0.32	
A	4	5.00	4.64	0.36	
A	5	5.00	4.56	0.44	
A	6	5.00	4.82	0.18	
A	7	5.00	4.41	0.59	
A	8	5.00	4.56	0.44	
A	9	5.00	4.64	0.36	
A	10	5.00	4.30	0.70	
	Avg		**4.38**	**0.62**	

Trt	Rep	Initial Wt (g)	Post Wt (g)	Diff. Wt (g)	Notes
B Siesta Pellets	1	5.00	1.94	3.06	
B for TLCA	2	5.00	2.79	2.21	
B	3	5.00	3.08	1.92	
B	4	5.00	4.76	0.24	fire ants
B	5	5.00	4.77	0.23	fire ants
B	6	5.00	3.01	1.99	
B	7	5.00	3.32	1.68	fire ants
B	8	5.00	4.49	0.51	fire ants
B	9	5.00	2.57	2.43	
B	10	5.00	2.60	2.40	
	Avg		**3.33**	**1.67**	

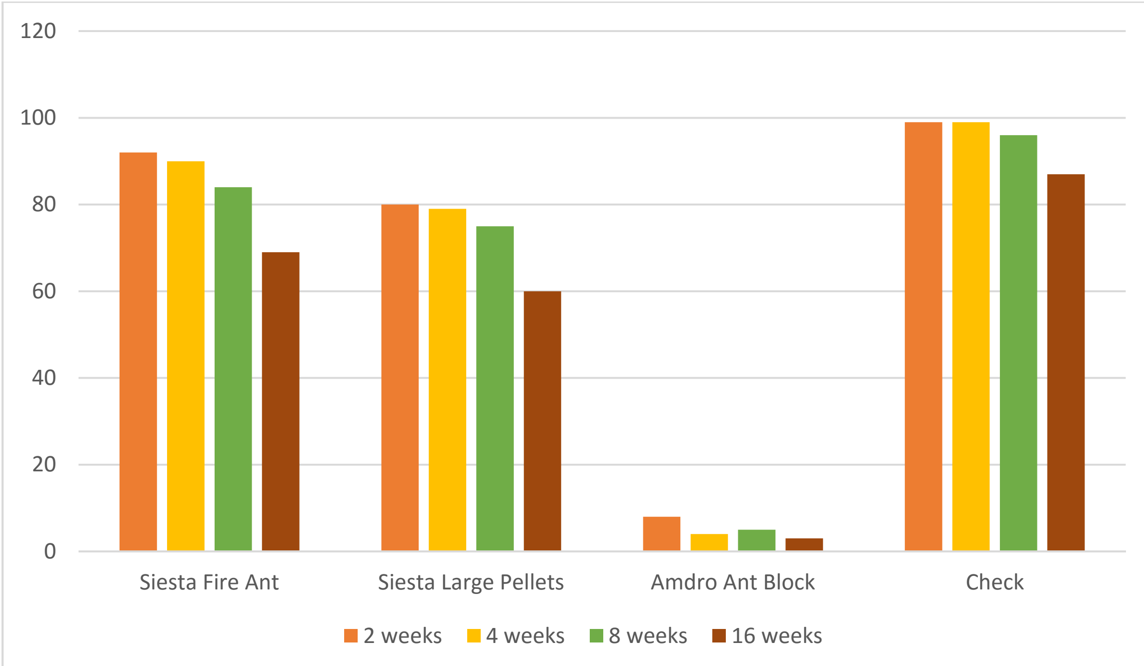

Figure 17: Proportion of active colonies following treatment with Siesta™ commercial fire ant bait and Siesta bait offered as large pellets compared to Amdro Ant Block™ and untreated colonies, East Texas, 2016.

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EVALUATING THE EFFECTIVENESS OF WINTER INJECTIONS OF EMAMECTIN BENZOATE FOR CONTROL OF THE SOUTHERN PINE BEETLE:

Initiated December 2015; completed in 2016

Funding: $10,284 (Grant from Syngenta, Inc.)

Justification: The southern pine beetle (SPB) (Coleoptera: Curculionidae, Scolytinae) is considered the most destructive insect pest of southern pine forests. Since 1997, no SPB infestations have been detected in Western Gulf states (TX, AR, LA & OK) and very few SPB have been caught in pheromone traps in East Texas since 2001 (11 SPB). Pheromone traps deployed during the spring have proven effective for predicting SPB population increases since 1988 across the South (Billings and Upton 2010). SPB populations in 2012 -2015 were at unprecedented low population levels throughout the South and Northeast, with the exception of southern New Jersey, the Hommochitto and Bienville National Forest and surrounding private lands in Mississippi, and local areas in Alabama and Virginia. A method for effectively dealing with SPB outbreaks in early stages of development is needed. Much is known about SPB biology and seasonal habits (see Coulson and Klepzig 2011). Most new SPB infestations are initiated following long-distance dispersal in the spring (March-May) and to a lesser extent in the fall (October-December). SPB adults, however, may emerge from brood trees, fly, and attack additional trees throughout the winter, whenever ambient temperatures exceed the flight threshold of ca. 59 degrees F.

A new systemic insecticide (emamectin benzoate) has been developed by the Texas A&M Forest Service (TFS) Forest Pest Management Cooperative (FPMC) and is sold by Syngenta under the trade name Tree-äge™. This insecticide is effective against SPB (Grosman et al 2009, 2010) and has been registered and is now available for pine bark beetle control in forest situations. This is the only insecticide registered for control of SPB in forests. Allee effects (positive density dependence) have been shown to play an important role in the establishment and spread of invasive species. A certain population density is essential before an invasive species can become established and spread in a new environment (and because of Allee effects, many new introductions of invasive plants and animals fail to succeed). Increased interest in recent years is being focused on the potential to exploit Allee effects as a means to manage invasions of exotic species (Tobin et al. 2011).

Field studies conducted by the FPMC from 2012-2015 in Alabama, Virginia and Mississippi have documented the following:

- Loblolly pines injected with 1.25 - 5.0 ml/diameter inch of emamectin benzoate (TREE-äge) are effective as trap trees for absorbing attacking SPB during summer and fall months when SPB occur at low population levels (<2.0 SPB/trap/day).
- Attacked trees containing emamectin benzoate accumulate attack densities comparable to un-injected pines, but no SPB galleries are constructed and no broods emerge from treated trees.
- Pines that are injected and baited simultaneously also are successful trap trees, but only if initial attacks are delayed or occur over a prolonged period (allowing uptake of the insecticide).

Objectives:

- Determine the effectiveness of isolated trap trees injected with emamectin benzoate and baited with SPB pheromones during winter months (December through February).
- Evaluate three dosage levels of emamectin benzoate for effectiveness in a trap-tree tactic applied during winter months.

Cooperators:

Ms. Cindy Ragland	Oakmulgee R.D, Talladega N.F., Brent, AL
Mr. David Cox	Syngenta, Inc., Madera, CA

Study Sites: The study is to be conducted in the Talladega National Forest, Oakmulgee Ranger District in Bibbs and Perry Co., Alabama with SPB attacking loblolly pine, *Pinus taeda*. Isolated loblolly pines (8-15 inches DBH) will be selected for treatments.

Insecticides:

Emamectin benzoate (TREE-äge™, Arborjet Inc.) – an avermectin derivative

Treatments (Winter 2015-2016):

- Loblolly pine tree isolated from other pines by > 30 feet, injected with 1.25 ml/diameter inch of emamectin benzoate in December and baited four weeks after injection (10 trees).
- Loblolly pine tree isolated from other pines by > 30 feet, injected with 2.50 ml/diameter inch of emamectin benzoate in December and baited four weeks after injection (10 trees).
- Loblolly pine tree isolated from other pines by > 30 feet, injected with 5.0 ml/diameter inch of emamectin benzoate in December and baited four weeks after injection (10 trees).
- Baited and uninjected check tree (10 trees).

Treatment Methods and Evaluation:

Two sets of Lindgren funnel traps baited with frontalin + Sirex lure + *endo*-brevicomin (displaced by 4 m) and frontalin + Sirex lure will be deployed in the area 300 m away from injection plots, to monitor local southern pine beetle populations.

Note: Where possible, poor quality (form, health, etc.) trees were selected as trap trees.

TREE-äge™ will be injected at 1.25, 2.50 or 5.0 ml per inch DBH. The Tree IV™ microinfusion system (Arborjet, Inc. Woburn, MA) will be used to inject TREE-äge™ into 4 (for trees <12" DBH) or 8 (for trees ≥12" DBH) points 0.3 m above the ground. The injected trees will be allowed 4 weeks to translocate chemicals prior to being challenged by the application of synthetic pheromone baits.

Treatment evaluation:

- Treated trees will be revisited at intervals of 4, 8, 12 and 24 weeks after baiting to monitor attack level (occurrence of pitch tubes).

- During the winter and spring, 2016, each study tree will be monitored periodically to determine the approximate date of mass attack, based on presence of more than 100 pitch tubes along the bole.
- All dead study trees will be felled when they begin to fade. Bark plates (10 X 10 cm = 100 cm2) will be collected at approximately 1.5, 4.0 and 6.5 m height at northern and southern aspects. SPB gallery length, density of emergence holes, and presence of cerambycid galleries and percent of surface area covered with blue stain will be recorded.
- Ambient temperatures will be monitored at the closest weather station (Tuscaloosa, AL) to determine number of days favorable for SPB flight throughout the winter.

Expected outcome: SPB activity, generation times, long-range dispersal and intensity of attacks are known to be seasonally dependent (Coulson and Klepzig 2011). Field studies conducted by the FPMC to date have been conducted in the summer and fall months. This study will provide insight into the utility of trap trees containing emamectin benzoate for application in winter months, when SPB flight is more sporatic and duration of SPB attack occurs over prolonged periods and at lower levels. The optimal dosage level of emamectin benzoate for use to create trap trees during winter months will be determined.

