Forest Pest Management Cooperative

Research Accomplishments in 2010

Prepared by:

Dr. Donald M. Grosman, Research Coordinator
Dr. Ronald F. Billings, Administrative Coordinator
William W. Upton, Staff Forester II
Billi Kavanagh, Research Specialist I
Larry Spivey, Staff Assistant I

Texas Forest Service, Forest Health
P.O. Box 310, Lufkin, TX 75902-0310
Phone: (936) 639-8170, -8177; FAX: (936) 639-8175
E-mail: dgrosman@tfs.tamu.edu, rbillings@tfs.tamu.edu,
bupton@tfs.tamu.edu, bkavanagh@tfs.tamu.edu, lspivey@tfs.tamu,edu

2010 FPMC Members

Anthony Forest Products Company
ArborGen, LLC.
CellFor Inc.
Forest Investment Associates
Hancock Forest Management Inc.
International Forestry Company
North Carolina Division of Forest Resources
Plum Creek Timber Company, Inc.
Potlatch Forest Holdings, Inc.
Rayonier
Texas Forest Service
The Campbell Group
U.S.D.A. Forest Service - Forest Health Protection R8
Weyerhaeuser Company

April 2011

Table of Contents

Forest Pest Management Cooperative
Research Accomplishments in 2010

Executive Summary

The Forest Pest Management Cooperative (FPMC) made significant strides in 2010. A brief summary of FPMC activities is given below. Three primary research projects (systemic injection studies, tip moth impact/hazard/control, and leaf-cutting ant control) were continued from 2009. We also revisited weevil control and expanded into imported fire ant and invasive pest control. These projects contained **32** smaller studies that were initiated, continued and/or completed. Separate detailed reports for each study are attached. The purpose of this report is to provide executive committee members with an update on research findings and a basis for evaluating the merits of the attached 2011 Project Proposals.

Several changes occurred in the FPMC membership in 2010. North Carolina Division of Forest Resources, International Forestry Company, and CellFor Inc. joined as associate members in 2010. James West will represent North Carolina Division of Forest Resources, Wayne Bell and Chris Rosier will represent International Forestry Company, and Nick Muir will represent CellFor on the Executive Committee. **Thank you to all members for your continued support!**

William Upton, our staff forester, continued to manage the systemic insecticide injection and leaf-cutting ant trials, while Billi Kavanagh, research specialist, is managing the tip moth and weevil projects. Staff Assistant, Larry Spivey, and seasonals Niko Battise, Penny Whisnent, James Fox, Chris Bartley, and Regine Skelton provided assistance with field and lab studies. Southern Pine Beetle Prevention Foresters Mike Murphrey and Aleksandar Dozic assisted with cone evaluations and GPS/GIS work. We also greatly appreciate the time and effort provided by member representatives on the various projects. They are acknowledged in each report.

Service to members has always been an important part of the FPMC. To this end, four issues of the *PEST* newsletter were prepared and distributed in 2010. Two manuscripts (tip moth and tree injection) were published. Also, 11 presentations, 20 meeting requests, 4 training sessions, and 96 phone/e-mail requests were addressed relating to the following topics: leaf-cutting ants, pine tip moths, reproduction and deodar weevils, cone and seed insects, bark beetles (*Ips* engravers, black turpentine beetle and mountain pine beetle), fall webworm, scales, aphids, saltcedar beetle, soapberry borer, pitch canker, Afghan pine chalcid wasps, and needle cast disease.

In 2010, rainfall was below normal in many locations across the South (Table 1). Lufkin, which normally receives 46+ inches of rainfall per year, finished the year a little more than 16 inches below average. Similarly, AR, LA, MS, VA, NC, SC, northeast FL and southeast GA had large deficits (Table 1). In contrast, other areas (AL, western FL, and central GA) had more rainfall. Thankfully, no significant hurricanes made landfall in the South in 2010.

The Texas leaf-cutting ant can be a significant pest in newly-planted pine plantations. A new product, PTM™ was registered for use against leaf-cutting ants in December 2009. Several companies have begun using this product in 2010 and all have reported excellent results. New modified (larger) Amdro® bait was developed in 2009 in cooperation with Central Garden and Pet (CGP). Efficacy trials demonstrated that this new bait was significantly more effective in

Table 1: Total rainfall (inches) at locations across the South compared to annual average: 2005 - 2010. (Black is surplus and red is a deficit)

Location	2005	2006	2007	2008	2009	2010	Average	10 to Avg Difference
Lufkin, TX	27.26	41.08	50.49	40.63	55.19	30.01	46.02	-16.01
Monticello, AR	26.96	---	37.61	51.58	68.21	32.27	55.33	-23.06
Alexandria, LA	33.45	53.62	47.92	57.02	55.53	37.31	61.44	-24.13
Jackson, MS	---	41.92	32.63	54.55	58.79	37.84	58.64	-20.80
Birmingham, AL	49.27	56.55	28.86	55.64	71.66	47.89	52.16	-4.27
Macon, GA	47.54	34.45	39.85	48.14	61.63	44.13	45.00	-0.87
Richmond, VA	40.84	53.29	37.90	48.90	48.32	35.86	44.10	-8.24
Raleigh, NC	37.56	53.69	35.81	50.22	40.43	36.94	46.55	-9.61
Columbia, SC	39.44	38.95	30.19	46.38	49.15	35.92	50.14	-14.22
Tallahassee, FL	68.36	49.34	44.52	60.28	57.91	58.67	63.21	-4.54

Source: Weather Underground (www.wunderground.com).

completely halting ant activity compared to the standard Amdro® Ant Block treatment after 16 weeks. Additional tests in 2010 showed good efficacy except in the summer trial when drought conditions prevailed. The FPMC has requested that CGP submit this product for EPA registration. Assuming all goes well, this product should be registered for use by summer 2011.

Populations and damage caused by several defoliators, including forest tent caterpillar, oak leaf roller and walnut caterpillars, were light and localized in the Western Gulf Region. However, pine tip moth damage levels increased dramatically on second-year trees from 43% of shoots infested to nearly 59%; numerous locations averaged 100% infested shoots by mid-summer (Figure 1). Coneworm and seed bug pressure were generally stable at moderate levels in 2010 compared to 2009 in several Western Gulf seed orchards. On the positive side, no infestations of the southern pine beetle were reported again in Texas, Arkansas or Oklahoma in 2010 (Table 2), as predicted by early season pheromone traps. Southern pine beetle populations continued to decline on state and national forests in Georgia and South Carolina, but increased slightly in Mississippi and Alabama. SPB infestations were generally stable at low levels in all other southern states. The latest overall trend appears to be generally lower SPB activity. With extensive drought conditions, *Ips* engraver beetle (and in some cases deodar weevil) populations increased dramatically in the Western Gulf Region and Atlantic Coast states, resulting in considerable tree mortality.

Progress continues on the evaluation and development of systemic insecticides and injection systems. Emamectin benzoate continues to be the most effective insecticide tested to date for protection of trees against bark beetles, woodborers, lepidopteran and coleopteran defoliators and several non-native, invasive pests. Several trials have shown effectiveness for 3+ years. Other chemicals, including abamectin and fipronil, also were tested and showed promise against bark beetles.

We also are interested in determining if these chemicals are effective against more aggressive *Dendroctonus* species. Trials established in 2005, 2006 and 2007 in Mississippi and Alabama for southern pine beetle (*D. frontalis*) on loblolly pine, in California for western pine beetle (*D. brevicomis*) on ponderosa pine, in Utah for spruce beetle (*D. rufipennis*) on Englemann spruce,

Figure 1. Extensive 4th generation pine tip moth damage to loblolly pine at end of the third growing season, October 2010, DeRidder, LA.

Table 2: Southern pine beetle infestations by state, 2001 - 2010 and latest trend.

State	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Latest Trend
OK	0	0	0	0	0	0	0	0	0	0	Stable
AR	0	0	0	0	0	0	0	0	0	0	Stable
TX	0	0	0	0	0	0	0	0	0	0	Stable
LA	0	0	0	0	0	0	5	1	1	0	Stable
MS	143	689	65	158	92	50	208	31	0	10	Up
AL	11,849	4,991	206	1,434	1,791	1,286	765	222	9	22	Up
GA	4,938	9,070	333	73	0	0	2,077	115	24	4	Down
TN	12,746	6,394	1,294	257	5	14	39	1	0	0	Stable
KY	3,456	NA	NA	0	0	0	0	0	1	0	Stable
VA	763	274	50	10	0	0	64	33	25	25	Stable
FL	2,892	650	2	10	7	3	43	22	15	1	Stable
SC	22,270	67,127	9,514	4,324	2,388	2,267	734	990	142	0	Down
NC	3,871	4,028	181	10	24	49	15	131	5	5	Stable
Total	62,928	93,223	11,645	6,276	4,307	3,669	3,950	1,546	222	67	Down

and in Idaho, British Columbia and Colorado for mountain pine beetle (*D. ponderosae*) on lodgepole pine have been completed. Data from Mississippi, California and Alabama trials indicate that emamectin benzoate is highly effective in reducing tree mortality by bark beetles. Fipronil showed some activity at these sites as well. In contrast, results for mountain pine beetle from Idaho and British Columbia and spruce beetle from Utah were relatively poor for both chemicals, most likely due to short growing seasons and cold temperatures. A manuscript presenting the results of the *Dendroctonus* trials in California, Idaho and Utah was published in the Western Journal of Applied Forestry. A second manuscript based on results of fipronil trials in these same three states was published in the Journal of Entomological Science. Two new trials (AL and UT) were established in 2009 and continued in 2010, to evaluate the potential of combining emamectin benzoate with a fungicide mix to improve tree survival. In the both trials, the combination treatment was no better than emamectin benzoate alone for protecting trees against either southern pine beetle or mountain pine beetle.

A trial established in a Florida pine seed orchard in fall 2008 evaluated emamectin benzoate, abamectin and imidacloprid and their effects against coneworms and seed bugs. The 2009 and 2010 data indicated that emamectin benzoate had excellent activity against coneworms, but no treatment affected seed bug damage levels. A second trial established in 2009 in a Texas oak orchard showed that emamectin benzoate reduced the incidence and damage caused by leaf beetles, borers, tussock moth caterpillars, leaf-rolling weevils, and oakworm caterpillars on cherrybark and bur oaks compared to untreated checks. Second-year effects were observed against leaf beetles, borers, oakworm caterpillars and leafminers. Two more small trials were established in 2009 to determine the efficacy of emamectin benzoate against a chalcid wasp (unknown species) attacking Afghan pine near El Paso and the soapberry borer (*Agrilus prionurus*) attacking western soapberry near Dallas and Houston. Emamectin benzoate was highly effective in preventing additional chalcid wasp colonization of host and markedly improved the health of treated western soapberry trees.

Syngenta submitted a registration package to EPA for emamectin benzoate (TREE-äge™) in January 2008. The standard registration process takes 18 months. EPA approved the registration for use on ash for emerald ash borer in July 2009. EPA approval for use of emamectin benzoate in other deciduous trees, conifers and palms for several forest pests (seed and cone insects, bark beetles, etc.) was finally given in December 2010. Approval of the final label is required at the state level as well. As of March 2011, 30 states including TX, OK, FL, NC, SC and VA have approved the full label. Availability of TREE-äge™ in the remaining southern states is expected by late spring 2011.

The pine tip moth project, established in 2001, to evaluate the true impact of this insect pest on the growth of loblolly pine and to identify site characteristics that influence the occurrence and severity of pine tip moth infestations, was further expanded in 2010. One hundred and six (106) impact plots on 76 sites are now established in the Western Gulf Region. An additional four hazard-rating plots were established in 2010, bringing the total to 146. The analysis of impact data indicates that protected trees continue to grow at an accelerated rate through the fifth year after establishment. The threshold at which tip moth damage significantly impacts growth was calculated to be an average of 11% or greater of the shoots infested over the first two growing seasons. Considerable progress was made on the hazard-rating model and cost:benefit analysis in 2010. The FPMC arranged to have a graduate student, Mr. Trevor Walker, work on model development and cost:benefit analysis as part of a Master's in Forestry degree with the guidance of Drs. Dean Coble and Jimmie Yeiser, Stephen F. Austin State University. Mr. Walker has nearly completed his analysis and is writing his thesis.

Systemic insecticide trials revealed that single applications of PTM™ (fipronil) and SilvaShield™ (imidacloprid) continued to be effective against pine tip moth using different application techniques and for extended periods of time.

Trials were established in 2008 to assess the efficacy of fipronil applied at different depths to one-year old pine seedlings. Shallow (4") fipronil applications provided slightly better protection compared to deeper (8") applications. The trial established in 2007 on two sites to test the efficacy of fipronil applied to containerized seedlings prior to planting was continued in 2010. The effects were still good in 2009, but faded completely in 2010. BASF is now willing to consider a request to modify the PTM™ label to include use on containerized seedlings if FPMC can address concerns related to chemical leaching and worker exposure. A new trial is planned in 2011 to further evaluate the performance of plug injections of PTM™ at different rates on ten sites across the South.

After the registration of SilvaShield™ Forestry tablet (imidacloprid plus fertilizer) in 2006, trials were established on six sites in 2007 to further evaluate application techniques. Tablets applied in plant holes continued to work well in 2009 to reduce tip moth damage and improve tree growth. Tablets applied next to seedlings after planting were less effective. New trials were established in 2008 to refine application techniques, evaluate different rates, and develop operational procedures. One, two and three tablets were equally effective when applied shallow (4") or deep (8") at planting. Post-plant treatments were more effective against tip moth at higher rates, but inconsistent in their effect on pine growth. Operational treatments were more effective against tip moth when applied just after planting compared to application at the beginning of the second growing season. However, both applications significantly improved growth parameters.