Project Timetable:

CY 2015 - December:

1) Select and inject treatment trees
2) Install pheromone traps

CY 2016 – January - June:

3) Bait and monitor trees
4) Collect pheromone traps
5) Rebait injected trees (March)
6) Sample all study trees (April)
7) Data summary and analyses (May)
8) Progress report (August)

Literature Cited:

Billings, R. F., and W. W. Upton. 2010. A methodology for assessing southern pine beetle risk across the southern region using pheromone traps, pp.73–85. *In* J. M. Pye, H. M. Rauscher, Y. Sands, D. C. Lee, and J. S. Beatty (eds.), Advances in threat assessment and their application to forest and rangeland management, vol. 1. PNW-GTR-802, U.S. Department of Agriculture Forest Service, Portland, OR.

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Grosman, D.M., S.R. Clarke, and W.W. Upton. 2009. Efficacy of two systemic insecticides injected into loblolly pine for protection against southern pine bark beetles (Coleoptera: Curculionidae). J. Econ. Entomol. 102: 1062-1069.

Grosman, D.M., C.J. Fettig, C.L. Jorgensen, and A.S. Munson. 2010. Efficacy of two systemic insecticides for protection of western conifers against *Dendroctonus* bark beetles (Coleoptera: Curculionidae, Scolytinae). W. J. Appl. For. 25: 181-185.

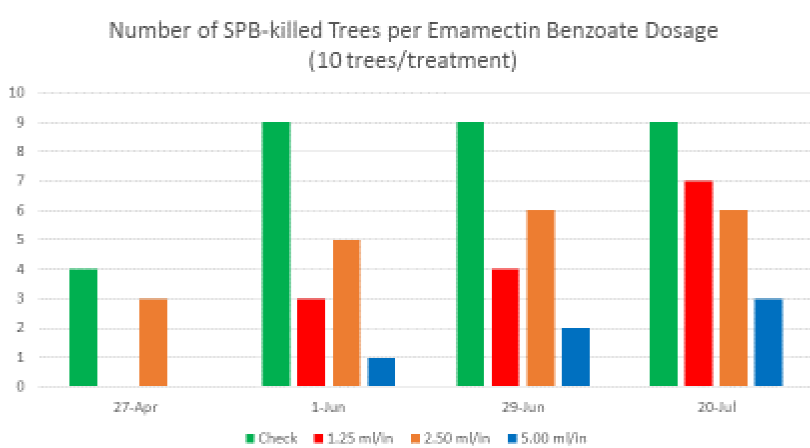
Preliminary Results:

The study trees were injected during the first week of December, 2015, and baited with SPB pheromones one month later. Attacks were observed on baited trees on February 4 and by March 2, 31 of 40 trees (78%) had more than 100 SPB pitch tubes visible from the ground. By the April 13th visit, 37 of 40 study trees had been mass attacked (>200 pitch tubes/tree).

Results of trees killed, SPB egg gallery length per 100 cm^2, SPB emergence holes, and percent blue stain by treatment are shown below (Figure 20). The most effective treatment for protecting loblolly pines from mortality due to SPB attacks was 5.0 ml/diameter inch of emamectinn benzoate. Trees in this treatment exhibited essentially no SPB galleries, no emergence holes and high levels of blue stain infection at all levels sampled. Only 3 of 10 trees had begun to fade as of 20 July (presumably due to blue stain infection). Compared to check trees, those trees treated with lower dosages of emamectin benzoate (2.5 ml and 1.25 ml/diameter inch) showed reduced SPB galleries and emergence, but to a lesser extent than trees treated at the 5.0 ml/in dosage. As of July 20, 2016, 6 and 7 of 10 trees injected with 2.5 ml or 1.25 ml/diameter inch, respectively, and 3 of 10 trees injected at 5.0ml/in had faded from successful colonization of blue stain following mass attack of SPB.

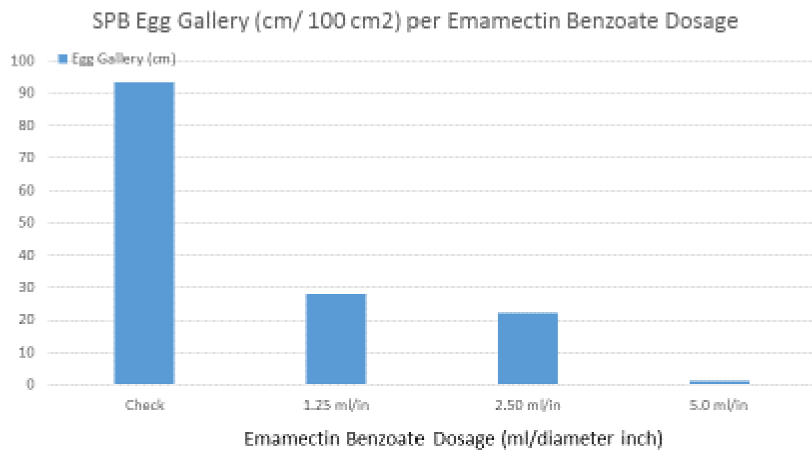
A. SPB Injection: Winter Study 2016

Oakmulgee Ranger District, AL



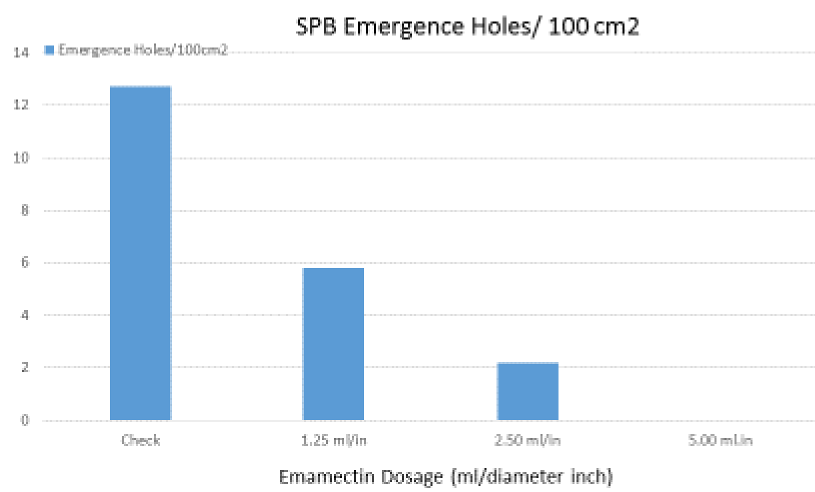
B. SPB Injection: Winter Study 2016

Oakmulgee Ranger District, AL



C. SPB Injection: Winter Study 2016

Oakmulgee Ranger District, AL



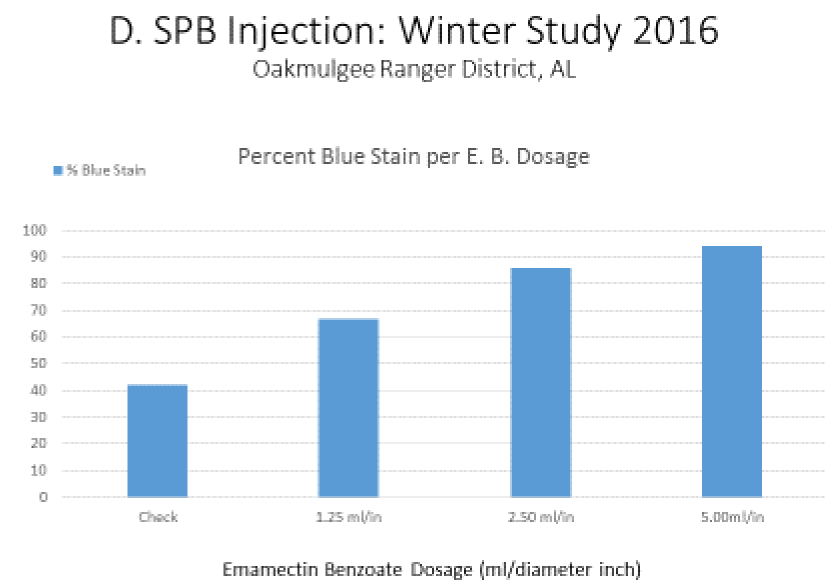


Figure 18: **A.** Number of SPB-killed trees, **B.** density of emergence holes, **C.** length of SPB egg galleries, and **D.** percent blue stain per 100 cm^2 in pines injected with increasing dosages of emamectin benzoate during the winter, 2015-2016 and monitored up through July 20, 2016; Oakmulgee Ranger District, AL.

EVALUATING THE DURATION OF EMAMECTION BENZOATE INJECTIONS FOR CONTROL OF SOUTHEN PINE BEETLE

Initiated in 2014 and Completed in 2016

Budget: \$9,580 (Grant from Syngenta, Inc.)

Justification: The southern pine beetle (SPB) (Coleoptera: Curculionidae, Scolytinae) is considered the most destructive insect pest of southern pine forests. Since 1997, no SPB infestations have been detected in Western Gulf states (TX, AR, LA & OK) and very few SPB have been caught in pheromone traps in East Texas since 2001 (11 SPB). Pheromone traps deployed during the spring have proven effective for predicting SPB population increases since 1988 across the South (Billings and Upton 2010). SPB populations in 2012 -2015 were at unprecedented low population levels throughout the South and Northeast, with the exception of southern New Jersey, the Homochitto and Bienville National Forest and surrounding private lands in Mississippi, and local areas in Alabama and Virginia. A method for effectively dealing with SPB outbreaks in early stages of development is needed. Much is known about SPB biology and seasonal habits (see Coulson and Klepzig 2011). Most new SPB infestations are initiated following long-distance dispersal in the spring (March-May) and to a lesser extent in the fall (October-December). SPB adults, however, may emerge from brood trees, fly, and attack additional trees throughout the winter, whenever ambient temperatures exceed the flight threshold of ca. 59 degrees F.