A new trial established in 2010 directly compared the performance of PTM™ and SilvaShield™. Preliminary first-year results indicated that both products are highly and equally effective when applied at planting. However, SilvaShield™ generally performed better when applied post plant.

TEXAS LEAF-CUTTING ANT

Control Option Development and Evaluation - East Texas

Highlights:

- Efficacy trials were conducted in winter, spring, summer and fall 2010 to evaluate the efficacy of modified Amdro® Ant Block (Schirm 4) against the Texas leaf-cutting ant.
- The moderate-sized (Schirm 4) Amdro treatment was more effective than Amdro® Ant Block and quickly reduced ant activity after 2 weeks during spring and fall trials. After 8 weeks, 61% of the treated colonies were still inactive, a 29% improvement in efficacy over the standard Ant Block.
- Severe drought and high temperature conditions reduced ant activity resulting in poor bait performance during the summer trial.
- Bait stations were ineffective: in many cases, fire ants inhibited leaf-cutting ant bait retrieval or animal(s) disturbed the stations.

Justification: Currently, there is no safe and effective control option available for control of Texas leaf-cutting ants. Volcano™ (sulfluramid/citrus pulp bait) and methyl bromide were phased out in 2003 and 2005, respectively. In 2003, Grant Laboratories, CA, began marketing their Grant's Total Ant Killer bait. Trials conducted by the FPMC early in 2004, found that a single application only halted the activity of 25% of the treated colonies – about equal to the efficacy of the old Amdro® bait used in the mid-1990s. In late 2004, Central Garden and Pet (formerly Ambrands and American Cyanamid) began marketing new Amdro® Ant Block bait. Additional trials conducted in early spring 2005 and later in 2006 found that a single application of this bait did not halt the activity of most treated colonies, but did reduce all colonies by 60% compared to untreated colonies. Grosman hypothesized that the poor efficacy of Amdro is at least in part due to the small particle size of the bait. He surmised that perhaps modifying the bait to increase the particle size would improve effectiveness. The goal of the proposed research is to evaluate the potential of modified (larger) Amdro® Ant Block bait as an effective alternative to methyl bromide fumigation and unmodified Amdro® Ant Bock, for control of the Texas leaf-cutting ant in forestry applications. As bait efficacy tends to change with season (Grosman, personal observation), there is a need to determine to what extent the optimal application rate varies with season.

Objective: Evaluate the efficacy of new bait modified from Amdro® Ant Block for eliminating or reducing activity in Texas leaf-cutting ant colonies and determine if efficacy changes with season.

Cooperators:

Ms. Kimberley Dickinson	Central Garden and Pet, N. Richland Hills, TX
Mr. Regan Bounds	Hancock Forest Management, Silsbee, TX
Mr. Bill Stansfield	Campbell Group, Diboll, TX
Mr. Mark Hebert	Rayonier

Study Sites: Active colonies (111) were located in East Texas on lands owned by Campbell Group, Hancock Forest Management, Rayonier and private landowners.

Insecticides:

Hydramethylnon – undetectable, slow-acting poison

Amdro® Ant Block bait - concentration (0.88% a.i.); defatted corn grit carrier with soybean oil; packing (tight); color (yellow); size modified from 2 mm dia. to 2.5 mm X 7 mm length).

Research Approach:

Amdro® Ant Block bait plus water were run through a pellet mill (Schirm USA) to create larger pellets [2.3 mm (3/32") dia. X 7 mm (1/4") length (Schirm 4)] for winter, spring, summer and fall trials. The above bait was compared to larger pellets [3.3 mm (7/64") dia. X 4 mm length (Schirm 2) Trial 1] or smaller pellets [2.3 mm length X 4 mm (Schirm 3) Trials 1 and 2].

Experiments were conducted in East Texas, within 75 miles of Lufkin. In this area, Texas leaf-cutting ant colonies were selected depending on the season. 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 2-14 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 are not included in the central nest area. Application rates were based on label rates and/or the area (length X width) of the central nest. Three trials were conducted in 2010 (so far); the treatments included:

Trial 1 (winter 2010):

1) Schirm 2 Amdro® bait (large diameter and short length) - bait was spread uniformly over CNA at 10.0 g/m^2.
2) Schirm 3 Amdro® bait (medium diameter and short length) - bait was spread uniformly over CNA at 10.0 g/m^2.
3) Small Amdro® Ant Block - bait was spread uniformly over CNA at 3/4 lb per colony.
4) Untreated colony (Check)

Trial 2 (spring 2010):

5) Schirm 2 Amdro® bait (large diameter and short length) - bait was spread uniformly over CNA at 10.0 g/m^2.
6) Schirm 3 Amdro® bait (medium diameter and short length) - bait was spread uniformly over CNA at 10.0 g/m^2.
7) Schirm 4 Amdro® bait (Optimal - medium diameter and long length) - bait was spread uniformly over CNA at 10.0 g/m^2.
8) Small Amdro® Ant Block - bait was spread uniformly over CNA at 3/4 lb per colony.
9) Untreated colony (Check)

Trial 3 (summer 2010):

1) Schirm 4 Amdro® bait (Optimal - medium diameter and long length) - bait was spread uniformly over CNA at 10.0 g/m^2.
2) Schirm 4 Amdro® bait (Optimal - medium diameter and long length) - bait stations (containing 23 g of bait) were deployed uniformly (@ 4 stations / 9.3 m) over CNA (= 10.0 g/m^2).
3) Schirm 3 Amdro® bait (medium diameter and short length) - bait was spread uniformly over CNA at 10.0 g/m^2.
4) Small Amdro® Ant Block - bait was spread uniformly over CNA at 3/4 lb per colony.
5) Untreated colony (Check)

Trial 4 (fall 2010):

1) Schirm 4 Amdro® bait (Optimal - medium diameter and long length) - bait was spread uniformly over CNA at 10.0 g/m^2.
2) Schirm 4 Amdro® bait (Optimal - medium diameter and long length) - bait stations (containing 23 g of bait) were deployed uniformly (@ 4 stations / 9.3 m) over CNA (= 10.0 g/m^2).
3) Small Amdro® Ant Block - bait was spread uniformly over CNA at 3/4 lb per colony.
4) Untreated colony (Check)

Trial 5 (winter 2011):

1) Schirm 4 Amdro® bait (Optimal - medium diameter and long length) - bait was spread uniformly over CNA at 10.0 g/m^2.
2) Small Amdro® Ant Block - bait was spread uniformly over CNA at 3/4 lb per colony.
3) Untreated colony (Check)

Bait treatments were applied with a cyclone spreader to evenly spread amounts over the CNA (Trials 1 – 5) or in bait stations (5" X 3" X 3"; Trials 3 and 4) (Fig 1). Stations, each containing 23 g of bait, were even spaced within the CNA at four stations per 100 ft^2 (Fig. 2 and 3).

Figure 1. Amdro bait station

Figure 2. Bait station containing 23 g of modified Amdro bait (Schirm 4)

Figure 3. Bait stations deployed on Texas leaf-cutting ant central nest area at 4 stations per 100 ft2.

Data Collection: 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 2, 4, 8, and 16 weeks. Six to eight untreated colonies were included as checks and monitored to account for possible seasonal changes in ant activity. For each colony, the percent of initial activity was calculated as the current number of active mounds at each post-treatment check (X 100) divided by the initial number of active mounds.

Results:

Moisture conditions were good through March. In the winter trial, 4-8 colonies were treated with the two modified Amdro (Schirm 2 and 3), in February and March 2010 (prior to spring flush). Both Amdro treatments quickly reduced ant activity (>82%) on treated colonies compared to initial activity within 2 weeks after treatment (Table 3). At this time (2 weeks), 100% of the Schirm 2 treatment colonies were completely inactive. By 16 weeks post treatment, all colonies were still inactive. The smaller modified Amdro (Schirm 3) bait was less effective.

The moisture conditions were unusually dry during the spring of 2010 with very little rainfall occurring in April (0.66”). In the spring trial, 2-6 colonies were treated with the three different modified Amdro baits, in April and early May 2010. The new optimal Amdro (Schirm 4) treatment quickly reduced ant activity (>88%) on treated colonies compared to initial activity within 2 weeks after treatment (Table 4). At this time (2 weeks), 40% of the treatment colonies were completely inactive. By 16 weeks post treatment, 80% of the colonies were inactive. The larger and smaller modified Amdro baits (Schirm 2 and Schirm 3, respectively) were less effective.

Moisture conditions remained low into and through much of the summer. A few colonies (4-5) were treated with each of the different Amdro treatments in June. Due to drought conditions and generally low ant activity, the remaining colonies were not treated until late August and early September. The new modified Amdro (optimal) even spread treatment again quickly reduced ant activity (>87%) on treated colonies compared to initial activity within 2 weeks after treatment (Table 5). However, only one colony had gone completely inactive 8 weeks after treatment (Table 5). Very little of the optimal bait in bait stations was retrieved. As a result, there was little reduction in ant activity and none of the colonies have gone inactive. In this trial, the regular Amdro Ant Block-treated colonies had significantly lower activity after 8 weeks compared to the other treated colonies.

The fall trial was initiated the week of November 15th after temperatures had cooled and some rainfall had been received. However, conditions quickly became dry again and ant activity was reduced throughout December. The new modified Amdro (optimal) even spread treatment again reduced ant activity (>79%) on treated colonies compared to initial activity within 2 weeks after treatment (Table 6). After 8 weeks, 7 of 13 colonies (54%) had gone completely inactive (Table 4).

The winter trial was initiated the first week of January after moisture conditions improved (over 7" of rainfall was received for the month). The new modified Amdro (optimal) even spread treatment again quickly reduced ant activity (>94%) on treated colonies compared to initial activity within 2 weeks after treatment (Table 7). We expect to see markedly better results compared to the summer (Table 7).

Overall, the trials conducted from spring 2009 through fall 2010 have shown that the larger modified Amdro baits (TFS Amdro and Schirm 2 – 4) are superior in their ability to halt leaf-cutting ant activity with a single application compared to the standard Amdro Ant Block (Table 8). When results are combined, the larger baits improved efficacy by 23%. If we were to eliminate the summer 2010 results (due to effects of drought), the difference in efficacy would climb to 33%.

Conclusions:

The spring and fall 2010 efficacy trials showed that the modified (optimal; Schirm 4) bait was more effective in halting ant activity compared to the standard Amdro Ant Block, as well as the large (Schirm 2) and small (Schirm 3) modified Amdro baits. The poor result observed during the summer trial was in part due to very little ant activity during periods of high temperatures and severe drought. During these periods, ant colonies appeared smaller than they actually were, thus insufficient bait was applied.

Bait treatments applied in bait stations were largely ineffective in halting ant activity in two separate trials (Tables 3 and 4). In addition, several problems arose or may arise with their use in citrus orchards, agricultural sites and/or residential areas, including: 1) fire ants often swarmed to and within the bait stations because of their attraction to the corn grit and soybean oil. Their presence prevented leaf-cutting ants from retrieving the bait; 2) animals (armadillo, opossum, raccoon, skunks, or possibly sasquatch) have attempted to open the bait stations on several occasions; sometimes they have succeeded; 3) the box is white and quite noticeable from a distance, thus children and/or pets could be attracted to the stations if they are deployed near residences. Note: leaf-cutting ant colonies do NOT occur within citrus orchards due to excessive disturbance (flooding). Thus, there is no need for use of bait stations within the orchards.

Based on field observations and trial results, the larger modified Amdro bait (Schirm 2, 3 and 4) is a significant improvement over the standard Ant Block. The dimensions - 2.3 mm (3/32”) in diameter X 7 mm (1/4”) long and weight of about 0.04 g (25 particles per gram) allow for maximum retrieval by average-sized, semi-energetic worker ants.

Acknowledgements: Thanks go to Campbell Group, Hancock Forest Management, Rayonier and several private landowners who provided access to ant colonies. We appreciate the donation of Amdro formulation from Central Garden and Pet for the trials.

Table 3. Efficacy of modified (optimal, small & large) Amdro bait and Amdro Ant Block applied during winter to control the Texas leaf-cutting ant, *Atta texana* , in East Texas (February - June 2010).

Treatment	No. of colonies treated	Mean central nest area (ft^2)	Mean # mounds at Trt	Mean % of initial activity[a] (% of colonies inactive after): 2 weeks		4 weeks		8 weeks		16 weeks	
Schirm (3) Amdro (sm. dia. & short) (10.0g/m^2) even spread	8	533	156	17.3 **b**	(63)	16.0 **b**	(63)	17.8 **b**	(63)	16.4 **b**	(75)
Schirm (2) Amdro (lg dia. & short) (10.0g/m^2) even spread	4	504	136	0.0 **a**	(100)	0.0 **a**	(100)	0.0 **a**	(100)	0.0 **a**	(100)
Amdro Ant Block (0.75-1.5 lb / colony = 9g/m^2)	3	607	182	0.0 **a**	(100)	0.0 **a**	(100)	0.0 **a**	(100)	0.0 **a**	(100)
Check (no treatment)	4	531	198	101.7 **c**	(0)	93.2 **c**	(0)	86.7 **c**	(0)	92.8 **c**	(0)
Total/Mean	19	538	165								

[a] Means followed by the same letter within each column are not significantly different at the 5% level (Fisher's Protected LSD).