A new systemic insecticide (emamectin benzoate) has been developed by the Texas A&M Forest Service (TFS) Forest Pest Management Cooperative (FPMC) and is sold by Syngenta under the trade name TREE-äge™. This insecticide is effective against SPB (Grosman et al 2009, 2010) and has been registered and is now available for pine bark beetle control in forest situations. This is the only insecticide registered for control of SPB in forests. Allee effects (positive density dependence) have been shown to play an important role in the establishment and spread of invasive species. A certain population density is essential before an invasive species can become established and spread in a new environment (and because of Allee effects, many new introductions of invasive plants and animals fail to succeed). Increased interest in recent years is being focused on the potential to exploit Allee effects as a means to manage invasions of exotic species (Tobin et al. 2011).
Field studies conducted by the FPMC from 2012-2015 in Alabama, Virginia and Mississippi have documented the following:

- Loblolly pines injected with 1.25 - 5.0 ml/diameter inch of emamectin benzoate are effective as trap trees for absorbing attacking SPB during summer and fall months when SPB occur at low population levels (<2.0 SPB/trap/day).
- Attacked trees containing emamectin benzoate accumulate attack densities comparable to un-injected pines, but no SPB galleries are constructed and no broods emerge from treated trees.
- Pines that are injected and baited simultaneously also are successful trap trees, but only if initial attacks are delayed or occur over a prolonged period (allowing uptake of the insecticide).

Objectives:

- Determine the duration of isolated trap trees injected with emamectin benzoate and baited with SPB pheromones 18 months post-injection during spring months (April through June).
- Evaluate the duration of two dosage levels (2.5 and 5.0 ml/diameter inch) of emamectin benzoate for effectiveness in a trap-tree tactic.

Cooperators:

Ms. Cindy Ragland	Oakmulgee R.D, Talladega N.F., Brent, AL
Mr. David Cox	Syngenta, Inc., Madera, CA

Study Sites: The study is to be conducted in the Talladega National Forest, Oakmulgee Ranger District in Bibbs and Perry Co., Alabama with SPB attacking loblolly pine, *Pinus taeda*. Isolated loblolly pines from 8 to 14 inches DBH will be selected for treatments.

Insecticides:

Emamectin benzoate (TREE-äge™, Arborjet Inc.) – an avermectin derivative

Treatments (Fall 2014):

- Loblolly pine tree isolated from other pines by > 30 feet, injected with 2.50 ml/diameter inch of emamectin benzoate in November 2014 and baited in April 2016 (6 trees).
- Loblolly pine tree isolated from other pines by > 30 feet, injected with 5.0 ml/diameter inch of emamectin benzoate in November 2014 and baited in April 2016 (18 trees).
- Uninjected check tree (loblolly pine) isolated from other pines by > 30 feet (10-12 trees) to be baited in April 2016 (6 trees).

Treatment Methods and Evaluation:

Two sets of Lindgren funnel traps baited with frontalin + Sirex lure + *endo*-brevicomin (displaced by 4 m) and frontalin + Sirex lure will be deployed in the area 300 m away from injection plots, to monitor local southern pine beetle populations.

Note: Where possible, poor quality (form, health, etc.) trees were selected as trap trees.

TREE-äge™ was injected at 2.50 or 5.0 ml per inch DBH in the fall, 2014. The Tree IV™ microinfusion system (Arborjet, Inc. Woburn, MA) was used to inject TREE-äge™ into 4 (for trees <12” DBH) or 8 (for trees $\geq$12” DBH) points 0.3 m above the ground. The injected trees will be allowed 16 months to translocate chemicals prior to being challenged by the application of synthetic pheromone baits.

Treatment evaluation:

- Treated trees will be revisited at intervals of 4, 8, 12 and 24 weeks after baiting to monitor attack level (occurrence of pitch tubes).
- All study trees with SPB attacks will be felled when they begin to fade. Bark plates (10 X 10 cm = 100 cm2) will be collected at approximately 1.5, 4.0, 6.5 and 17 m height at northern and southern aspects. SPB itch tubes, adult gallery length, density of emergence holes, and presence of blue stain and cerambycid larval galleries will be measured.

Expected outcome: Field studies conducted by the FPMC to date have involved inducing SPB attacks simultaneously with tree injection or 2 and 4 weeks post injection. This study will evaluate the duration of treatment effectiveness by inducing SPB attacks on trees that were injected ca. 18 months earlier. This information will be useful for developing a practical trap-tree control method for SPB populations.

Project Timetable:
CY 2014 - October:

9) Select and inject treatment trees

CY 2016:

10) Bait and monitor trees (April)
11) Collect pheromone traps
12) Rebait injected trees if not mass attacked (June)
13) Sample all study trees (when they begin to fade)
14) Data summary and analyses (October)
15) Progress report (November)

Literature Cited:

Billings, R. F., and W. W. Upton. 2010. A methodology for assessing southern pine beetle risk across the southern region using pheromone traps, pp.73–85. *In* J. M. Pye, H. M. Rauscher, Y. Sands, D. C. Lee, and J. S. Beatty (eds.), Advances in threat assessment and their application to forest and rangeland management, vol. 1. PNW-GTR-802, U.S. Department of Agriculture Forest Service, Portland, OR.

Coulson, R. N. and K. D. Klepzig (eds) 2011. Southern Pine Beetle II. *USDA Forest Service, Gen. Tech. Rpt. SRS 140. 512 pp.*

Grosman, D.M., S.R. Clarke, and W.W. Upton. 2009. Efficacy of two systemic insecticides injected into loblolly pine for protection against southern pine bark beetles (Coleoptera: Curculionidae). J. Econ. Entomol. 102: 1062-1069.

Grosman, D.M., C.J. Fettig, C.L. Jorgensen, and A.S. Munson. 2010. Efficacy of two systemic insecticides for protection of western conifers against *Dendroctonus* bark beetles (Coleoptera: Curculionidae, Scolytinae). W. J. Appl. For. 25: 181-185.

Preliminary Results

All trees in this study were baited with SPB pheromones on March 16, 2016. By July 20, all 6 check trees had become infested and were felled for bark analysis. On that same date, 5 of 6 trees treated with 2.5 ml emamectin benzoate also had begun to fade and were felled while 12 of 18 trees injected with 5.0 ml/diameter inch also were fading and were felled. Interestingly, trees treated with emamectin benzoate with either 2.5 ml or 5.0 ml/diameter inch in November, 2014 failed to produce SPB galleries or brood even when baited 18 months later. Monitoring is continuing.

IMPROVING THE PREDICTION SYSTEM FOR THE SOUTHERN PINE BEETLE

Special Technology Development Project Number: R8-2016-1
Starting Date: February 15, 2016
Expected Completion Date: February 14, 2018
Grant: $50,000 from USDA Forest Service, Forest Health Protection

Brief Description of Project:

- **FY 2016**: Conduct a replicated, statistically-designed bioassay to compare the relative attractiveness to southern pine beetle (SPB) and clerid predators of traps baited with frontalin and 1) one commercial Sirex lure (*alpha*- and *beta*-pinene); and 2) two Sirex lures to double the release rate; 3) steam-distilled pine turpentine released from amber bottle with wick; 4) pine turpentine released from sealed polyethylene pouch; and 5) one Sirex lure with *endo*-brevicomin during the spring and fall dispersal periods of SPB.
- **FY 2017 (if federal funding is provided)**: Repeat the comparison bioassay in various locations throughout the South (FL, VA, SC, GA, MS) in fall and spring, using the three most attractive lure combinations from the 2016 bioassays. Modify the standard SPB prediction chart (Appendix 4) and trapping protocol based on the most effective bait.
- **FY 2018 (If federal funding is provided)**: Implement and validate the modified prediction chart across the southern U.S.

Project Objectives:

- To answer the questions: Is a higher elution rate of host volatiles and/or presence of *endo*-brevicomin an important factor for making low SPB populations visible? Is pine turpentine more attractive than the commercial Sirex lure as a host component for SPB traps? Are fall surveys useful for making SPB predictions?
- Modify the traditional SPB prediction chart to reflect comparative attractiveness of single or double Sirex lures/trap.
- Develop, implement and validate a revised South-wide protocol for improved prediction of SPB infestation trends.

Justification:

The southern pine beetle (SPB), *Dendroctonus frontalis* Zimm. (Coleoptera: Curculionidae) is one of the most serious insect pests of loblolly pine in the southeastern United States (Thatcher et al. 1980, Coulson and Klepzig, 2011). In recent years, SPB has reached outbreak levels at both the northern (New Jersey, New York) and southern (Honduras) extremes of its range (Billings 2015). In 2012-2015, local outbreaks of SPB also have occurred on national forests in Mississippi and Alabama. The SPB prediction system developed by the Texas A&M Forest Service in the mid-1980s (Billings 1988, Billings and Upton 2010) and implemented across the South proved to correctly predict SPB outbreaks or declines over 70% of the time during those years when steam-distilled pine turpentine was used as the host component in trap lures (1986-2007). Since 2008, the turpentine has been replaced with the commercial Sirex lure, comprised primarily of *alpha*-pinene. The change was adopted to maintain consistency in the host lure and for ease of deployment. Recent SPB outbreaks in Mississippi from 2012-2015 failed to be forecasted by the SPB prediction system, perhaps due to low trap catches in traps deployed with Sirex lures in these areas. These results suggest the Sirex lure is a poor substitute for pine turpentine (the host compound used to develop the prediction model in the 1980s), possibly due to a low release rate (ca. 2.5 g/day compared to ca. 6 g/day for bottle and wick (see: www.fs.fed.us/foresthealth/technology/elutionrate/). High release rates of host volatiles are known to substantially increase responses of SPB and associated predators (Billings 1985). The SPB male-produced compound e*ndo*-brevicomin (Vité et al. 1985), placed 4-16 m distance from a baited trap, also increases attraction to SPB (Sullivan et al. 2007, Sullivan and Mori 2009) and may have utility in improving the prediction system. It is urgent that the prediction model is modified to increase its ability to detect increasing SPB outbreaks early in their development, prior to the next large-scale SPB event. The current study builds on previous research studies that led to development and implementation of the only bark beetle prediction system in the nation and complements other current studies (Appendix 3).

Scope of Application: The results would be relevant throughout the range of the pest. The current network of Federal and State cooperators, in place since 1986, would put any modifications in SPB prediction to immediate use. Initiation of a fall prediction survey using pheromone traps also would be useful to these cooperators to extend the time between early alert and SPB detection flights. An effective SPB prediction system would be useful throughout the extensive range of SPB.

Measures of Success:

- **Expected outcomes:** A more attractive bait combination for SPB will yield a more effective means to detect SPB outbreaks in early stages of development.
- **Products and Due Dates**: Identification of most attractive bait combination (Dec. 2016); revised protocol for predicting SPB outbreaks (December 2017); implementation and validation of new protocol across SPB range in southeastern U.S. (October 2018)
- **Benefits:** Improved ability to forecast SPB outbreaks early in their development and more efficacious SPB management strategy.