Table 4. Efficacy of modified (optimal, small & large) Amdro bait and Amdro Ant Block applied during the spring to control the Texas leaf-cutting ant, *Atta texana* , in East Texas (April - September 2010).

Treatment	No. of colonies treated	Mean central nest area (ft^2)	Mean # mounds at Trt	Mean % of initial activity[a] (% of colonies inactive after):			
				2 weeks	4 weeks	8 weeks	16 weeks
Schirm (4) Amdro (optimal)							
(10.0g/m^2) even spread	5	658	148	11.9 **a** (40)	10.3 **a** (40)	11.1 **a** (60)	2.7 **a** (80)
Schirm (3) Amdro (sm. dia. & short)							
(10.0g/m^2) even spread	6	677	163	49.7 **b** (0)	29.8 **a** (0)	29.0 **a** (0)	34.2 **a** (17)
Schirm (2) Amdro (lg dia. & short)							
(10.0g/m^2) even spread	2	682	150	92.9 **cd** (0)	72.9 **b** (0)	48.6 **a** (0)	37.2 **a** (0)
Amdro Ant Block							
(0.75-1.5 lb / colony = 9g/m^2)	4	743	213	59.0 **bc** (0)	13.3 **a** (50)	12.5 **a** (50)	11.7 **a** (50)
Check							
(no treatment)	4	531	178	96.2 **d** (0)	98.7 **b** (0)	103.8 **b** (0)	98.1 **b** (0)
Total/Mean	21	658	170				

[a] Means followed by the same letter within each column are not significantly different at the 5% level (Fisher's Protected LSD).

Treatment	colonies treated	central nest area (ft^2)	mounds at Trt	Mean % of initial activity[a] (% of colonies inactive after):			
				2 weeks	4 weeks	8 weeks	16 weeks
Schirm (4) Amdro (optimal) (10.0g/m^2) even spread	14	555	170	9.2 **a** (10)	7.8 **a** (30)	33.7 **a** (10)	51.6 **b** (0)
Schirm (3) Amdro (sm. dia. & short) (10.0g/m^2) even spread	7	692	218	19.6 **a** (0)	14.6 **a** (17)	11.0 **a** (0)	42.1 **ab** (0)
Schirm (4) Amdro (optimal) (10.0g/m^2) in bait station	14	434	132	62.0 **b** (0)	42.5 **b** (0)	101.0 **b** (0)	126.2 **c** (0)
Amdro Ant Block (0.75-1.5 lb / colony = 9g/m^2)	6	647	184	12.1 **a** (33)	9.3 **a** (33)	4.4 **a** (33)	10.5 **a** (50)
Check (no treatment)	4	531	198	95.1 **c** (0)	91.7 **c** (0)	83.3 **b** (0)	80.8 **b** (0)
Total/Mean	45	561	174				

[a] Means followed by the same letter within each column are not significantly different at the 5% level (Fisher's Protected LSD).

Table 6. Efficacy of modified (Optimal) Amdro bait (even spread or bait station) and Amdro Ant Block applied during the fall to control the Texas leaf-cutting ant, *Atta texana* , in East Texas (November 2010 - March 2011).

Treatment	No. of colonies treated	Mean central nest area (ft^2)	Mean # mounds at Trt	Mean % of initial activity[a] (% of colonies inactive after):			
				2 weeks	4 weeks	8 weeks	16 weeks
Schirm (4) Amdro (optimal) (10.0g/m^2) even spread	13	559	219	20.4 **a** (15)	10.4 **a** (38)	5.1 **a** (54)	
Schirm (4) Amdro (optimal) (10.0g/m^2) in bait station	9	373	163	64.2 **b** (0)	61.1 **b** (0)	61.0 **bc** (22)	
Amdro Ant Block (0.75-1.5 lb / colony = 9g/m^2)	6	713	161	28.0 **a** (0)	28.0 **b** (33)	32.5 **ab** (33)	
Check (no treatment)	6	647	182	96.6 **c** (0)	91.1 **c** (0)	90.1 **c** (0)	
Total/Mean	34	553	189				

[a] Means followed by the same letter within each column are not significantly different at the 5% level (Fisher's Protected LSD).

Table 7. Efficacy of modified (Optimal) Amdro bait (even spread) and Amdro Ant Block applied during the winter to control the Texas leaf-cutting ant, *Atta texana* , in East Texas (January - April 2011).

Treatment	No. of colonies treated	Mean central nest area (ft^2)	Mean # mounds at Trt	Mean % of initial activity[a] (% of colonies inactive after):			
				2 weeks	4 weeks	8 weeks	16 weeks
Schirm (4) Amdro (optimal)							
(10.0g/m^2) even spread	17	597	254	3.3 **a** (53)	1.2 **a** (82)		
Amdro Ant Block							
(0.75-1.5 lb / colony = 9g/m^2)	6	738	241	3.1 **a** (83)	3.1 **a** (83)		
Check							
(no treatment)	6	719	226	101.1 **b** (0)	101.1 **b** (0)		
Total/Mean	29	658	245				

[a] Means followed by the same letter within each column are not significantly different at the 5% level (Fisher's Protected LSD).

Table 8. Efficacy of modified (optimal, small & large) Amdro bait and Amdro Ant Block applied to control the Texas leaf-cutting ant, *Atta texana* , in East Texas (Spring 2009 - Winter 2010).

	Mean % of initial activity[a] (% of colonies inactive) at different periods post treatment								
Treatment	Spring '09	Summer '09	Fall '09	Winter '10	Spring '10	Summer '10	Fall '10	All Trials	Winter '11
	<------------------------------ after 16 weeks ------------------------------>						after 8 weeks	after 8 weeks	after 2 weeks
Schirm (4) Amdro (sm. dia. & long) (10.0g/m^2) even spread					2.7 **a** (80)	51.6 **bc** (0)	5.1 **a** (54)	18.1 **a** (39)	5.1 **a** (50)
Schirm (3) Amdro (sm. dia. & short) (10.0g/m^2) even spread				0.0 **a** (100)	34.2 **b** (17)	42.1 **b** (0)		18.5 **a** (33)	
Schirm (2) Amdro (lg dia. & short) (10.0g/m^2) even spread			6.7 **a** (70)	0.0 **a** (100)	37.2 **b** (0)			8.6 **a** (69)	
Schirm (1) Amdro (lg dia. & long) (10.0g/m^2) even spread		87.5 **c** (33)						23.1 **a** (33)	
TFS Amdro (med dia. & long) (10.0g/m^2) even spread	0.5 **a** (86)	8.3 **a** (67)	33.9 **b** (55)					13.9 **a** (67)	
TFS Amdro, Schirm 2 & 4 combined (10.0g/m^2) even spread								14.5 **a** (56)	
Amdro Ant Block (0.75-1.5 lb / colony = 9g/m^2)	21.6 **b** (38)	36.9 **b** (13)	31.8 **ab** (0)	0.0 **a** (100)	11.7 **ab** (50)	10.5 **a** (50)	32.5 **a** (33)	17.2 **a** (33)	15.4 **b** (33)
Check (no treatment)	86.3 **c** (0)	99.7 **c** (0)	104.4 **c** (0)	92.8 **b** (0)	98.1 **c** (0)	80.8 **c** (0)	90.1 **b** (0)	91.0 **b** (0)	89.6 **c** (0)
LCA Colonies evaluated	22	30	34	19	21	27	32	185	11

[a] Means followed by the same letter within each column are not significantly different at the 5% level (Fisher's Protected LSD).

IMPORTED FIRE ANT

Control Option Evaluation - East Texas and Louisiana

Highlights:

- Efficacy trials were conducted in winter and spring 2010 to evaluate the efficacy of soil injections of PTM™ (fipronil) against the imported fire ant.
- In the winter, all PTM™ treatments quickly reduced ant activity after 2 weeks. After 12 weeks ≥90% of the colonies receiving a shallow treatment were inactive.
- In the spring, all PTM™ treatments quickly reduced ant activity after 2 weeks. Higher volumes and more injection points provided the best control. After 12 weeks ≥88% of the colonies receiving a high volume treatment were inactive.

Justification: Red imported fire ants (IFA), *Solenopsis invicta*, cause billions of dollars per year in various costs across the southern United States. Individual mound treatments play an important role in fire ant management. Mound treatments are selective and often faster acting than broadcast insecticide treatments (Merchant and Drees, 2000). One desirable characteristic of fire ant mound treatments is low toxicity. This test evaluates a relatively new, lower toxicity treatment: PTM™ Insecticide (9.1% fipronil) applied using a backpack soil injection probe to single fire ant mounds that have been established in a loblolly pine seed orchard next to orchard trees. The trial was designed to observe the effectiveness of PTM™ applied using different techniques in reducing fire ant activity over a 12-week period.

Objective: Evaluate the efficacy of PTM™ soil injection for reducing activity in imported fire ant colonies.

Cooperators:

Dr. Harry Quicke	BASF Corporation, Auburn, AL
Mr. Shannon Stewart	ArborGen, Livingston, TX
Mr. Todd Nightingale	Texas Forest Service, Hudson, TX
Mr. Jim Tule	Forest Capital Partners, Merryville, TX

Study Sites:

1) ArborGen's Woodville seed orchard, Tyler Co, Texas (30.71º N, 94.46º W; 58 m elevation),
2) Texas Forest Service's Hudson orchard, Angelina Co., TX (31.31º N, 94.83º W; 105 m elevation), and
3) Forest Capital Partner's Merryville seed orchard, Beauregard Parish, LA (30.89º N, 93.52º W; 25 m elevation)

Insecticide:

Fipronil (PTM™ Insecticide, BASF) – undetectable, slow-acting poison in liquid formulation

Research Approach:

Experiments were conducted in east Texas and Louisiana; within 100 miles of Lufkin. In this area, 200-240 imported fire ant colonies were selected each season (winter and spring). Study colonies were at least 7m (23 ft) apart, 8 inches or more in diameter and with newly-excavated soil. Mounds less than 12 inches apart were considered a single colony. No other observable IFA colonies occurred within 2m (6 ft) of a study colony. Treatments were then randomly assigned to the selected ant nests with 40 replicates per treatment.

Winter 2010 Trial Treatments:

A) 45 ml PTM™ dilution injected 8 cm below soil surface at one (1) injection point
B) 45 ml PTM™ dilution injected at colony base (~30 – 46 cm deep) at one (1) injection points
C) 90 ml PTM™ dilution injected at 8 cm and base at two (2) injection points (45 ml per point).
D) 45 ml water injected 8 cm below soil surface at one (1) injection point (Check 1)
E) 45 ml water injected at colony base at one (1) injection point (Check 2)
F) Check3 – untreated

Spring 2010 Trial Treatments:

A) 45 ml PTM™ dilution injected 8 cm below soil surface at one (1) injection point (45 ml per point).
B) 45 ml PTM™ dilution injected 8 cm below soil surface at two (2) injection points (22 ml per point).
C) 90 ml PTM™ dilution injected 8 cm below soil surface at two (2) injection points (45 ml per point).
D) 90 ml PTM™ dilution injected 8 cm below soil surface at four (4) injection points (22 ml per point).
E) Check – untreated

Colonies were injected with fipronil (PTM™ Insecticide) dilution using the PTM™ Injection Probe (Enviroquip Inc., Monroe, NC) on 9 December 2009 (Woodville), 7 April 2010 (Merryville), and 14 April 2010 (Hudson) (Figure 2). Three control groups were used to assess ant activity during the winter/spring 2010, and one control group was used to assess ant activity in the two spring/summer trials in 2010.

Procedures used to evaluate the effect of treatments on fire ant colonies followed those described by Nester (2001a and b). Study colonies were marked with a pin flag (see definition of central nest area above). Treatments were applied in April 2010. At 0, 7, 14, 30, 80 and/or 117 days after treatment (DAT) each mound was checked for presence or absence of fire ant activity. A small diameter stick was inserted into the mound. If no fire ants appeared after 15 seconds, the mound was considered inactive (0). If fire ants were present within the allotted time period the mound activity was assigned a 1 (< 10 fire ants or freshly worked soil), 2 (some fire ants, not aggressive), or 3 (many aggressive fire ants). At least forty untreated colonies were included as checks and monitored to account for possible seasonal changes in ant activity. Results were analyzed using Analysis of Variance (ANOVA) at $P < 0.05$ for active ant mound assessment data, with means separated using Fisher's Protected LSD test.

Results:

Winter Trial: All PTM™ treatments applied at the Woodville orchard significantly reduced fire ant activity 7 and 14 days after treatment, but most colonies still exhibited some ant activity (Table 9). Extended cold weather (< 0^oC) considerably reduced ant activity in all colonies (including checks) during most of a two month period (January – February). Ultimately, shallow (8 cm) treatments proved more effect; activity was halted in 93% of the treated colonies 16 weeks post treatment.

Spring Trials: All PTM™ treatments applied at both locations significantly reduced ant activity within 7 days post-treatment (Tables 10 and 11). Extended dry weather considerably reduced ant activity in all colonies (including checks) during most of a two-month period (April – May).

Ultimately, treatments having higher volumes and/or more injection points were most effective in halting ant activity at both locations.

Sub-freezing temperatures (winter) and low soil moisture (spring) apparently reduced ant activity within colonies and subsequent exposure to the active ingredient, fipronil. Thus, the ability of the treatments to halt ant activity was delayed in both the winter and spring trials.

These trials provide evidence that PTM™ treatments applied in the winter or spring can be highly effective in halting imported fire ant activity in seed orchards. To ensure maximum treatment efficacy, we recommend that a total volume of 90 ml (3 fl oz) of 2% PTM™ dilution be applied into 2 (small colonies) or 4 points (large colonies) on the colony mound at a depth of 8 cm (3 inches) using soil injection equipment [e.g., PTM™ spot gun (Red River Specialties), PTM™ Injection Probe (Enviroquip Inc.), or Kioritz soil injector.

References

Barr, C.L., B. Summerlin, and B.M. Drees. 1999. Evaluation of different rates and formulations of bifenthrin for control of individual red imported fire ant colonies, Brazos Co., Texas – 1997. http://fireant.tamu.edu/research/arr/category/individual/97-99pg40/97-99pg40.pdf.

Environmental Protection Agency. 1998. Product Performance Test Guidelines: OPPTS 810.3100. Soil Treatments for Imported Fire Ants. EPA 712-C-98-410 3 p.

Nester, P. 2001. Evaluation of fire ant insecticide bait products as single mound treatments. http://fireant.tamu.edu/research/arr/category/individual/97-01pg24/97-01pg24.pdf.

Acknowledgments

We thank L. Nettles (ArborGen), J. Tules (Forest Capital Partners) and S. Anderson (Texas Forest Service) for technical assistance, ArborGen, Forest Capital Partners and Texas Forest Service for providing the study sites, and Enviroquip Inc. and BASF for providing equipment and product, respectively. This work was supported by a BASF grant and the Forest Pest Management Cooperative.

Table 9. Efficacy of PTM™ soil injection applied during the winter to control the imported fire ant, *Solenopsis invicta,* in East Texas (December 2009 - March 2010).

Treatment	No. of colonies treated	Mean nest dia. (in)	Mean ant activity ranking[a b] (% of colonies inactive after):					
			0 Days	7 Days	14 Days	49 Days	87 Days	117 Days
PTM Soil Injection (45 ml @ 3" below mound surface)	40	15.8	3.0 **a** (0)	1.2 **a** (0)	1.3 **a** (20)	0.3 **a** (73)	0.2 **a** (90)	0.2 **a** (93)
PTM Soil Injection (45 ml @ colony base)	40	14.5	3.0 **a** (0)	2.1 **b** (5)	2.3 **b** (8)	0.6 **b** (53)	1.3 **b** (50)	1.0 **b** (65)
PTM Soil Injection (45 ml each @ 3" and base)	40	16.2	3.0 **a** (0)	1.4 **a** (5)	1.3 **a** (20)	0.2 **a** (80)	0.2 **a** (93)	0.2 **a** (93)
Check (water only or no treatment)	120	14.4	2.9 **a** (0)	2.8 **c** (1)	2.7 **c** (3)	2.5 **c** (4)	2.8 **c** (5)	2.4 **c** (17)

[a] Colonies were ranked on number of ants after distubance and amount of recent soil excavation.

[b] Means followed by the same letter within each column are not significantly different at the 5% level (Fisher's Protected LSD).

Table 10. Efficacy of PTM™ soil injection applied during the spring to control the imported fire ant, *Solenopsis invicta* , at Forest Capital Partner's Merryville seed orchard, Beauregard Parish, LA (April - June 2010).

	No. of colonies	Mean nest	Mean ant activity ranking[a b] (% of colonies inactive after):				
Treatment	treated	dia. (in)	0 Days	7 Days	14 Days	30 Days	80 Days
PTM Soil Injection (45 ml @ 1 point 3" below mound surface)	40	14.2	3.0 **a** (0)	2.2 **c** (13)	2.1 **b** (20)	2.1 **b** (13)	0.4 **b** (80)
PTM Soil Injection (22 ml @ 2 points 3" below mound surface)	40	16.1	3.0 **a** (0)	1.4 **b** (35)	1.2 **a** (48)	1.4 **a** (40)	0.4 **b** (85)
PTM Soil Injection (45 ml @ 2 points 3" below mound surface)	40	15.6	3.0 **a** (0)	1.1 **ab** (55)	1.2 **a** (43)	1.0 **a** (50)	0.3 **ab** (88)
PTM Soil Injection (22 ml @ 4 points 3" below mound surface)	40	16.4	3.0 **a** (0)	0.8 **a** (55)	0.8 **a** (55)	1.0 **a** (50)	0.3 **a** (88)
Check (no treatment)	40	16.9	2.9 **a** (0)	2.9 **d** (0)	2.9 **c** (0)	2.8 **c** (4)	1.9 **c** (23)

[a] Colonies were ranked on number of ants after distubance and amount of recent soil excavation.

[b] Means followed by the same letter within each column are not significantly different at the 5% level (Fisher's Protected LSD).

Table 11. Efficacy of PTM™ soil injection applied during the spring to control the imported fire ant, *Solenopsis invicta* , at Texas Forest Service's Hudson seed orchard, Angelina Co., TX (April - June 2010).

Treatment	No. of colonies treated	Mean nest dia. (in)	Mean ant activity ranking[a b] (% of colonies inactive after):				
			0 Days	7 Days	14 Days	30 Days	80 Days
PTM Soil Injection (45 ml @ 1 point 3" below mound surface)	40	12.1	3.0 **a** (0)	1.1 **ab** (40)	0.8 **a** (53)	0.5 **a** (60)	0.3 **ab** (78)
PTM Soil Injection (22 ml @ 2 points 3" below mound surface)	40	11.8	3.0 **a** (0)	1.2 **b** (35)	0.8 **a** (58)	0.6 **a** (68)	0.4 **b** (78)
PTM Soil Injection (45 ml @ 2 points 3" below mound surface)	40	12.3	3.0 **a** (0)	1.5 **b** (23)	0.7 **a** (53)	0.6 **a** (63)	0.2 **ab** (93)
PTM Soil Injection (22 ml @ 4 points 3" below mound surface)	40	11.9	3.0 **a** (0)	0.7 **a** (50)	0.4 **a** (73)	0.3 **a** (80)	0.1 **a** (93)
Check (no treatment)	40	12.9	3.0 **a** (0)	2.7 **c** (0)	2.3 **b** (13)	1.9 **b** (18)	1.4 **c** (28)

[a] Colonies were ranked on number of ants after distubance and amount of recent soil excavation.

[b] Means followed by the same letter within each column are not significantly different at the 5% level (Fisher's Protected LSD).

Summary and Registration Status of Leaf-cutting Ant and Fire Ant Control Options

Based on our previous experience with leaf-cutting ant baits, marginally-effective baits (including the "old" Amdro® and Grant's baits) can significantly reduce worker ant populations and activity for 4 to 12 weeks after treatment. However, if the active ingredient is not passed to all the queen ants, the surviving queens will ultimately repopulate the colony. The data collected during the 2005 and 2006 Amdro® trial indicated that ant activity in most colonies had not recovered to the initial level. This suggests that the Amdro® Ant Block bait was somewhat effective in reducing the number of queens in each treated colony and preventing the colony's population from recovering fully. However, communications with several forest industries, TIMOs and private landowners continue to indicate that this bait is rarely effective in completely halting ant activity with several applications, let alone a single application.

Evaluation of two alternative options was continued in 2008 - 2010. One was to modify the Amdro® Ant Block™ bait into larger pellets. Central Garden and Pets (CGP) provided bait for modification. Several trials have shown that larger modified bait provided significantly better control in all seasons compared to the original Ant Block bait. According to CGP, EPA registration of the modified bait would be simple since the active and inert ingredients are already registered for other species of ants (fire ants). If all goes well, a new leaf-cutting ant bait could be registered and available by spring 2011.

The other option tested soil injection of PTM™ Insecticide (fipronil) solution into entrance holes within the central nest area of leaf-cutting ant colonies. This treatment was highly effective during most seasons. As a result of these trials, EPA approved the addition of leaf-cutting ants to the PTM™ label in December 2009. Additional trials in 2010 showed PTM™ applications to imported fire ant colonies are similarly effective. BASF has submitted a request to EPA to add fire ants to the PTM™ label as well.

Two soil injection systems are now available for application of PTM™ dilution for leaf-cutting ant control: Aqumix's (formerly Enviroquip) PTM™ Injection Probe and Prima Tech's PTM™ Spot Gun. A third applicator, the Kioritz soil injector, has been discontinued.

.

Figure 2. Soil injection systems: A) PTM™ Injection Probe and B) PTM™ Spot Gun

SYSTEMIC PESTICIDE INJECTION TRIALS

Potential Insecticides for Seed Bug Control in Pine Seed Orchards - Florida, Arkansas and Texas

Highlights:

- Tree IV injections of imidacloprid and dinotefuran significantly reduced seed bug damage on second-year cones by 46% and 54%, respectively, during the first year after injection.
- Tree IV injections of abamectin, acelepryn, emamectin benzoate, and fipronil all significantly reduced coneworm damage; EB was best, reducing damage by 99%. Imidacloprid and abamectin did not significantly reduced coneworm damage compared to checks.

Justification: Trials conducted from 1998 – 2006 at Texas, Louisiana, Alabama and Florida seed orchards showed that emamectin benzoate was very effective in reducing damage caused by coneworms, but to a lesser extent damage caused by seed bugs. New formulations of abamectin, acephate, azadiractin, chlorantraniliprole, dinotefuran, fipronil and imidacloprid, recently have been developed and trials were established to evaluate their efficacy against cone and seed insect pests.

Objectives: 1) Evaluate the potential efficacy of new formulations of abamectin, acephate, azadiractin, chlorantraniliprole, dinotefuran, fipronil and imidacloprid against seed bugs in pine seed orchards and 2) determine the duration of treatment efficacy.

Cooperators:

Mr. Early McCall	Rayonier, Yulee, FL
Mr. Steve Smith	Weyerhaeuser Company, Magnolia, AR
Mr. Lance Nettles	ArborGen, Woodville, TX
Mr. Joseph Doccola	Arborjet, Inc., Worchester, MA
Mr. Joe Meating	BioForest Technologies Inc., Sault Ste. Marie, ON
Mr. Jim Bean	BASF, Auburn, AL
Mr. T.V. Smith	DuPont, Allen, TX
Ms. Marianne Waindle	JJ Mauget, Arcadia, CA

Study Site

Rayonier's Yulee orchard containing loblolly pine near Yulee, FL (Nassau Co.)
Weyerhaeuser's Magnolia Seed Orchard, Magnolia, Arkansas (Columbia Co.)
ArborGen's Woodville Seed Orchard, Woodville, Texas (Tyler Co.)

Insecticides:

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

Abamectin (Abacide™2, Mauget) – a mix of avermectins ((B1a and B1b)

Imidacloprid (IMA-jet™, Arborjet, Inc.) – neonicotinoid insecticide with reported activity against sucking insects.

Dinotefuran (Valent/Mauget) - neonicotinoid insecticide with reported activity against sucking insects.

Chlorantraniliprole (Acelepryn, DuPont) - Anthranilic diamide insecticide with activity against moths, beetles, caterpillars, etc.

Azadiractin (TreeAzin, BioForest Tech.) – a liminoid compound that affect over 200 species of insects (including sucking insects) by acting mainly as an antifeedant and growth disruptor

Acephate (Ace-jet, Arborjet) – an organophosphate with reported activity against sucking insects

Fipronil (BASF) - a phenyl pyrazole insecticide with reported activity against sucking insects.

Research Approach: The first phase of the study was initiated in 2008 in a loblolly block (Rayonier's Fernandino Beach Seed Orchard, Florida). A second phase of the study was initiated in fall 2009 in a loblolly pine block (Weyerhaeuser's Magnolia Seed Orchard, Arkansas). A third phase of the study was initiated in fall 2009 in a loblolly pine block (ArborGen's Woodville Seed Orchard, Texas). A block in each orchard was selected that had not been sprayed with insecticide for 1 or more years prior to initiation of this experiment. In January 2008, 7 ramets from each of 6 loblolly clones were selected in Florida. In September 2009, 6 ramets from each of 6 clones were selected in Arkansas and 10 ramets from each of 7 clones were selected in Texas. The treatments were evaluated using the experimental design protocol described by Gary DeBarr (1978) (i.e., randomized complete block with clones as blocks).