Technology Transfer: State and federal cooperators involved in the annual SPB prediction survey in at least 13 states in the southeastern U. S. are available to immediately implement changes in protocols for SPB prediction that result from this study. In addition to these cooperators, the improved prediction model would be immediately applicable to northeastern states as the SPB population extends its range north. Forest pest specialists in Mexico and Central America have been working in collaboration for many years with the principal investigator and are anxiously awaiting an effective early alert system for SPB.

Research Basis: The SPB Prediction System, in operation across the South since 1986 (Billings 1988, Billings and Upton 2010), will be improved with results from this project.

Methods:

SPB Prediction System Performance: Using procedures described in Billings and Upton 2010, historical data from the South-wide SPB Prediction System will be analyzed to compare relative accuracy of SPB predictions when pine turpentine eluted from bottles was used (1988-2007) to more recent years when the commercial Sirex lure was exclusively used on pheromone-baited traps (2008-2015). Predictions based on SPB and clerid catches across the South for years when the Sirex lure was used will be compared to actual numbers of SPB infestations detected at the end of the year for each county or National Forest Ranger District trapped, as was previously done for years when pine turpentine was used as the host factor in traps (Billings and Upton 2010). This proposal is one step towards improving the SPB prediction system and will complement other on-going studies. For example, Mississippi State University and USFS FHP are developing a degree-day model for the SPB survey to ascertain when best to deploy traps and how long to leave them in the field for predictive purposes. Also, the University of Georgia and US Forest Service/SRS have a collaborative study to determine if average body size of SPB collected in survey traps can be used to enhance prediction of the onset and the decline of SPB outbreaks.

<u>Host volatile bioassays</u>: The first replicated field bioassays, to be conducted in the spring and fall using Lindgen funnel traps, will compare the attractiveness of frontalin plus the following: 1) one Sirex lure deployed from sealed polyethylene pouch (standard lure or check); 2) Caribbean pine turpentine (from Synergy Semiochemicals) deployed from polyethylene pouch plus *endo*-brevicomin displaced by 4 m; 3) steam-distilled Caribbean pine turpentine, deployed from a 240 ml amber bottle and wick (as per Billings 1988); 4) turpentine used in treatment 3, deployed from sealed polyethylene pouch used for Sirex lure, and 5) one Sirex lure + *endo*-brevicomin displaced by 4 m. Traps will be situated at least 200 m apart and at least 15m from live pines in mixed pine-hardwood stands (or pure hardwood stands adjacent to pine stands) and will be placed on metal poles at a standard height of 2 m above ground. Insects will be collected every 5-7 days for 10 consecutive weeks beginning in mid-February and mid-October of 2016.

Lures will be rotated in a Latin-square design following collection of insects at each trap location to eliminate positional effects (every treatment will be tested twice at every trap location). Lures will be replaced with fresh lures every 5 weeks (or sooner if needed). An analysis of variance will document the significance of observed differences in trap catches of SPB and clerids among treatments. The pine and hardwood basal area, mean diameter at breast height and mean tree height will be documented for each trap location and subsequently correlated with trap catches of SPB and clerids. The bioassay will be replicated eight times by conducting the bioassay on at two (2) different sites each season on each of three (3) or more National Forests or adjacent private lands in Mississippi (Homochitto, Bienville N.F.), Alabama (Oakmulgee R.D.) and Louisiana (Sicily Island) where SPB is present. John Riggins or a student from his lab (Mississippi State University) and USFS personnel from Pineville, LA (Jim Meeker or technicians) and Lufkin, TX (Steve Clarke) will assist in making trap collections and counting SPB and clerids.

A second bioassay will be conducted by the principal investigator and cooperators in selected counties or National Forest Ranger Districts across the South in FY2017 and FY2018 as part of the SPB Prediction Survey (if federal funding is provided). To test traps baited with frontalin and the most attractive host lures from the first bioassay, the following treatments will be compared in spring and fall seasons: 1) one Sirex lure (standard); 2) two Sirex lures or one pouch or bottle of turpentine (whichever is more attractive, based on the first bioassay); and 3) one Sirex lure with *endo*-brevicomin displaced by 4 m. Mean trap catches of SPB and clerids per treatment will be compared to number of SPB spots detected by the end of the year (spring bioassay) or by the end of the following year (fall bioassay) in each county or Ranger District trapped (Billings and Upton 2010). Elution rates (gm/day) and mean daily temperatures will be monitored for each lure and elution device tested. The chemical composition of the pine turpentine will be determined by chemical analysis. Results from these studies will be used to modify and improve the accuracy the standard SPB prediction chart (Appendix 4b) that was developed using pine turpentine as a host volatile (Billings 1988). The modified chart will be implemented by all State and Federal cooperators involved in the SPB Prediction Survey in FY 2019 and results validated by year-end SPB detection records available in the SPB Portal.

Cooperators

Name	Affiliation (Office or Dept.)	Phone, E-mail, Fax
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PRINCIPAL INVESTIGATOR:		
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COOPERATORS:		
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James Meeker, Ph. D.	USDA Forest Service, FHP 2500 Shreveport Hwy. Pineville, LA 71360	318-473-7284 (p) 318-472-7292 (f) jrmeeker@fs.fed.us
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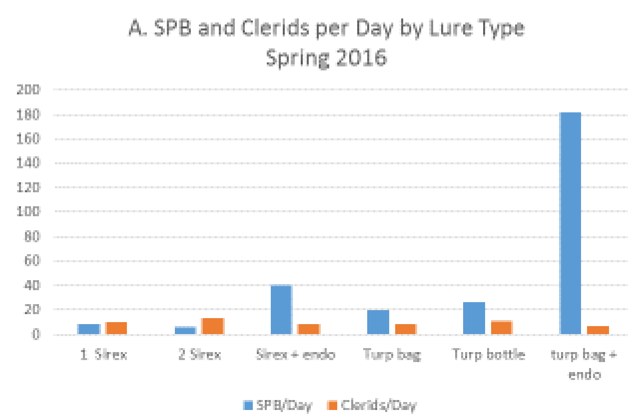
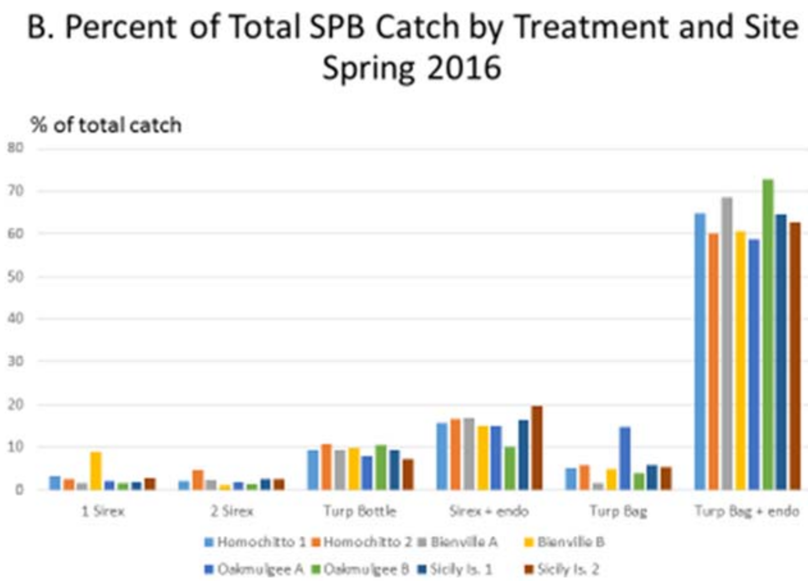
Jeff Eickwort	Florida Forest Service Florida Dept. of Agriculture 1911 SW 34th Street Gainesville, FL 32608	Office: (352) 395-4689 Fax: (352) 395-4623 Jeffrey.Eickwort@FreshFromFlorida.com
David Jenkins	South Carolina Forestry Comm. PO Box 21707 Columbia, SC 29212-1707	Office: (803) 896-8838 Fax: (803) 896-8827 djenkins@scfc.gov
Lori Chamberlin	Virginia Dept. of Forestry 900 Natural Resources Dr Charlottesville, VA 22903	Office: 434-220-9026 Cell: 434-326-7279 lori.chamberlin@dof.virginia.gov

Preliminary Results:

The spring bioassays were conducted from February 19 to April 20 (10 weeks) on 8 sites, two each in Louisiana, Mississippi, and Alabama. Preliminary results are shown in Figure 19. The treatment containing two bags of Sirex lures was replaced after 5 weeks with a combination treatment containing frontalin, Caribbean turpentine deployed from a polyethylene bag, and *endo*-brevicomin (displaced 4 m from the trap). Clearly the most attractive treatment in all eight sites was the combination containing frontalin, turpentine bag, and *endo*-brevicomin (Figure 19 A). This treatment caught approximately 60% of all the southern pine beetles trapped per site, consistently more than the combination of Sirex lure + frontalin + *endo*-brevicomin (Figure 19 B). Interestingly, most attractive treatment caught the fewest clerids (96% SPB) (Figure 19 C).

The least attractive treatment was the frontalin + Sirex lure, which has been the standard lure used in SPB prediction surveys since 2007, possibly explaining why SPB pheromone traps have failed to detecting pending outbreaks in recent years. The same 5 treatment test (utilizing the turpentine bag + frontalin + *endo*-brevicomin in place of the 2 bags of Sirex lure) will be repeated in the same locations in the fall of 2016. Results will be used to improve the SPB prediction system.