Treatments:

FL Orchard (Loblolly pine)

1) Imidacloprid (IMA-jet™, Arborjet) (0.4 g AI per inch DBH) injection + 5X foliar spray
2) Abamectin (Abacide™ 2, Mauget) (0.4 g AI per inch DBH) injection + 5X foliar spray
3) Emamectin benzoate (TREE-äge™, Arborjet) (0.4 g AI per inch DBH) injection + 5X foliar spray.
4) Imidacloprid + Abamectin (Arborjet) (0.2 g AI each per inch DBH) injection + 5X foliar spray
5) Imidacloprid + Abamectin (Dutrex, Mauget) injection + 5X foliar spray
6) Imidacloprid + Emamectin benzoate (each at 0.2 g AI per inch DBH) injection + 5X foliar spray
7) Check (5X foliar spray only)

AR Orchard (Loblolly pine)

1) Imidacloprid (IMA-jet™) (0.4 g AI per inch DBH of tree) applied in fall 2009
2) Imidacloprid (IMA-jet™) (0.4 g AI per inch DBH of tree) applied in fall 2009 and spring 2010
3) Imidacloprid + Emamectin benzoate (each at 0.4 g AI per inch DBH of tree) applied in fall 2009
4) Imidacloprid + Emamectin benzoate (each at 0.4 g AI per inch DBH of tree) applied in fall 2009 and Imidacloprid applied again in spring 2010.
5) Dinotefuran + Emamectin benzoate (each at 0.4g AI per inch DBH of tree) applied in spring 2010.
6) Check

TX Orchard (Loblolly pine)

1) Imidacloprid (Ima-jet™, Arborjet) (0.4 g AI per inch DBH of tree) in Fall 2009
2) Emamectin benzoate (TREE-äge™, Arborjet) (0.4 g AI per inch DBH of tree) in Fall 2009
3) Dinotefuran (Valent/Mauget) 0.4 g AI per inch DBH of tree) in Spring 2010
4) Abamectin (Abacide™ 2, Mauget) (0.4g AI per inch DBH of tree) in Fall 2009
5) Chlorantraniliprole (Acelepryn, DuPont) 0.4g AI per inch DBH of tree) in Fall 2009
6) Azadiractin (TreeAzin®, BioForest Tech.) (0.4g AI per inch DBH of tree) in Fall 2009
7) Acephate (Ace-jet™, Arborjet) (0.4g AI per inch DBH of tree) in Spring 2010
8) Fipronil (BASF) 0.4g AI per inch DBH of tree) in Fall 2009
9) Emamectin benzoate (TREE-äge™, Arborjet) (0.4 g AI per inch DBH of tree) in Fall 2009 plus two foliar sprays (1 in spring and 1 in late summer).
10) Check

At each location, at least four holes, 0.95 cm (3/8 in) in diameter and 5-8 cm (2-3 in) deep, were drilled about 30 cm above ground at cardinal points at the base of the tree bole. Arborplugs™ were installed in each hole. The Arborjet™ Tree IV system was used to inject a predetermined amount of product into each hole. The length of time to inject each tree varied from 5-30 min and was dependent on tree, species, location and weather.

Foliar spray treatments (Fanfare®, Asana® XL, and Confirm®) were aerially applied 5X to the orchard block (FL) every 6 weeks starting in April. In Texas, Asana® XL, was applied to foliage beginning in April and July using a hydraulic sprayer at 10 gal/tree. The distance between test trees will be >20 m to minimize the effects of drift.

Data Collection:

Seed Bug Damage to Conelets - 10 healthy first-year cones were picked "at random" from each tree in October; conelets were pealed to expose seed ova; seeds were categorized as healthy or damaged.

***Dioryctria* Attacks** -- All cones that could be reached by bucket truck were picked in September; cones were categorized as small dead, large dead, green infested, with other insect or disease damage, or healthy.

Seed Bug Damage to Cones -- 10 healthy second-year cones were picked "at random" from all healthy cones collected from each ramet; seeds were extracted and radiographed (X-ray); seeds were categorized as full seed, empty, seed bug-damaged, 2nd year abort, seedworm-damaged, and other damage.

Results:

Several of the study trees treated in spring 2010 with imidacloprid or dinotefuran at the AR orchard exhibited phytotoxic symptoms. Severe drought condition (23" below normal rainfall) may have made certain clones ((H35 and S4PT6) more sensitive to these compounds. Trees treated with these compounds at other locations (TX and FL) have not exhibited phytotoxic symptoms.

The study orchard blocks have been sprayed for several years suggesting that pressure from coneworms and seed bugs (in particular) would likely be low to moderate. This was confirmed for coneworm by 14% (AR), 22% (TX), and 38% (FL) damage on check cones (Table 12, 15 and 18). In 2010, several leaffooted and shieldbacked pine seed bugs were observed in the study trees (Steve Smith, personal communication). This was confirmed for seed bugs by 41% (TX) and 62% (AR) damage on second-year seeds from check cones (Table 16 and 19).

Florida:

Treatment Effect on Coneworm Damage:

(2009) Both injection treatments containing emamectin benzoate significantly reduced early and late coneworm damage compared to the checks (Table 12). Overall, the emamectin benzoate treatments provided the greatest reductions in total coneworm damage (90 - 100%) compared to the check. None of the treatments improved the percentage of healthy cones.

(2010) Both injection treatments containing emamectin benzoate again significantly reduced early and late coneworm damage compared to the checks (Table 12). Overall, the emamectin benzoate treatments provided the greatest reductions in total coneworm damage (94 - 96%) compared to the check. Only emamectin benzoate alone significantly improved the percentage of healthy cones; by 41%.

Treatment Effect on Seed Bug Damage: In 2009, evaluation of conelet ovules from Yulee Seed Orchard showed none of the injection treatments improved the percentage of good ovules in conelets compare to checks (standard spray) (Table 10). Analysis of seed lots indicated that none of the injection treatments reduced seed bug damage compared to checks (standard spray treatment) (Table 10). Since no treatments were effective in 2009, no evaluations were made in 2010.

Arkansas:

Treatment Effect on Conelet and Cone Survival:

All injection treatments significantly improved conelet survival compared to checks (Table 14). However, treatments containing emamectin benzoate had the highest survival (95-98%). Similarly, most emamectin benzoate treatments improved cone survival.

Treatment Effect on Coneworm Damage:

All three injection treatments containing emamectin benzoate significantly reduced early and late coneworm damage compared to the checks (Table 15). Overall, the emamectin benzoate treatments provided the greatest reductions in total coneworm damage (40 - 78%) compared to the check. All injection treatments significantly improved the percentage of healthy cones; but Imid + EB (fall) had the greatest improvement at 43%.

Treatment Effect on Seed Bug Damage to First-Year Conelets and Second-Year Cones: In 2010, evaluation of conelet ovules and seed lots from Magnolia Orchard showed that all injection treatments reduced the percentage of damaged ovules in conelets and damaged seed in cones compare to checks (Table 13). The best treatment was the Imid + EB (fall) + Imid (spring), which reduced conelet and cone damage by 99% and 61%, respectively. Treatments containing emamectin benzoate + imidacloprid or dinotefuran improved the number of filled seeds per cone by 54-89%.

Texas:

Treatment Effect on Conelet and Cone Survival:

Three injection treatments (abamectin, emamectin benzoate and emamectin benzoate + 2 sprays) significantly improved conelet survival compared to checks (Table 17). Treatments containing emamectin benzoate had the highest survival (99%). Similarly, emamectin benzoate treatments and also acelopryn improved cone survival.

Treatment Effect on Coneworm Damage:

Injection treatments containing abamectin, acelopryn, emamectin benzoate and fipronil significantly reduced early and late coneworm damage compared to the checks (Table 18). Overall, the emamectin benzoate treatments provided the greatest reductions in total coneworm damage (97 - 99%) compared to the check. Emamectin benzoate, fipronil and acelopryn significantly improved the percentage of healthy cones; by 32-41%.

Treatment Effect on Seed Bug Damage to First-Year Conelets and Second-Year Cones: In 2010, evaluation of conelet ovules from the Woodville seed orchard showed that emamectin benzoate, abamectin, dinotefuran and imidacloprid treatments reduced the percentage of damaged ovules in conelets compared to checks (Table 19). The best treatment was the emamectin benzoate + 2 sprays which reduced conelet damage by 98%. Similarly, evaluation of seed lots showed emamectin benzoate, dinotefuran and imidacloprid treatments reduced the percentage of damaged seed in cones compared to checks (Table 19). The best treatment, dinotefuran, reduced cone damage by 54%. Both imidacloprid and dinotefuran improved the number of filled seeds per cone by 35% and 56%, respectively.

Conclusions:

As in the past, imidacloprid and dinotefuran alone or combined with other chemicals significantly improved protection against seed bug damage compared to checks (standard foliar spray of Asana®). However, neither appears to be any more effective than emamectin benzoate alone.

Also as in past trials, emamectin benzoate was highly effective against coneworms in 2010. The fall 2009 application at the Woodville seed orchard allowed emamectin benzoate to completely circulate in treated trees through the winter, thus trees were completely protected from the start of the next season. Abamectin, acelopryn and fipronil also significantly reduced coneworm damage but none was equal to or better than emamectin benzoate.

Based on the above results, we will continue these trials to evaluate for duration of treatment efficacy against seed bugs and coneworms.

Acknowledgements: We appreciate the assistance provide by Early McCall, Rayonier, Steve Smith, Weyerhaeuser, and Lance Nettles, ArborGen. We thank Arborjet, Inc., Mauget, Syngenta, Bioforest Technologies, BASF and Dupont for the financial support, chemical donations, and/or loans of injection equipment.

Table 12. Mean percentages (± SE) of cones killed early and late by coneworms, other-damaged cones, and healthy cones on loblolly pine protected with systemic injections of imidacloprid, abamectin, emamectin benzoate (EB) or combinations, Yulee, FL, 2009 and 2010.

			Mean Coneworm Damage (%)				
Year	Treatment	N	Early (small dead)	Late (large dead and infested)	Total	Mean Other Damage (%) *	Mean Healthy (%)
2009	Imidacloprid	6	1.1 ± 0.3 *†	15.5 ± 5.2	16.7 ± 5.3	16.9 ± 5.3	66.4 ± 9.7
	Abamectin	6	0.2 ± 0.1 *	11.6 ± 3.9	11.8 ± 3.9	19.4 ± 5.2	68.8 ± 8.2
	Emamectin benzoate	6	0.0 ± 0.0 *	0.0 ± 0.0 *	0.0 ± 0.0 *	16.4 ± 3.8	83.6 ± 3.8
	Imidacloprid + Abamectin (AJ))	6	1.1 ± 0.5 *	10.7 ± 3.5	11.8 ± 3.6	24.0 ± 6.2	64.2 ± 9.7
	Imidacloprid + Abamectin (M)	6	0.6 ± 0.3 *	9.7 ± 4.1	10.3 ± 4.3	15.5 ± 2.2	74.2 ± 5.6
	Imidacloprid + Emamectin benzoate	6	0.0 ± 0.0 *	1.5 ± 1.0 *	1.5 ± 1.0 *	29.5 ± 14.0 *	69.0 ± 13.9
	Check	6	2.9 ± 0.9	11.8 ± 3.8	14.7 ± 4.3	14.7 ± 3.3	70.7 ± 5.9
2010	Imidacloprid	4	6.2 ± 2.3	31.1 ± 7.4	37.3 ± 8.3	11.9 ± 3.8 *	50.8 ± 10.7
	Abamectin	4	4.5 ± 0.7	27.5 ± 7.0	32.0 ± 6.8	6.6 ± 3.4	61.4 ± 7.1
	Emamectin benzoate	4	0.7 ± 0.7 *	1.4 ± 1.4 *	2.1 ± 2.1 *	14.8 ± 8.1 *	83.1 ± 7.8 *
	Imidacloprid + Abamectin (AJ))	4	4.0 ± 1.4 *	33.0 ± 9.9	37.0 ± 9.5	4.9 ± 1.4	58.1 ± 10.3
	Imidacloprid + Abamectin (M)	4	4.9 ± 1.7	26.2 ± 13.4	31.0 ± 12.7	13.7 ± 4.6 *	55.3 ± 13.7
	Imidacloprid + Emamectin benzoate	4	0.5 ± 0.3 *	1.3 ± 0.6 *	1.7 ± 0.3 *	18.5 ± 4.5 *	79.8 ± 4.6
	Check	4	11.0 ± 2.7	26.9 ± 10.6	38.0 ± 13.2	3.0 ± 1.8	59.0 ± 13.6

† Means followed by an asteriks in each column of the same year are significantly different from the check at the 5% level based on Fisher's Protected LSD.

Table 13. Seed bug damage, seed extracted, and seed quality (Mean ± SE) from first- and second-year cones of loblolly pine and slash pine protected with systemic injections of imidacloprid, dinotefuran, emamectin benzoate and combinations, Yulee, FL, 2009 and 2010.

			Mean Seed Bug Damage (%) to:				
			First-year Conelet Ovules	Second-year Cone Seed			
Year	Treatment	N	Late (Oct.)	Early (2nd Yr Abort)	Late	Total	Mean No. Filled Seed per Cone
2009	Imidacloprid	7	1.74 ± 1.29 †	0.3 ± 0.1	17.3 ± 5.1	17.6 ± 5.2	112.7 ± 8.3
	Abamectin	7	0.04 ± 0.04	0.4 ± 0.1	19.9 ± 6.6	20.3 ± 6.6	107.2 ± 12.7
	Emamectin benzoate	7	0.19 ± 0.19	0.5 ± 0.2	17.2 ± 5.6	17.8 ± 5.7	103.4 ± 7.9
	Imidacloprid + Abamectin (AJ)	7	1.24 ± 1.24	0.3 ± 0.1	14.3 ± 3.4	14.6 ± 3.5	112.4 ± 7.2
	Imidacloprid + Abamectin (M)	7	1.46 ± 1.08	0.3 ± 0.1	14.3 ± 3.3	14.6 ± 3.3	105.9 ± 11.6
	Imidacloprid + Emamectin benzoate	7	0.33 ± 0.29	0.3 ± 0.1	19.0 ± 4.3	19.3 ± 4.4	108.8 ± 9.1
	Check	7	3.83 ± 2.87	0.2 ± 0.1	17.0 ± 5.7	17.2 ± 5.8	107.0 ± 11.2
2010	Imidacloprid	7	Data not available				
	Abamectin	7					
	Emamectin benzoate	7					
	Imidacloprid + Abamectin (AJ)	7					
	Imidacloprid + Abamectin (M)	7					
	Imidacloprid + Emamectin benzoate	7					
	Check	7					

† Means followed by an asteriks in each column of the same site are significantly different from the checks at the 5% level based on Fisher's Protected LSD.