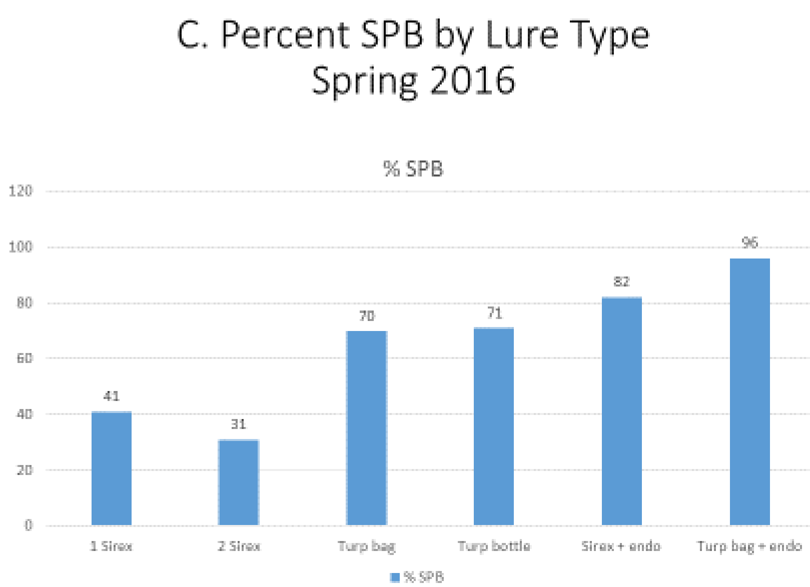


Figure 19: Results of spring bioassays to test the attractiveness of different pheromone lures for southern pine beetle and clerids; **A:** Numbers of SPB (*Dendroctonus frontalis*) and clerids (*Thanasimus dubius*) caught by lure type for all 8 locations combined; **B:** Percent of total catch of SPB by trap location and lure type; **C:** Percent SPB (SPB/SPB + clerids) by lure type for all 8 locations combined. February-April 2016.

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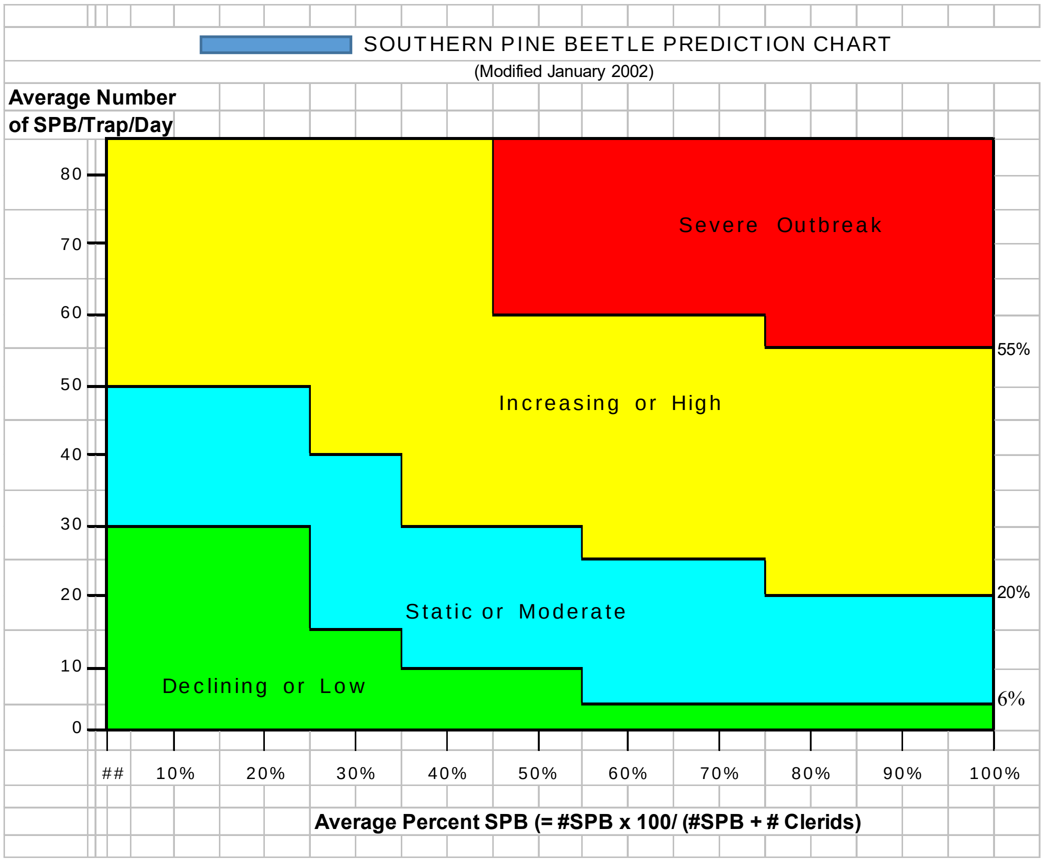
SPB PREDICTION CHART



PRELIMINARY EVALUATION OF BOTANIGARD™ (a.i. *Beauveria bassiana*) FOR LONGEVITY AND CONTROL OF SOUTHERN PINE BEELE

Initiated in 2016

Cooperators: Brian Strom and Rabiu Olatinwo, US Forest Service, Southern Research Station

Funding: FPMC

Objectives:

The objectives of this study are to:

1. Evaluate the duration of Botanigard™ 22WP on loblolly pine logs under various environmental conditions in east Texas.
2. Conduct a preliminary assessment of the efficacy of Botanigard 22WP for control of southern pine beetle populations using standing loblolly pine trap trees in Mississippi.

Methods:

Objective 1: This study will be conducted on state and private forestlands in East Texas. In May (spring-summer conditions), and November (fall-winter conditions), the following trial will be established. Six log sections, each 4-feet in length, will be cut from two 8-inch loblolly pine trees and treated with Botanigard. Two log sections will be placed horizontally under each of the following conditions: full sun, partial shade, and full shade in a typical pine forest. The treated logs will be sampled at intervals of 4, 8, 12 and 16 weeks following treatment by removing 100 square cm samples of bark from the upper and lower surfaces of each log. Samples will be sent to Rabiu Olatinwo (Southern Research Station) to sample for *Beauvaria bassiana* presence and activity.

Objective 2:. There will be two treatments conducted on the Bienville National Forest in Mississippi; a Botanigard treatment and a control. The treatments will consist of two loblolly pine trees each applied during the late spring of 2016..

Pines to be treated will be sprayed from the ground with 4 liters of Botanigard formulation to contain a nominal $8X10^7$ conidia/ mL. The Botanigard mix will include:

- 20 liters clean water
- 450g of *Beauveria bassiana* (Bb) wettable powder formulation
- 10ml Silwet L-77 Ag (.05% final concentration)
- 2ml of biologically benign Sigma life sciences Antifoam O-30 at a concentration of 1% previously mixed into cold water.

The spore formula will be mixed/shaken vigorously in 20 L plastic carboys 1-2 hours before use and mixed repeatedly thereafter.

Botanigard will be applied using a Solo hand pump backpack with an adjustable spray tip. Spray using this backpack has been found to reach approximately 8 m (Products).

At the time of application, trees will show no evidence of southern pine beetle attack. Trees will be sprayed vertically with the narrowest pattern in short controlled bursts onto each aspect of tree as high as possible until wet and just starting to drip, but not running. The spray will then be adjusted to a narrow cone for the middle range (10'-20'), moving to every face of tree until wet. Finally, standing farther from the tree and the nozzle will be adjusted to the width of the bottom until wet and dripping slightly, but not washing/running off of tree. Each tree will be checked for dry areas and spot sprayed if necessary.

Treated and control trees will be baited with species specific pheromone attractants (frontalin, Sirex lure, and endo-brevicomin) immediately after application to attract beetles.

Treatment evaluation

Each study tree will be nondestructively sampled every four weeks through the end of November following application of Botanigard. Following successful colonization and progeny emergence, all study trees will be felled. Bark plates 20 X 25 cm (500 cm^2) will be collected at approximately 1.5, 4 and 7 m in height at northern and southern aspects. Southern pine beetle gallery length and density of emergence holes will be measured.

The average number of SPB attacks, the density of emergence holes, and lengths of galleries per 500 cm^2 will be compared between treated and check trees. The number of Bb-infected SPB adults or immature stages and/or predators will be counted and recorded from each bark sample.

Similarly, 100 cm bark samples will be collected at heights of 2, 5 and 8 m from the northern and southern aspects of each treated tree and sent to the Southern Research Station to evaluate presence and level of *Beauvaria bassiana* activity.
The treated logs were sampled at intervals of 4, 8, 12 and 16 weeks following treatment by removing 100 square cm samples of bark from the upper and lower surfaces of each log. Samples were sent to Dr. Rabiu Olatinwo (USDA Forest Service, Southern Research Station) to sample for *Beauvaria bassiana* presence and activity.

Results (Table 33) suggest that the fungal spores don't survive for long periods of time, particularly when exposed to full sunlight and Texas summer heat. No viable spores were found on treated bark after just 4 weeks of exposure to full sunlight on the top of treated logs. When exposed in partial sunlight, 50% of the sampling points had viable spores on the top of logs after 4 weeks, but this percentage dropped to 0 by week 16. On the bottom side of the same logs, 62% of the sampling points had viable spores after 4 weeks, which declined to 25% after 16 weeks.

For logs maintained in full shade, viable spores were detected on 100% of the points sampled on the top of logs after 4 weeks, but none were found at week 16. On the bottom side of shaded logs, viable spores were detected on 100% of the sampling points after 8 weeks, but this level of viability dropped to 50% by week 16. When data for all sampling sites were combined, the average percentage of points with viable fungal spores declined from 67% after four weeks to just 14% after 16 weeks. Whether the viability of *Beauvaria* spores in BotaniGard applications is sufficient to have an effect on southern pine beetle during its 4-5 week life cycle within host trees was the objective of a field test applied to standing trees colonized by SPB.

Table 33: Percent of four sampling points per 100 cm2 with viable spores of *Baeuvaria bassiana* under different environmental conditions in East Texas (June-October 2015).

Week	4	8	12	16
Full sun/top	0%	0%	0%	0%
Full sun/bottom	37%	75%	12%	25%
Partial shade/top	50%	37%	37%	0%
Partial shade/bottom	62%	100%	12%	25%
Full shade/Top	100%	37%	50%	0%
Full shade/Bottom	87%	100%	50%	50%

A preliminary evaluation of the effectiveness of BotaniGard™ for control of southern pine beetle was conducted on the Oakmulgee National Forest in Alabama in June, 2015. Two pines were treated with BotaniGard 22 WP from ground level to a height of 12 feet using a backpack sprayer. On the same day, the treated trees were baited with SPB lures (frontalin and alpha-pinene) to induce attacks. The trees were monitored until the crowns began to fade, indicating successful SPB. Colonization. Examination of bark samples taken at heights of 4 and 10 feet revealed no apparent treatment effect (Table 34). Beetles had attacked the baited trees at typical densities and SPB brood developed and emerged at densities comparable to baited trees without BotaniGard™ application.