Table 14. Mean percentages (± SE) of surviving conelets and cones on branches of loblolly pine pine protected with systemic injections of imidacloprid (Imid), dinotefuran (Dino) or emamectin benzoate (EB), Weyerhaeuser's Magnolia Seed Orchard, 2010 and 2011.

		Mean Survival (%)			
		Conelets		Cones	
Treatment	N	2010	2011	2010	2011
Imidacloprid (IMID) (fall '09)	6	95.6 ± 0.9 *		84.0 ± 3.7	
IMID (fall '09 + spring '10)	5	95.0 ± 2.0 *		85.5 ± 6.3	
IMID + Emamectin benzoate (EB) (fall '09)	6	98.2 ± 1.4 *		96.1 ± 1.7 *	
IMID + EB (fall ' 09) + IMID (spring '10)	5	96.2 ± 2.3 *		89.9 ± 5.1	
Dinotefuran + EB (spring '10)	5	95.2 ± 3.0 *		93.7 ± 3.8 *	
Check	6	72.8 ± 6.5		83.9 + 5.4	

† Means followed by an asteriks in each column of the same year are significantly different from the check at the 5% level based on Fisher's Protected LSD.

Table 15. Mean percentages (± SE) of cones killed early and late by coneworms, other-damaged cones, and healthy cones on loblolly pine protected with systemic injections of imidacloprid (Imid), dinotefuran (Dino) or emamectin benzoate (EB), Magnolia, AR, 2010 and 2011.

			Mean Coneworm Damage (%)				
Year	Treatment	N	Early (small dead)	Late (large dead and infested)	Total	Mean Other Damage (%) *	Mean Healthy (%)
2010	Imidacloprid (IMID) (fall '09)	6	4.3 ± 0.6 †	8.3 ± 2.0	12.5 ± 2.6	19.5 ± 6.4 *	68.0 ± 8.1 *
	IMID (fall '09 + spring '10)	5	2.8 ± 0.7 *	7.8 ± 2.6	10.6 ± 2.7	20.9 ± 8.1 *	68.5 ± 10.7 *
	IMID + Emamectin benzoate (EB) (fall '09)	6	1.5 ± 1.1 *	1.7 ± 1.0 *	3.2 ± 2.2 *	17.2 ± 8.6 *	79.6 ± 10.4 *
	IMID + EB (fall ' 09) + IMID (spring '10)	6	1.6 ± 1.0 *	7.1 ± 5.7	8.7 ± 6.4 *	18.9 ± 7.4 *	72.4 ± 11.9 *
	Dinotefuran + EB (spring '10)	6	3.2 ± 2.3 *	3.2 ± 1.2 *	6.5 ± 3.6 *	18.4 ± 7.1 *	75.2 ± 9.3 *
	Check	6	6.2 ± 1.1	8.2 ± 2.7	14.4 ± 3.6	30.0 ± 9.5	55.6 ± 12.8
2011	Imidacloprid (IMID) (fall '09)	6					
	IMID (fall '09 + spring '10)	6					
	IMID + Emamectin benzoate (EB) (fall '09)	6					
	IMID + EB (fall ' 09) + IMID (spring '10)	6					
	Dinotefuran + EB (spring '10)	6					
	Check	6					

† Means followed by an asteriks in each column of the same year are significantly different from the check at the 5% level based on Fisher's Protected LSD.

Table 16. Seed bug damage, seed extracted, and seed quality (Mean ± SE) from first- and second-year cones of loblolly pine and slash pine protected with systemic injections of imidacloprid (Imid), dinotefuran (Dino) or emamectin benzoate (EB), Magnolia, AR, 2010 and 2011.

			Mean Seed Bug Damage (%) to:				
			First-year Conelet Ovules	Second-year Cone Seed			Mean No. Filled Seed per Cone
Year	Treatment	N	Early (July)	Early (2nd Yr Abort)	Late	Total	
2010	Imidacloprid (IMID) (fall '09)	6	12.7 ± 4.4 *	15.5 ± 7.2 *	25.9 ± 7.0	41.5 ± 10.5 *	55.0 ± 16.8
	IMID (fall '09 + spring '10)	6	2.4 ± 1.5 *	5.4 ± 2.5 *	25.6 ± 5.2	31.0 ± 5.3 *	52.6 ± 13.0
	IMID + Emamectin benzoate (EB) (fall '09)	6	1.6 ± 0.4 *	3.1 ± 1.0 *	22.4 ± 5.6 *	25.5 ± 5.6 *	60.6 ± 8.0 *
	IMID + EB (fall ' 09) + IMID (spring '10)	6	0.6 ± 0.5 *	3.8 ± 1.1 *	20.5 ± 5.3 *	24.3 ± 5.7 *	68.4 ± 13.8 *
	Dinotefuran + EB (spring '10)	6	0.8 ± 0.4 *	5.1 ± 1.6 *	28.8 ± 7.3	33.9 ± 6.4 *	55.6 ± 9.2 *
	Check	6	40.7 ± 5.8	25.2 ± 5.6	36.5 ± 5.4	61.7 ± 5.0	36.1 ± 5.9
2011	Imidacloprid (IMID) (fall '09)	6					
	IMID (fall '09 + spring '10)	6					
	IMID + Emamectin benzoate (EB) (fall '09)	6					
	IMID + EB (fall ' 09) + IMID (spring '10)	6					
	Dinotefuran + EB (spring '10)	6					
	Check	6					

† Means followed by an asteriks in each column of the same site are significantly different from the checks at the 5% level based on Fisher's Protected LSD.

Table 17. Mean percentages (± SE) of surviving conelets and cones on branches of loblolly pine pine protected with trunk injection of different systemic insecticides at Arborgen's Woodville Seed Orchard, 2010 and 2011.

		Mean Survival (%)			
		Conelets		Cones	
Treatment	N	2010	2011	2010	2011
Abamectin	7	98.7 ± 0.9 *		80.3 ± 7.7	
Acephate	7	87.4 ± 4.9		80.8 ± 5.3	
Acelopryn	7	91.4 ± 3.1		95.5 ± 1.0 *	
Azadirachtin	7	89.1 ± 4.0		81.4 ± 6.2	
Dinotefuran	4	95.3 ± 2.2		85.5 ± 5.9	
Emamectin benzoate	6	99.1 ± 0.6 *		90.1 ± 4.6 *	
Emamectin benzoate + 2 sprays	7	99.3 ± 0.5 *		92.7 ± 1.8 *	
Fipronil	7	90.1 + 4.0		87.6 ± 3.3	
Imidacloprid	7	93.9 ± 2.1		80.6 ± 3.7	
Check	7	89.5 + 3.6		77.8 ± 2.9	

† Means followed by an asteriks in each column of the same year are significantly different from the check at the 5% level based on Fisher's Protected LSD.

Table 18. Mean percentages (± SE) of cones killed early and late by coneworms, other-damaged cones, and healthy cones on loblolly pine protected with trunk injections of different systemic insecticides, Woodville, TX, 2010 and 2011.

Year	Treatment	N	Mean Coneworm Damage (%)				
			Early (small dead)	Late (large dead and infested)	Total	Mean Other Damage (%) *	Mean Healthy (%)
2010	Abamectin	7	0.6 ± 0.6 *†	4.3 ± 3.0 *	5.0 ± 3.6 *	23.0 ± 6.9	72.0 ± 8.2
	Acephate	7	3.0 ± 0.8 *	16.0 ± 3.0	19.0 ± 3.3	13.5 ± 2.3	67.5 ± 4.9
	Acelopryn	7	0.5 ± 0.4 *	3.8 ± 2.2 *	4.3 ± 2.6 *	12.5 ± 2.6	83.2 ± 4.3 *
	Azadirachtin	7	2.7 ± 0.7 *	12.5 ± 3.3	15.2 ± 3.1	13.4 ± 4.7	71.4 ± 5.6
	Dinotefuran	4	1.3 ± 0.4 *	14.8 ± 4.6	16.1 ± 4.8	12.1 ± 4.0	71.9 ± 8.4
	Emamectin benzoate	6	0.0 ± 0.0 *	0.6 ± 0.3 *	0.6 ± 0.3 *	10.5 ± 2.5	88.9 ± 2.5 *
	Emamectin benzoate + 2 sprays	7	0.3 ± 0.2 *	0.0 ± 0.0 *	0.3 ± 0.2 *	15.5 ± 3.4	84.2 ± 3.5 *
	Fipronil	7	1.8 ± 0.8 *	2.3 ± 0.9 *	4.1 ± 1.3 *	11.0 ± 3.5	85.0 ± 4.4 *
	Imidacloprid	7	3.7 ± 0.5	20.5 ± 4.4	24.2 ± 4.8	9.9 ± 2.3	65.9 ± 6.0
	Check	7	4.9 ± 0.7	17.4 ± 3.4	22.3 ± 3.3	14.5 ± 3.8	63.2 ± 4.2
2011	Abamectin	7					
	Acephate	7					
	Acelopryn	7					
	Azadirachtin	7					
	Dinotefuran	4					
	Emamectin benzoate	6					
	Emamectin benzoate + 2 sprays	7					
	Fipronil	7					
	Imidacloprid	7					
	Check	7					

† Means followed by an asteriks in each column of the same year are significantly different from the check at the 5% level based on Fisher's Protected LSD.

Table 19. Seed bug damage, seed extracted, and seed quality (Mean ± SE) from first- and second-year cones of loblolly pine and slash pine protected with trunk injections of different systemic insecticides,Woodville, TX, 2010 and 2011.

			Mean Seed Bug Damage (%) to:				
			First-year Conelet Ovules	Second-year Cone Seed			Mean No. Filled Seed per Cone
Year	Treatment	N	Late (Oct.)	Early (2nd Yr Abort)	Late	Total	
2010	Abamectin	7	1.1 ± 0.3 *†	3.8 ± 2.0	27.7 ± 5.3	31.6 ± 5.3	90.7 ± 7.3
	Acephate	7	17.1 ± 4.8	8.5 ± 6.2	27.7 ± 6.7	36.2 ± 6.9	82.8 ± 8.8
	Aceloprynr	7	9.8 ± 3.5	7.1 ± 2.7	35.6 ± 5.1	42.7 ± 4.6	73.0 ± 8.8
	Azadirachtin	7	25.8 ± 3.0	10.9 ± 3.0	27.5 ± 5.7	38.4 ± 7.9	77.3 ± 10.4
	Dinotefuran	4	3.6 ± 2.4 *	2.0 ± 0.7	17.1 ± 5.6 *	19.1 ± 5.3 *	114.2 ± 13.9 *
	Emamectin benzoate	6	1.7 ± 1.1 *	2.2 ± 0.5	25.2 ± 4.7	27.4 ± 4.5 *	90.2 ± 7.3
	Emamectin benzoate + 2 sprays	7	0.3 ± 0.1 *	2.8 ± 0.6	25.9 ± 4.2	28.7 ± 4.3 *	85.1 ± 5.0
	Fipronil	7	13.9 ± 6.0	3.9 ± 1.3	33.4 ± 7.1	37.3 ± 7.4	81.4 ± 9.1
	Imidacloprid	7	6.3 ± 3.3 *	1.8 ± 0.4 *	20.5 ± 3.5 *	22.3 ± 3.4 *	99.0 ± 6.4 *
	Check	7	18.2 ± 4.9	7.4 ± 2.3	34.0 ± 3.8	41.3 ± 3.7	73.2 ± 4.9
2011	Abamectin	7					
	Acephate	7					
	Acelopryn	7					
	Azadirachtin	7					
	Dinotefuran	4					
	Emamectin benzoate	6					
	Emamectin benzoate + 2 sprays	7					
	Fipronil	7					
	Imidacloprid	7					
	Check	7					

† Means followed by an asteriks in each column of the same site are significantly different from the checks at the 5% level based on Fisher's Protected LSD.

SYSTEMIC PESTICIDE INJECTION TRIALS

Evaluation of Emamectin Benzoate (TREE-äge™) for Protection of Oaks Against Insect Pests

Highlights:

- Tree IV injections of emamectin benzoate (EB) continued to significantly reduce occurrence/damage caused by insects, including leaf beetles, borers, oakworm caterpillars, solitary oak leafminer on cherrybark and/or bur oaks compared to untreated checks.
- Tree IV injections of EB significantly reduced level of cerambycid larval feeding, but not the number of live larvae in water oak logs 20 months after treatment.

Justification: Injection trials conducted by the Forest Pest Management Cooperative, Arborjet Inc. (Woburn, MA) and others from 1999 – 2008 have shown that emamectin benzoate (TREE-äge™), injected into conifers and hardwoods, are highly effective against coneworm, bark beetles, wood borers, forest tent caterpillar and winter moth. Syngenta submitted TREE-äge™ for registration by EPA in January 2008. Syngenta is interested in generating additional data in support of TREE-äge™ against foliar, bud and stem pests of hardwood.

Objective: Evaluate the potential for systemic injections of TREE-äge™ (emamectin benzoate) in reducing foliar, bud and stem insect pest damage on bur oak, cherrybark oak and water oak.

Cooperators:

Dr. Tom Byram	Western Gulf Tree Improvement Program, College Station, TX
Dr. Jackie Driver	Syngenta, Waco, TX
Dr. David Cox	Syngenta, Modesta, CA
Mr. Joseph Doccola	Arborjet, Inc., Worchester, MA

Study Site: Three acre orchard block containing 10 - 20 year-old water oak (*Quercus nigra)*, cherrybark oak (*Q. pagoda),* and bur oak (*Q. macrocarpa)* -- Texas Forest Service Hudson Hardwood Seed Orchard, Angelina Co., TX.

Insecticides:

Emamectin benzoate (TREE-äge™) -- avermectin derivative that has shown systemic activity against Coleoptera and Lepidoptera

Research Approach:

Bur Oak - randomized complete block with clones as blocks. 2 treatments X 7 clones X 2 ramets per clone = 28 ramets used for study.

Cherrybark Oak - randomized complete block with clones as blocks. 2 treatments X 7 clones X 2 ramets per clone = 28 ramets used for study.

Water Oak – 2 X 2 X 3 factorial design. 2 treatments X 2 felling dates X 3 evaluation periods X 10 replicates = 120 replicates used for study

The treatments include:

Bur Oak Trial

1) Emamectin benzoate (TREE-äge™, 4% ai) applied undiluted at 10 ml of product per inch tree diameter at breast height (DBH) (0.4g active per inch DBH) (N = 14)
2) Check (untreated) (N = 14)

Cherrybark Oak Trial

1) Emamectin benzoate (TREE-äge™, 4% ai) applied undiluted at 10 ml of product per inch tree diameter at breast height (DBH) (0.4g active per inch DBH) (N = 14)
2) Check (untreated) (N = 14)

Water Oak Trial

1) Emamectin benzoate (TREE-äge™, 4% ai) applied undiluted at 10 ml of product per inch tree diameter at breast height (DBH) (0.4g active per inch DBH) (N = 20)
2) Check (untreated) (N = 10)

In late April 2009, study trees were selected and measured for DBH to determine volume of insecticide to be injected. Eight (8) holes, 0.95 cm (3/8 in) in diameter and 4 cm (1.5 in) deep, were drilled into the root flare of the tree bole (5 cm above ground). Arborplugs were installed in each hole. The Arborjet™ QUIK-jet system was used to inject an equal amount of product into each injection point.

Data Collection:

Bur and Cherrybark Oak Trials

All study trees were visibly inspected for insect damage at the time of treatment and at one or two month intervals thereafter (May 21, June 22, August 4, and September 30, 2009 and May 11, June 29, August 20 and October 29, 2010). Damage levels were ranked on a scale of 0 to 5 (0 = absent, 1 = isolated, 2 = light, 3 = moderate, 4 = heavy, or 5 = extensive) and recorded. If damage was occurring to foliage, a sample was collected for proper identification of the causal agent.

Water Oak Trial

The injected trees were allowed 4 (August 2009) and 12 (April 2010) months to translocate product. In June, a series of 10 trees per treatment were felled and 1.5 m bolts taken from the 3, 4.5 and 6 m heights. The bolts were randomly placed 1 m from other bolts on discarded, hardwood bolts to maximize surface area available for colonization as well as to discourage predation by ground and litter-inhabiting organisms. To facilitate timely insect colonization, an amber bottle with wick, containing ethanol, was attached to 1 m stakes evenly spaced in the study area.

A series of bolts (10 for each treatment) was/will be retrieved 8 (August), 25 (December) and ~42 (March 2010) weeks after deployment. In the laboratory, the length and diameter of each bolt was measured. The bark was removed from each bolt. The following measurements were recorded from each bark sample:

1) Number of cerambycid egg niches on bark surface
2) Number of live and dead cerambycid larvae
3) Percent of bark sample with cerambycid activity, estimated by overlaying a 100 cm^2 grid on the underside of each bark strip and counting the number of squares where cerambycid larvae had fed
4) Number of ambrosia beetle entry holes
5) Number of cerambycid larval entrance holes into the sapwood, and
6) Number of adult cerambycid exit holes out of the sapwood

Treatment efficacy was determined by comparing the number of cerambycid and/or ambrosia beetle attacks and the area of cerambycid feeding for each treatment and felling date. Data was transformed by $\log_{10}(x+1)$ if necessary to satisfy criteria for normality and homoscedasticity (Zar 1984) and analyzed by GLM and the Fisher's Protected LSD test using the Statview® statistical program (SAS Institute Inc.).

Results:

A hard frost in early April 2009 caused considerable damage to young leaves and flowers, particularly on the bur oaks. Many trees had to put out new shoots. Early season damage due to insects was difficult to see. A significant drought occurred in 2010 (April – December), making trees more susceptible to certain insect pests.

Observations in 2009 and 2010 indicated that several insect species attack oaks through the year: most common were a chrysomelid beetle (May and June 2009 and 2010), trunk borer (family and species unknown, June 2009 and 2010), and tussock moth caterpillars (June 2009) on cherrybark oaks, and a leaf-rolling weevil (Coleoptera: Attelabidae**,** June 2009), oakworm caterpillars (September 2009 and 2010), and solitary oak leafminer (August and September 2010) on bur oaks (Table 20 and photos). The emamectin benzoate treatment significantly reduced damage levels of pests on one or both tree species. Another common pest, acorn weevil (Coleoptera Curculionidae) appeared to be unaffected by the emamectin benzoate treatment (Table 21). No chemical was detected in acorns from treated trees (Table 22). Other pests observed in very low numbers included branch gall insects, aphids, walking sticks, fall webworm and twig girdler.

Logs from emamectin benzoate-treated water oaks had significantly fewer cerambycid egg niches and live larvae, and less feeding area compared to untreated checks in 2009 (Table 23). There was no difference between treatments in the number of dead cerambycid larvae or ambrosia beetle holes penetrating into xylem tissue. The number of live and dead borers and ambrosia beetles found in logs in 2010 did not differ between treatments. Only the level of cerambycid larval feeding was still significantly lower in emamectin benzoate logs compared to unprotected logs.

Conclusions:

A moderate concentration of emamectin benzoate in treated trees can protect hardwoods against several defoliators and can suppress damage from leaf beetles, weevils, caterpillars, and leafminers. Based on these results, the duration of emamectin benzoate efficacy on bur and cherrybark oak will be evaluated in 2011. Protection against borers and ambrosia beetles on water oak was limited. Thus, no additional evaluations will be made.

No emamectin benzoate was detected in the nutmeat of acorns from cherrybark oak. This likely explains the lack of protection against acorn weevils. However, this discovery may open the possibility that EB could be used to protect foliage, branches and trunks of edible nut crop trees (pecan, walnut, etc.) against several important pests yet safe for consumption. No protection would be provided from nut-infesting insects (acorn weevil).

Acknowledgements:

We appreciate the assistance provide by Todd Nightingale, Joe Hernandez and Marvin Lopez of the Texas Forest Service. We thank Arborjet, Inc. and Syngenta Crop Protection for the financial support, chemical donations, and/or loans of injection equipment.

Figure 3. A) Leaf beetle (Coleoptera: Chrysomelidae) and B) skeletonized leaves of bur oak.

Figure 4. Leaf-rolling weevil, *Homoeolabus analis* (Coleoptera: Curculionidae), and damage on bur oak leaves.

Figure 5. Banded tussock moth caterpillar, *Halysidota tessellaris* (Lepidoptera: Arctiidae).

Figure 6. Borer damage on trunk of cherrybark oak.

Figure 7. Spiny oakworm caterpillar, *Anisota stigma* (Lepidoptera: Saturnidae) and pink-striped caterpillar, *A. virginiensis*, on bur and cherrybark oaks.

Figure 8. Acorn weevil and damage in cherrybark oak acorns.

Figure 9. Solitary oak leafminer, *Cameraria hamadryadella* (Lepidoptera: Gracillariidae) on bur oak leaves.

Figure 10. Bur oak (left) defoliated as a result of solitary oak leafminer attack. Tree on right was treated with emamectin benzoate.

Figure 11. Leaf curl on bur oak leaves at branch tips. Causal agent may be fungal pathogen, perhaps *Taphrina communis*.

Table 20: Occurrence/severity of insect damage on bur and cherrybark oak treated with emamectin benzoate, Hudson, TX; 2009 and 2010

				Causal Agent						
Tree Species	Year	Treatment	N	Chrysomelid leaf skeletinizer	Borer	Tussock moth caterpillar	Leaf-rolling weevil	Oakworm caterpillar	Solitary Oak Leafminer	Leaf Curl (unknown cause)
Bur Oak	2009	Emamectin benzoate	14	1.29 ± 0.19 *†	0.00 ± 0.00	0.00 ± 0.00	0.14 ± 0.10 *	0.00 ± 0.00 *	-------	-------
		Check	14	2.07 ± 0.17	0.14 ± 0.10	0.14 ± 0.10	0.64 ± 0.20	0.57 ± 0.25	-------	-------
	2010	Emamectin benzoate	14	0.07 ± 0.07 *	-------	-------	-------	0.21 ± 0.11 *	0.50 ± 0.17 *	1.57 ± 0.32
		Check	14	1.14 ± 0.23	-------	-------	-------	1.07 ± 0.25	3.21 ± 0.23	1.18 ± 0.26
Cherrybark Oak	2009	Emamectin benzoate	14	1.57 ± 0.20 *	0.00 ± 0.00 *	0.00 ± 0.00 *	-------	0.00 ± 0.00	-------	-------
		Check	14	2.29 ± 0.16	0.50 ± 0.14	0.64 ± 0.22	-------	0.43 ± 0.20	-------	-------
	2010	Emamectin benzoate	14	0.00 ± 0.00 *	0.00 ± 0.00 *	-------	-------	0.00 ± 0.00 *	0.36 ± 0.13 *	-------
		Check	14	0.86 ± 0.14	0.50 ± 0.20	-------	-------	0.43 ± 0.14	1.43 ± 0.17	-------

Damage Ranking: 0=absent, 1=isolated, 2=light, 3=moderate, 4=heavy, or 5=extensive

† Means followed by an asteriks in each column of the same tree species are significantly different from the checks at the 5% level based on Fisher's Protected LSD.

Table 21: Acorn weevil damage to cherrybark oak acorns; Hudson, TX; 2009

		1-Oct-09		5-Dec-09	
Treatment*	N	Weevil Damaged	Healthy	Weevil Damaged	Healthy
Emamectin benzoate (2005)	3	6.5 ± 3.9 †	90.5 ± 6.8	21.7 ± 15.8	78.3 ± 15.8
Emamectin benzoate (2009)	3	32.5 ± 6.7	55.6 ± 10.7	46.2 ± 6.9	53.8 ± 6.9
Check	5	20.9 ± 5.3	72.1 ± 6.1	37.0 ± 10.7	63.0 ± 10.7

† Means followed by an asteriks in each column of the same tree species are significantly different from the checks at the 5% level based on Fisher's Protected LSD.

Table 22: Emamectin benzoate concentration (ppb) in cherrybark oak leaves and acorns; Hudson, TX; 2009

Treatment	N	Leaves (fallen)	N	Acorn nutmeat
Emamectin benzoate (2005)	4	0.8 ± 0.8 †	3	< 1.0
Emamectin benzoate (2009)	4	151.5 ± 49.4 *	3	< 1.0
Check	5	0.6 ± 0.6	5	< 1.0

† Means followed by an asteriks in each column are significantly different from the checks at the 5% level based on Fisher's Protected LSD.

Table 23: Level of insect damage on logs from water oaks treated with emamectin benzoate, Hudson, TX; 2009 - 2010

			Insect Activity						
Date	Treatment*	N	Cerambycid Egg Niches	Live Cerambycid Larvae	Dead Cerambycid Larvae	Feeding Area (cm^2)	Ambrosia Beetle holes	Cerambycid Entrance Holes into Sapwood	Cerambycid Exit Holes from the Sapwood
24-Aug-09	Emamectin benzoate	9	5.1 ± 1.1 *†	1.2 ± 0.5 *	1.6 ± 0.6	43.2 ± 12.9 *	20.8 ± 3.5		
	Check	10	13.1 ± 1.3	15.5 ± 1.8	0.8 ± 0.4	194.8 ± 26.1	22.5 ± 4.5		
17-Dec-09	Emamectin benzoate	12	2.0 ± 0.3 *	10.3 ± 2.2 *	1.3 ± 0.5	164.7 ± 37.3 *	20.3 ± 6.9		
	Check	9	7.3 ± 1.2	47.2 ± 13.2	1.6 ± 0.5	689.7 ± 77.2	17.3 ± 5.1		
14-Jan-11	Emamectin benzoate	9		8.4 ± 3.3	0.7 ± 0.4	142.0 ± 41.6 *	27.3 ± 8.8	1.7 ± 0.9	0.9 ± 0.4
	Check	10		11.6 ± 4.3	1.2 ± 0.9	258.1 ± 35.9	35.6 ± 14.2	2.8 ± 0.8	0.3 ± 0.2

† Means followed by an asteriks in each column of the same tree species are significantly different from the checks at the 5% level based on Fisher's Protected LSD.

SYSTEMIC INSECTICIDE INJECTION TRIALS

Systemic Insecticide Timing, Dose Rate and Volume for Single Tree Protection from Southern *Ips* Engraver Beetles

Highlights:

- The FPMC continued to evaluate the efficacy of a formulation of abamectin and fipronil, for preventing attacks and brood production of *Ips* engraver beetles and wood borers on bolt sections of loblolly pine in East Texas.
- Both rates (0.4 and 0.8 g AI/inch DBH) of abamectin applied in the spring and fall and fipronil in the fall were highly effective against *Ips* engraver beetles and wood borers 22 to 28 months after injection.