Table 34: Summary of 2015 BotaniGard SPB Trap-tree Trial

Height	Treatment	SPB Attacks #	SPB Emerg. holes #	Cerambycid egg niches #	Mean/100 cm2 SPB egg galleries (cm)
1.5 m	BotaniGard	3.2	30	0.5	114
	Check	3.5	17	0.2	75
4 m	BotaniGard	2.7	47.2	1.2	76
	Check	2.3	26.5	1	100
6.5 m	BotaniGard	2.5	48.5	1.7	51
	Check	2	22.5	1.2	75
15 m	BotaniGard	0.7	18.7	0.7	75
	Check	2.2	20.5	1.7	17
Mean	BotaniGard	2.3	36.1	1.02	79.0
	Check	2.5	21.6	1.02	66.7

EVALUATION OF MACRO- AND MICRO-INJECTION SYSTEMS FOR APPLICATION OF PROPICONIZOLE IN LIVE OAK TO PREVENT OAK WILT

Initiated: 2016

Sponsor: USDA Forest Service, Forest Health Protection (Pesticide Impact Assessment Project)

Grant: $58,000 for 3 years (shared between FPMC and TAMU Department of Plant Pathology and Microbiology)

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Abstract:

This project will compare the effectiveness of macro- (high volume, low concentration) versus micro-injection (low volume, high concentration) systems for treating live oak trees with propiconazole for prevention of oak wilt, caused by the vascular fungus *Ceratocystis fagacearum*. The field trials will be conducted in central Texas on the leading edge of expanding oak wilt centers.

Objectives:

1) Evaluate effectiveness of macro-infusion compared to one micro-infusion (the Arborjet's Tree I.V.) system for injecting propiconazole (Alamo® or Propizol™) into live oak for prevention of oak wilt.
2) Evaluate the standard macro-infusion system versus one micro-infusion system (Tree I.V.) for speed and distribution of propiconazole movement within live oaks by monitoring uptake and movement of the fungicide in study trees at periodic intervals following injection.

Background/Justification Statement: Several cultural control techniques (minimize fungal inoculum, timing of branch pruning, painting wounds and pruning cuts on oaks, prompt removal of infected red oaks, and root disruption/trenching around expanding infection centers, among others) are available for management of oak wilt, caused by the plant pathogen, *Ceratocystis fagacearum* (Billings, 2001, Koch et al. 2010). However, these techniques are often impractical for treatment of high value individual trees or small groups at risk to infection. Currently, the most widely used treatment recommended for protecting high-value oaks is high volume treatments of the systemic fungicide propiconazole (Alamo®) diluted in water injected at the lower stem or root flare of trees (Appel and Kurdyla 1992, Appel 1995). Until recently, applications of propiconazole have been made almost exclusively through the use of macro-injection systems to deliver 20ml Alamo® diluted in 1 liter water per inch tree DBH. The intent is to saturate the xylem tissue of the root collar with fungicide to prevent movement of the pathogen into the above ground area of the trees. The treatment is often effective in preventing tree death for about 2 years in red oaks and longer in live oaks (Blaedow et al. 2010), but is labor intensive to perform. It often involves exposing root flares with an air spade or other tool. Arborists are interested to know if propiconazole can be applied at more concentrated levels to the lower trunk of live oak trees using available micro-injection/infusion systems and whether these applications are effective in preventing/reducing fungal infection and spread within the host. An initial comparison of various micro-infusion systems revealed that the Arborjet Tree I.V. system outperformed several other commercially available systems for injecting propiconazole into live oak (Grosman et al. 2015). Propiconazole is one of the fungicides undergoing Forest Service Health and Ecological Risk Assessment and is being reviewed by U. S. EPA for reregistration. Propiconazole is the fungicide most effective in preventing oak wilt and few other fungicide alternatives exist for this specific purpose. A new formulation of propiconazole, sold under the trade name Propizol by Arborjet, Inc., also will be tested. Propizol contains the same concentration of propiconazole as Alamo (14.3%), but has a different carrier.

Expected Accomplishments:

1. A side-by side comparison of two injection systems (macro- versus micro-) will demonstrate the advantages and disadvantages of each system for delivery of the fungicide propiconazole.
2. The field comparison will determine which system provides better distribution of propiconazole within the tree and corresponding prevention of oak wilt infection in live oaks challenged by oak wilt.

Research Approach:

One microinjection system and one macro-injection system will be evaluated:

<u>Tree IV</u> System (Arborjet, Inc.; contact: Joe Doccola) – low volume (20 ml fungicide/injection point); moderate pressure (60 psi)

<u>Macro Injection</u> System (Standard) (Rainbow Treecare Scientific Advancements; contact: Shawn Bernick) - high volume (1 liter water and 20ml fungicide/inch diameter); low pressure (20 - 30 psi)

A portion of the treated trees will be injected with Alamo® and a similar number will be injected with Propizol™, using both injection systems to determine if treatment effectiveness varies due to formulations produced by the two manufacturers (Syngenta and Arborjet).

<u>Treatment Methods and Evaluation</u>**:**

A Master's student at Texas A&M University will be employed to conduct the field and laboratory evaluations proposed herein. The study will be conducted in central Texas within untreated, expanding oak wilt centers on privately-owned property within the range of live oak and oak wilt in central Texas (specific locations to be determined). Non-symptomatic test trees (ca. 120), ranging from 15 to 46 cm (6 – 18 in) dbh (diameter at breast height), will be selected in proximity with trees showing oak wilt symptoms (veinal necrosis). In July and August, 2016, a minimum of forty (40) trees per delivery system will be injected with Alamo® (Syngenta) or Propizol™(Arborjet) at the label rate (20 ml/inch tree dbh) using the two systems described above. Forty (40) trees (5 trees per study site) will serve as untreated controls. The application procedure used to inject the propiconazole formulation will be based on the recommendations of each system manufacturer. The injected trees will be selected according to proximity to symptomatic trees naturally infected with *Ceratocystis fagacearum*. All of the injected or check trees will be located adjacent to the infected trees, at a distance of at least 50 - 75 ft but exhibiting no symptoms of oak wilt infection. The treatment will therefore be tested under conditions of natural infection with the pathogen.

Foliage samples will be removed from macro- and micro-injected trees 1 day, 1 week, and 1 month after infection to assay them for the presence of the fungicide. A bioassay will be used to estimate the relative levels of the funigcide in the leaves by extracting the tissues with a mix of organic solvents and processing the extract on thin layer chromatography plates. The dried plates will be oversprayed with a suspension of a dark-spored fungus, a *Cladosporium* spp. Inhibition of fungal growth will appear on the plates, providing evidence for the presence of fungicide in the original foliar tissues. A minimum of 10 samples to a maximum of 30 samples will be collected from the crowns, depending on the diameters of the trees.

Trees will be evaluated for oak wilt symptoms after one, six, twelve and eighteen months. Each oak crown will be given a rating of 0 (healthy), 1 (wilt symptoms comprising up to one-third of the crown), 2 (wilt symptoms comprising greater than one-third of the crown) (Mayfield et al. 2008), or 3 (dead tree). At each rating period, trees with a crown rating of 2 may be sampled from the stem and branches to determine the presence of *Ceratocystis fagacearum*.

At the termination of the experiment in June 2018, final crown ratings will be made. An analysis of variance will be used to test for differences among injection systems. A χ^2 (Chi-square) test for homogeneity will be used to test the null hypothesis that the percentage of trees with a crown rating of 2 did not differ between the fungicide-treated trees and the untreated control group (Mayfield et al. 2008). The null hypothesis will be rejected if more than 20% of the fungicide-treated trees reached a crown rating of 2. The test will be invalidated if fewer than 60% of the control trees reach a crown rating of 2.

Research Timetable:

CY 2016

<u>July, 2016</u>

- Select five study sites (expanding oak wilt centers on private land). Within each study site, select 120 study trees (80 trees of each treatment and 40 check trees)
- Inject each set of trees with either the macro- or the micro-injection system (excluding check trees)
- Collect foliage from injected trees for fungicide bioassay.

<u>May - December, 2016</u>

- Monitor for tree decline (June - October)
- Sample infected trees to confirm presence of *Ceratocystis fagacearum*.
- Conduct statistical analyses of data (November)
- Prepare and submit progress report to US Forest Service (December).

CY 2017

<u>April - December, 2017</u>

- Monitor for tree decline (April - October)

PART III

URBAN FOREST HEALTH SURVEY FOR TEXAS

The health of urban forests and residential trees in Texas is being threatened by a variety of environmental and pest issues, including a number of non-native, invasive species. To assess which forest health issues rank highest among Texas arborists and as a basis for identifying urban forest health research needs, the Texas A&M Forest Service's Forest Pest Management Cooperative (FPMC) prepared a two-page questionnaire in 2015. Results of this survey are summarized below.

Methods: The questionnaire consisted of five questions designed to identify the most important forest health issues facing urban foresters and arborists in the different regions of Texas. This questionnaire was distributed to active members of the International Society of Arboriculture as an on-line survey. Also, hard copies of the survey were distributed at the 2015 Texas Tree Conference, held September 30-October 1 in Waco, Texas.

Results: Results of this survey (Table 35) are based on a total of 64 responses, 10 of which were received in response to the on-line survey and the remainder from participants attending the Texas Tree Conference. Thirty-eight of the respondents (59%) worked in Central Texas, 7 (11%) in South Texas, 8 (12%) in East Texas, 6 (9%) along the Gulf Coast, and 5 (8%) in West Texas. Due to the small number of participants, all regional responses were combined for this analysis.

Question 1: Rank the following eighteen pest problems with regard to their relative importance as a pest of Texas trees in your region, where A = very important, B = occasionally important, C = seldom or never a problem, and D = I am unfamiliar with this one.

To rank the forest health issues, responses for A (very important) were assigned 6 points, B (occasionally important) were assigned 4 points, C (seldom or never a problem) were given 2 points, and D (unfamiliar) were given 0 points. The maximum possible was 276 points. The number of responses for each category, together with the total scores for each pest are listed in Table 1. The forest health issues were ranked in descending order in Table 1 by the total number of respondents who considered the pest problem very important (category A).

The top three pest problems were hypoxylon canker of hardwoods, oak wilt, and invasive plants; each of these were classified by more than half the respondents as very important. These were followed in rank by root and stem diseases, sucking insects, and wood borers (including emerald ash borer – an invasive pest of ash trees not yet detected in Texas). The five pest problems ranking lowest in relative importance were herbicide damage, bagworms, conifer defoliators, twig girdlers, and hardwood defoliators other than caterpillars (katydids, grasshoppers, June bugs, etc.).

Question 2: Which two invasive, non-native forest health problems affecting urban trees do you think the FPMC should address?

The three most common responses to this question were 1) invasive plants (45 responses), emerald ash borer (34 responses), and climate change effects on trees (10 responses). Other topics receiving a few votes (3 or less) included soapberry borer, Afghan pine chalcid, thousand cankers disease, laurel wilt, and scale insects.

Question 3: What are two invasive, non-native plants that most affect urban forests in your region?

The top three invasive plants were Chinaberry (24 responses), non-native privets (24 responses), and Chinese tallow (18 responses). Responses to this question tended to vary markedly with region. Accordingly, Brazilian pepper and Chinese tallow are common problems along the Gulf Coast, while saltcedar is common in West Texas. Chinaberry and privet were mentioned as important invasive plants in most regions of Texas.

Question 4: Which single insect or disease problem or forest health issue would you most like to have the FPMC address through applied research?

Most respondents had no specific opinion, but among those responses received to this question, the number one choice was oak wilt (15 responses). This was followed in order by hypoxylon canker (8 responses), Phytophthora root rot (7), wood borers, such as emerald ash borer (6), conifer bark beetles (2) and Texas leafcutting ant (2).

Question 5: Which of the following services would you like to have the FPMC provide in addition to applied research? Options are 1) leaflets on urban forest pests describing diagnosis, biology, and control; 2) web-based information on urban tree health issues; 3) workshops on forest health issues/pesticides applications; 4) a periodic newsletter on current or potential forest health/tree pest issues; and 5) presentations on FPMC research results at the Texas Tree Conference. Label as A = urgently needed; B = may be helpful, but I have other sources available, C = not needed.

Responses to question 6 are summarized in Table 35. To weight the various options, category A was assigned 6 points, category B was assigned 3 points, and category C merited 0 points for a maximum of 276 points. Ranked using this system of weights, the most interest was in receiving web-based information on forest health issues. This was followed by workshops on forest health issues/pesticide applications, and presentations of FPMC research at the annual ISAT Tree Conference. There was less interest in a periodic newsletter of forest health/tree pest issues or leaflets on urban pests.

<u>Conclusions</u>: Despite the low level of response to this survey, the results provide insight into the forest health problems considered most important by urban foresters and professional arborists in Texas as well as research needs. Two diseases (hypoxylon canker and oak wilt) and invasive plants rank at the top of the list of urban tree pests. No doubt, the severe droughts suffered in Texas since 2011 are responsible for an abundance of hardwoods affected by hypoxylon canker, usually considered a secondary pest associated with drought-stressed hardwood trees. Oak wilt, primarily a forest health concern in Central Texas, has been the subject of research and suppression programs for many decades in Texas.

Root and stem diseases and invasive plants were identified as common problems that warrant more applied research. Also, invasive pests, such as emerald ash borer, laurel wilt, and thousand cankers disease, that have the potential to damage or kill Texas trees if they become established are capturing the attention of many arborists. With the exception of several arborists in Central Texas, deer damage was not ranked as an important issue by most respondents, nor was herbicide damage.

Also, conifer bark beetles ranked low among respondents, perhaps due to the lack of southern pine beetle outbreaks in East Texas in recent decades or the fact that most Texas urban landscapes are dominated by hardwood trees.

Among the research needs that were identified, the FPMC has previously conducted research on oak wilt, hypoxylon canker, conifer bark beetles and Texas leafcutting ants and additional studies are being planned. Based on the results of this survey, applied research on invasive plants, emerald ash borer and *Phytophthora* root rots as pests of urban trees should be considered in future FPMC research plans. In addition to applied research on urban forest health issues, most respondents were in favor of web-based information and local workshops on urban tree pests. But the presentation of FPMC research results at the annual Texas Tree Conference and a periodic newsletter on urban tree health also was supported by most respondents.

Acknowledgements: The author expresses thanks to John Giedraitis, Executive Director of the Texas Chapter, International Society of Arboriculture, for formatting and distributing the forest health survey to members of ISAT. Also, this study would not have been possible without the urban foresters and professional arborists who took the time to respond to the survey. Their opinions, effort and contributions are appreciated.

Urban Forest Health Questionnaire

Purpose: The Forest Pest Management Cooperative (FPMC), administered by the Texas A&M Forest Service, has been conducting applied research on forest pest problems of pine seed orchards and commercial pine forests in East Texas since 1996. As it enters its third decade, the FPMC plans to expand its research and technology transfer efforts to address forest health issues affecting urban trees and forests throughout Texas. This questionnaire is being distributed to you and other Texas urban foresters and certified arborists as a means to identify the major forest health issues currently affecting Texas trees or those agents that pose a future threat. Results of this survey will be used to establish FPMC research priorities.

Survey: Please take a few minutes and record your opinions concerning tree pest or health issues in your region of Texas. Listing your name and organization (company) below is optional. Individual responses will remain anonymous.

1. In what general region(s) of Texas do you work? ____ East Texas; ____ Central Texas; ____Gulf Coast; ____ South Texas; ____ Panhandle; ____West Texas.

2. Please rank the following pest problems with regard to their relative importance as a pest of Texas trees in your region, where A = very important; B = occasionally important; C = seldom or never a problem; and D = I am unfamiliar with this one.
   ____ hardwood defoliating caterpillars (cankerworms, fall webworm, etc.)
   ____ other hardwood defoliators (katydids, grasshoppers, June beetles, etc.)
   ____ sucking insects (aphids, scales, thrips, spider mites)
   ____ herbicide damage
   ____ foliar or leaf diseases
   ____ pine and other conifer defoliating insects
   ____ hypoxylon canker of hardwoods
   ____ Texas leafcutting ants
   ____ root and stem rots
   ____ oak wilt
   ____ leaf or stem galls
   ____ bacterial leaf scorch
   ____ conifer bark beetles (on pine, cedar)
   ____ twig girdlers
   ____ invasive plants
   ____ bagworms
   ____ deer
   ____ wood borers (oak borer, carpenterworm, etc.)
   ____ other (specify)

3. Among the following, which two (2) invasive, non-native forest health problems affecting urban trees do you think the FPMC should address?
    ____ invasive plants
    ____ soapberry borer
    ____ Afghan pine chalcid wasp
    ____ emerald ash borer
    ____ laurel wilt
    ____ climate change effects
    ____ thousand cankers disease
    ____ other (specify)

4. What are two invasive, non-native plants that most affect urban forests in your region?
   a) ________________________________; b) ________________________________

5. Which single insect or disease problem or forest health issue would you most like to have the FPMC address via applied research?
   ____

6. Which of the following services would you like to have the FPMC provide in addition to applied research? Label as A= urgently needed; B = may be helpful, but I have other sources available; C = not needed.

   _____ leaflets on urban tree pests describing diagnosis, biology and control;

   _____ web-based information on urban tree health issues;

   _____ workshops on forest health issues/pesticide applications;

   _____ periodic newsletter on current or potential forest health/tree pest issues

   _____ presentations on FPMC research results at the Texas Tree Conference

   _____ other (specify): ____

Name: (optional): ________________ Company/Agency (optional): ______________________

Thank you for your cooperation.

Please return the completed questionnaire by August 1, 2015 to Dr. Ronald Billings by e-mail at rbillings@tfs.tamu.edu or fax to (979) 458-6655.

Table 35: Urban Forest Health Survey Results - Forest Pest Management Cooperative, December 9, 2015

(Based on 64 responses from Texas arborists and urban foresters)

Question		Responses	A 6 pts.	B 4 pts.	C 2 pts.	D 0 pts.	Total Score
1	Region of work	64					
	East Texas	8					
	Central Texas	38					
	Gulf Coast	6					
	South Texas	7					
	West Texas	5					
2	Forest Health Issues		A	B	C	D	Total
	Hypoxylon Canker		39	13	11	1	308
	Oak Wilt		34	9	20	1	280
	Invasive Plants		30	21	13	0	290
	Root & Stem Diseases		29	20	14	1	282
	Sucking Insects		28	23	13	0	286
	Wood Borers		18	31	14	1	260
	Foliar Disesaes		17	28	19	0	252
	Deer		15	11	36	2	206
	Conifer Bark Beetles		12	13	33	6	190
	Foliar & Stem Galls		11	27	23	2	220
	Hardwood Caterpillars		10	40	13	1	246
	Texas leafcutting Ant		9	15	38	2	192
	Herbicide damage		9	23	32	0	210
	Bagworms		5	32	27	0	212
	Conifer Defoliators		6	7	47	4	158
	Twig Girdlers		4	22	35	3	182
	Other Hardwood Defoliators		3	21	38	2	178
3	FPMC to Address		Number				
	Invasive Plants		45				
	Emerald Ash Borer		34				
	Climate Change Effects		10				
	Soapberry Borer		4				
	Afghan Chalcid		2				
	Thousand Cankers Disease		2				
	Laurel Wilt		2				
4	Most Important Invasive Plants						

Chinaberry	24			
Privet	24			
Chinese Tallow	18			
Heavenly Bamboo	2			

5 Research Needs

Oak Wilt	15
Hypoxylon Canker	8
Phytophthora Root Rot	7
Borers (EAB, etc.)	6
Conifer Bark Beetles	2
Texas Leafcutting Ant	2

6 FPMC Contributions

	A 6 pts.	B 3 pts.	C 0 pts.	Total
Web-based Information	40	20	3	300
Pest Workshops	34	24	2	270
Presentations at Tree Conference	33	24	4	270
Pest Newsletter	25	29	6	237
Pest Leaflets	23	27	12	219

2015 FPMC RESEARCH SURVEY

Introduction and Methods

In September 2015, a two-page questionnaire was sent to Executive and Contact Team representatives of the Forest Pest Management Cooperative (FPMC) as a means to identify research priorities. The 12 questions are listed below. Each responder was asked to assign a value to each question, as follows: A = Of high importance to my organization and should be pursued by the FPMC; B = May be of interest to my organization, but we would need a more detailed proposal; C = Not of interest to my organization at this time, but may be of interest to other FPMC members.; and D = Of no interest to my organization and not recommended as a research topic for the FPMC. To rank the responses, each response of A was assigned 6 points; B = 4 points; C = 2 points; and D = 0 points.

Results

Twelve responses were received from 10 members, all but two from Executive Team representatives. The Texas A&M Forest Service and Anthony Forest Products Company did not participate in this survey. The individual responses, the total points, and the ranking for each question (based on total points) are listed in Table 36.

The topic receiving the highest point total (54 points) was the evaluation of new insecticides (Sivanto™ and XXpire WG™) for control of insects in pine seed orchards. This topic was followed closely (50 points each) by 1) evaluating combinations of herbicides and/or prescribed burns for control of invasive plants in forestry situations; and 2) assessment of fungicides for control of cone rust in pine seed orchards.

There also was a tie for the fourth and fifth ranked proposals (48 points each): evaluating the potential use of drones (unmanned aerial vehicles) in forest pest management; and monitoring 10-15 year-old FPMC tip moth impact (treated in first two years) and untreated plots to determine long-term effects of early chemical control on tree volume growth and form.

Evaluation of new toxic baits for Texas leaf cutting ants remains of interest among several members. This topic, with 46 points, ranked sixth in relative importance. In turn, evaluating the potential use of systemic injections of emamectin benzoate for control of small southern pine beetle infestations with or without felling trees ranked seventh (38 points).

The remaining potential research topics proved of less interest among responders as a whole, totaling less than 35 points each. These, listed in descending order by total points received, were as follows:

- Development of a control tactic using emamectin benzoate and pheromones for maintaining southern pine beetle populations at non-outbreak levels (trap tree concept) (34 points)
- Establishing trials in different geographical regions with pine seedlings from different provenances to ascertain potential effects of changing weather patterns on level of tip moth damage (34 points)
- Developing improved pheromone/host odor baits for more accurately predicting southern pine beetle outbreaks (30 points)
- Comparing the relative effectiveness of micro- and macro-injection systems for injecting systemic fungicides to prevent oak wilt in live oaks (22 points).

- Testing systemic fungicides for prevention of hypoxylon canker in hardwood trees within urban landscapes (16 points).

The last question pertained to research topics not included in the questionnaire. Several members took advantage of this option to list research topics of interest to their organization. These included, in no particular order:

1. Pine decline
2. Genetic interactions and insects
3. Fusiform rust-Why we are seeing no decrease infection with new assessment?
4. Collaborate with other universities on disease and insect issues- UGA, U.F, Auburn. They have people on staff working on these issues.
5. Export and import of wood chemicals
6. Bareroot machine planting with injection of PTM
7. Carbon dioxide increase and its effects on insects and disease as well as other climate changes.
8. Evaluation of PGRs for fruit reduction, increased cone production, and or growth management.
9. Test new formulations of emamectin benzoate and or experimental active ingredients for bark beetles, cone and seed insects,
10. Emerald ash borer – using egg parasites for control or reduction of spread
11. Brown spot or needle cast in older loblolly plantations – evaluation and treatment
12. Provide all tip moth hazard rating and impact data on a CD or flash drive to those members that want it (and coop data for all past research as well).
13. Tip moth research on older trees that have exceeded the 10 foot height threshold. I have noticed a lot of trees recently that were near 20 feet tall heavily infested.
14. Sawfly impacts on older, thinned and fertilized plantations. Cyclical or silviculturally produced?
15. Control, if possible, of emerald ash borer.
16. Continue container seedling injection for tip moth control.

Discussion

In interpreting these results, keep in mind that the responders were principally FPMC members with vested interests in commercial pine forestry. Thus, research on seed orchard pests, invasive plant control, and leaf cutting ants are seen as important needs, whereas injections of fungicides for oak wilt and hypoxylon canker ranked very low.

The FPMC conducted trials of Sivanto™ and XX-pire™ insecticides against seed orchard insects in 2015 and results are discussed in this accomplishment report. A proposal to repeat the study in 2016 was prepared and submitted to the US Forest Service/Forest Health Protection as a Pesticide Impact Assessment Program (FS-PIAP) project but failed to be funded.

The FPMC also has prepared and submitted research proposals for outside funding on 1) treating small southern pine beetle infestations with emamectin benzoate injections for control, with or without tree felling (not funded in 2016); 2) improving southern pine beetle prediction system (in progress), controlling small SPB spots with systemic injections (not funded in 2016); and 3) comparison of micro- versus macro-injection systems for prevention of oak wilt (in progress).

Responders requested more detailed research proposals on several listed topics, primarily on 1) control of invasive plants; 2) use of drones in forest pest management; and 3) evaluation of new toxic baits for Texas leafcutting ants.

Finally, responders listed a myriad of additional research topics, with no common theme. Each of these will be taken into consideration as topics for future FPMC research, as time and available staff permit. Some of these topics are subjects of current research at other southern forest health cooperatives. For example, pine decline is being investigated by the forest health cooperative at Auburn. And the US Forest Service is conducting research and field investigations on control of emerald ash borer, invasive plants, and other invasive forest health issues. The FPMC coordinator maintains contact with these investigators.

As suggested, the FPMC is in the process of accumulating data from all its previous research in a single location, to satisfy the requests of those members that want a copy of these data files. Compiling such a massive data base, covering numerous research projects over twenty years, will take time and collaboration with the previous two FPMC coordinators.

We thank all those members who expressed their opinions by responding to this questionnaire and appreciate their continued support of the FPMC.

Potential Research Projects for the Forest Pest Management Coop in 2016-2018

FPMC Member: __________________________ Name of responder: ___________________

Please rank the following potential FPMC research projects from the point of view of your organization.

Rank as A: Of high importance to my organization and should be pursued by FPMC.
B. May be of interest to my organization, but we would need a more detailed proposal.
C. Not of interest to my organization at this time, but may be of interest to other FPMC members.
D. Of no interest to my organization and not recommended as a research topic for the FPMC.

Rank Title

____ 1. Evaluation of new insecticides (i.e., Sivanto™, XXpire WG™) for control of southern pine seed orchard pests.

____ 2. Development of a control tactic using emamectin benzoate and pheromones for maintaining southern pine beetle populations at non-outbreak levels (trap tree concept).

____ 3. Evaluating use of systemic insecticides (emamectin benzoate) for control of small southern pine beetle infestations with or without felling trees.

____ 4. Developing improved pheromone/host odor baits for more accurately predicting southern pine beetle outbreaks.

____ 5. Comparing the relative effectiveness of micro- and macro-injection systems for injecting systemic fungicides to prevent oak wilt in live oak trees.

_____ 6. Evaluating the potential use of drones (unmanned aerial systems) in forest pest management for monitoring the health of plantations or urban forests and other pest management applications.
_____ 7. Evaluation of new toxic baits to control Texas leafcutting ants.
_____ 8. Testing systemic fungicides for prevention of hypoxylon canker in hardwood trees within urban landscapes.
_____ 9. Evaluating combinations of herbicides and/or prescribed burns for control of invasive plants (Japanese climbing fern, Chinese privet, Chinese tallow, etc.) in forestry situations.
_____ 10. Monitoring 10-15 year-old FPMC tip moth impact (treated in first two years) and untreated plots in Texas, Louisiana and Arkansas to determine long-term effects of early chemical control on tree volume growth and form.
_____ 11. Establishing trials in different geographical regions with pine seedlings from seed sources in Bastrop, Texas (drought-hardy), SE Texas, NE Texas and Arkansas to ascertain potential effects of changing weather patterns on level of tip moth damage.
_____ 12: Assessment of fungicides for control of cone rust in pine seed orchards.
_____ 13. Other forest health issues that interest my organization warranting research are (Specify):

Table 36: FPMC Research Survey Results December 2015

	Member**													
Question	1	2	3	4	5	6	7	8	9	10	11	12	Total* points	Rank
1	A	A	C	B	C	A	C	B	A	A	B	A	54	1
2	D	C	B	C	B	C	A	B	B	C	C	C	34	8,9
3	B	C	B	C	B	C	A	B	B	C	C	C	38	7
4	D	C	B	C	B	C	C	B	B	C	C	C	30	10
5	C	D	C	D	C	C	A	A	D	C	D	D	22	11
6	B	B	D	B	A	B	C	A	A	B	A	B	48	4,5
7	B	B	C	A	A	B	C	B	A	C	C	B	46	6
8	C	D	C	D	C	D	A	B	D	D	D	D	16	12
9	B	B	B	B	A	D	B	B	B	A	B	C	50	2,3
10	C	A	B	A	B	D	C	C	A	B	A	A	48	4,5
11	C	C	D	B	B	C	C	C	A	B	C	B	34	8,9
12	B	A	C	C	C	B	B	B	A	A	B	A	50	2,3
	34	38	30	36	46	28	44	48	52	40	34	38		

* A = Of high importance to my organization; FPMC should pursue (6 points)
B = Of interest to my organization, but need detailed proposal (4 points)
C = Not of interest to my organization, but may be to other members (2 points)
D = Not recommended, FPMC should not pursue (0 points)

** FPMC Member/Responder

1 = Campbell Global (Bill Stansfield, Greg Garcia)
2 = Rayonier (Becki Stratton)
3 = FIA (Tom Trembath)
4 = Hancock (David Wilkinson)
5 = Hancock (Regan Bounds)
6 = International Forest Company (Wayne Bell)
7 = Arborjet (Don Grosman)
8 = US Forest Service (Forrest Oliveria)
9 = Weyerhaeuser (Wilson Edwards)
10 = Plum Creek (Conner Fristoe)
11 = Plum Creek (Terri Galinski)
12 = Arborgen (Mike Cunningham)