Justification: In 2004 and 2005, the FPMC conducted injection trials in East Texas to evaluate the potential efficacy of the systemic insecticides emamectin benzoate (EB) and fipronil for protection of loblolly pine against *Ips* engraver beetles (Coleoptera: Curculionidae). The results showed that EB and fipronil were highly effective in preventing both the successful colonization of treated bolts by engraver beetles and wood borers (Coleoptera: Cerambycidae) and the mortality of standing trees (see 2004 and 2005 Accomplishment Report). Abamectin is also an avermectin derivative. It is of interest to determine if abamectin is similarly effective against bark beetles and wood borers. If so, what is the best timing, dosage rate, and duration of abamectin treatments?

Objectives: 1) Evaluate the efficacy of systemic injections of fipronil and abamectin in reducing colonization success of pine engraver beetles and wood borers on loblolly pine; 2) evaluate the chemicals applied at different timings and dosage rates using Arborjet's Tree IV™ pressurized injection system; and 3) determine the duration of treatment efficacy.

Cooperators:

Mr. Doug Long	Rayonier, Lufkin, TX
Ms. Marianne Waindle	Mauget, Arcadia, CA

Study Sites: One 20-year-old, recently-thinned loblolly pine plantation was selected on land owned by Rayonier, Polk Co., TX. Selected trees were injected for use in a bolt study. A staging area was set up in a nearby plantation (Anderson Co., about 10 miles east of Palestine, TX) where bolts were exposed to bark beetles and wood borers.

Insecticides:

Abamectin (Abacide® 2, JJ Mauget) – a mixture of avermectin B1a and B1b; fermentation products from soil bacterium *Streptomyces avermitilis*.

Fipronil (experimental BASF BAS 350 PW) -- a phenyl pyrazole insecticide that has shown systemic activity against other Coleoptera (bark beetles)

Treatments:

Trial 1: Established April 2008

Trt #	Chemical	Formulation	Application Timing	Rate (g ai/inch dbh)	No. of Trees Treated	Felling Dates
1	Abamectin	Abacide	Apr-08	0.4	40	Sept '08, July '09, '10 & '11
2	Abamectin	Abacide	Apr-08	0.8	40	Sept '08, July '09, '10 & '11
3	Abamectin	Abacide	Oct-08	0.4	30	Jul '09, '10 & '11
4	Abamectin	Abacide	Oct-08	0.8	30	Jul '09, '10 & '11
5	Fipronil	BAS 350 PW	Oct-08	0.4	30	Jul '09, '10 & '11
6	Fipronil	BAS 350 PW	Oct-08	0.8	30	Jul '09, '10 & '11
7	Untreated				40	Sept '08, July '09, '10 & '11

Treatment Methods and Evaluation:

Loblolly pine trees (240), 15 – 20 cm DBH, were selected in April 2008. Thirty - forty trees were each injected with one of two treatments: abamectin (April and October 2008), or fipronil (October 2008) at two different rates (0.4g or 0.8g per 1 inch of tree diameter). Each injection treatment (1 - 6) consisted of a single insecticide formulation injected into four cardinal points about 0.3 m above the ground on each tree using the Arborjet Tree IV™.

After 5 (September '08), 15 (July '09), 27 (July '10), or 39 (July '11) months post-injection, 10 trees of each abamectin and fipronil treatment were/will be felled and one 1.5 m-long bolts were/will be removed from the 3 m height of the bole.

For each trial, 1.5 m bolts were transported to another plantation that was recently thinned and contained fresh slash material. Each bolt was placed about 1 m from other bolts on discarded, dry pine bolts to maximize surface area available for colonization as well as to discourage predation by ground and litter-inhabiting organisms. To facilitate timely bark beetle colonization, packets of *Ips* pheromones (racemic ipsdienol and cis-verbenol; Synergy Semiochemicals, Delta, BC, Canada) were attached separately to three 1 m stakes evenly spaced in the study area.

Each series of bolts was retrieved about 3 weeks after deployment, after many cerambycid egg niches were observed on the bark surface of most bolts. In the laboratory, two 10 cm X 50 cm samples (total = 1000 cm^2) of bark were removed from each bolt. The following measurements were recorded from each bark sample:

1) Number of unsuccessful attacks - penetration to phloem, but no egg galleries.
2) Number of successful attacks - construction of nuptial chamber and at least one egg gallery extending from it.
3) Number and lengths of egg galleries with larval galleries radiating from them.
4) Number and lengths of egg galleries without larval galleries.
5) Percent of bark sample with cerambycid activity, estimated by overlaying a 100 cm^2 grid on the underside of each bark strip and counting the number of squares where cerambycid larvae had fed.

Treatment efficacy was determined by comparing *Ips* beetle attacks, *Ips* egg gallery length and cerambycid feeding for each treatment. The data were transformed by $\log_{10}(x+1)$ to satisfy criteria for normality and homoscedasticity (Zar 1984) and analyzed by GLM and the Fishers Protected LSD test using the Statview statistical program.

Results:

Ips Attack Success – In 2008, the total number of attacks (nuptial chambers constructed) by male *Ips* engraver beetles did not differ among the abamectin treatments (Table 24). Most (87%) of the nuptial chambers were successfully constructed on untreated bolts; at least one egg gallery radiated from each nuptial chamber. In contrast, both abamectin treatments had significantly fewer nuptial chambers with egg galleries (Tables 24). Both treatments completely prevented brood development compared to check trees (Tables 25 and 26).

In 2009, the total number of attacks by male *Ips* engraver beetles did not differ among the abamectin and fipronil treatments (Table 24 and 28). Most (81%) of the nuptial chambers were successfully constructed on untreated bolts - with at least one egg gallery radiating from each nuptial chamber. In contrast, all abamectin and fipronil treatments had significantly fewer nuptial chambers with egg galleries (Tables 24 and 28). All treatments completely prevented brood development compared to check trees (Tables 25, 26, 29 and 30).

In 2010, the total number of attacks by male *Ips* engraver beetles did not differ among the abamectin and fipronil treatments (Table 24 and 28). Most (94%) of the nuptial chambers were successfully constructed on untreated bolts - with at least one egg gallery radiating from each nuptial chamber. In contrast, all abamectin and fipronil treatments had significantly fewer nuptial chambers with egg galleries (Tables 24 and 28). All abamectin treatments completely prevented brood development compared to check trees (Tables 25 and 26, Figure 12). There was a little brood development in one log treated with the high rate fipronil, but overall significantly less brood development occurred in treated logs compared to check logs (Tables 29 and 30, Figure 13).

Cerambycid Larval Feeding – In 2008, the attack level of wood borers (egg niches) on logs from injected trees did not differ from that on check logs (Table 27). Relatively little cerambycid feeding (10%) occurred on untreated bolts during the 3-week period between tree felling and bolt evaluation (Table 27). Both abamectin treatments reduced the amount of larval feeding and development compared to the check.

In 2009, the attack level of wood borers (egg niches) on logs from most injected trees did not differ from that on check logs (Table 27 and 31). Relatively little cerambycid feeding (8%) occurred on untreated bolts during the 3 weeks period between tree felling and bolt evaluation (Table 27 and 31). All abamectin and fipronil treatments reduced the amount of larval feeding and development compared to the check.

In 2010, the attack level of wood borers (egg niches) on logs from all treated trees did not differ from that on check logs (Table 27 and 31). A moderate level of cerambycid feeding (22%) occurred on untreated bolts during the 3-week period between tree felling and bolt evaluation (Table 27 and 31). All abamectin and fipronil treatments markedly reduced the amount of larval feeding and development compared to the check.

Conclusions:

The trial continues to show that abamectin and fipronil are highly effective against southern pine engraver beetles and wood borers for extended periods. No significant differences in the efficacy of abamectin or fipronil at the two rates were observed 22 - 28 months after injection.

Acknowledgements: Many thanks go to Doug Long, Rayonier, for providing thinned stands for the project. We thank JJ Mauget, Inc. for the financial support and donation of chemical and Arborjet for loan of injection equipment.

Table 24: Attack success and gallery construction of *Ips* engraver beetles on loblolly pine bolts cut 5 to 28 months after trunk injection with abamectin using the Tree IV injection system; Lufkin, Texas: 2008 - 2010.

				Mean # of nuptial chambers without egg galleries		Mean # of nuptial chambers with egg galleries		
Evaluation period	Season/Yr. Injected	Treatment	N	No.	% of total	No.	% of total	Mean total # of nuptial chambers
5 month post-injection (Sept '08)	Spring 2008	Aba 0.8 g AI	11	4.2 *	94	0.3 *	6	4.5
		Aba 0.4 g AI	9	3.3 *	79	0.9 *	21	4.2
		Check	11	0.6	13	4.2	87	4.8
10 month post-injection (Aug. '09)	Fall 2008	Aba 0.8 g AI	9	4.0 *	100	0.0 *	0	4.0
		Aba 0.4 g AI	8	3.9 *	100	0.0 *	0	3.9
16 month post-injection (Aug. '09)	Spring 2008	Aba 0.8 g AI	10	4.6 *	100	0.0 *	0	4.6
		Aba 0.4 g AI	10	4.5 *	100	0.0 *	0	4.5
		Check	10	0.8	19	3.2	81	4.0
22 month post-injection (Aug. '10)	Fall 2008	Aba 0.8 g AI	10	2.0 *	80	0.5 *	20	2.5
		Aba 0.4 g AI	10	2.0 *	91	0.2 *	9	2.2
28 month post-injection (Aug. '10)	Spring 2008	Aba 0.8 g AI	10	2.2 *	88	0.3 *	12	2.5
		Aba 0.4 g AI	10	3.1 *	86	0.5 *	14	3.6
		Check	10	0.2	6	2.5	94	2.6

* Means followed by an asterisk are not significantly different from the check at the 5% level based on Fisher's Protected LSD.

Table 25: Mean number of egg galleries constructed by *Ips* engraver beetles (per 1000 cm^2) in loblolly pine bolts cut 5 to 28 months after trunk injection with abamectin using the Tree IV injection system; Lufkin, Texas: 2008 - 2010.

				Number of egg galleries				
				Without larvae		With larvae		
Evaluation period	Season/Yr. Injected	Treatment	N	No.	% of total	No.	% of Total	Total #
5 month post-injection (Sept '08)	Spring 2008	Aba 0.8 g AI	11	0.2 *	100	0.0 *	0	0.2 *
		Aba 0.4 g AI	9	1.2	100	0.0 *	0	1.2 *
		Check	11	1.5	18	6.6	82	8.1
10 month post-injection (Aug. '09)	Fall 2008	Aba 0.8 g AI	9	0.0	#####	0.0 *	#####	0.0 *
		Aba 0.4 g AI	8	0.0	#####	0.0 *	#####	0.0 *
16 month post-injection (Aug. '09)	Spring 2008	Aba 0.8 g AI	10	0.0	#####	0.0 *	#####	0.0 *
		Aba 0.4 g AI	10	0.0	#####	0.0 *	#####	0.0 *
		Check	10	0.0	0	9.4	100	9.4
22 month post-injection (Aug. '10)	Fall 2008	Aba 0.8 g AI	10	0.4	100	0.0 *	0	0.4 *
		Aba 0.4 g AI	10	0.3	100	0.0 *	0	0.3 *
28 month post-injection (Aug. '10)	Spring 2008	Aba 0.8 g AI	10	0.3	100	0.0 *	0	0.3 *
		Aba 0.4 g AI	10	0.5	100	0.0 *	0	0.5 *
		Check	10	1.2	21	4.5	79	5.7

* Means followed by an asterisk are not significantly different from the check at the 5% level based on Fisher's Protected LSD.

Table 26: Mean length of egg galleries constructed by *Ips* engraver beetles (per 1000 cm^2) in loblolly pine bolts cut 5 to 28 months after trunk injection with abamectin using the Tree IV injection system; Lufkin, Texas: 2008 - 2010.

				Length of egg galleries				
				Without larvae		With larvae		
Evaluation period	Season/Yr. Injected	Treatment	N	cm	% of Total	cm	% of Total	Total length
5 month post-injection (Sept '08)	Spring 2008	Aba 0.8 g AI	11	0.5 *	100	0.0 *	0	0.5 *
		Aba 0.4 g AI	9	3.9	100	0.0 *	0	3.9 *
		Check	11	8.5	10	74.0	90	82.5
10 month post-injection (Aug. '09)	Fall 2008	Aba 0.8 g AI	9	0.0	#####	0.0 *	#####	0.0 *
		Aba 0.4 g AI	8	0.0	#####	0.0 *	#####	0.0 *
16 month post-injection (Aug. '09)	Spring 2008	Aba 0.8 g AI	10	0.0	#####	0.0 *	#####	0.0 *
		Aba 0.4 g AI	10	0.0	#####	0.0 *	#####	0.0 *
		Check	10	0.0	0	94.9	100	94.9
22 month post-injection (Aug. '10)	Fall 2008	Aba 0.8 g AI	10	1.4	100	0.0 *	0	1.4 *
		Aba 0.4 g AI	10	1.7 *	100	0.0 *	0	1.7 *
28 month post-injection (Aug. '10)	Spring 2008	Aba 0.8 g AI	10	0.8 *	100	0.0 *	0	0.8 *
		Aba 0.4 g AI	10	3.2	100	0.0 *	0	3.2 *
		Check	10	14.7	20	73.2	83	87.9

* Means followed by an asterisk are not significantly different from the check at the 5% level based on Fisher's Protected LSD.

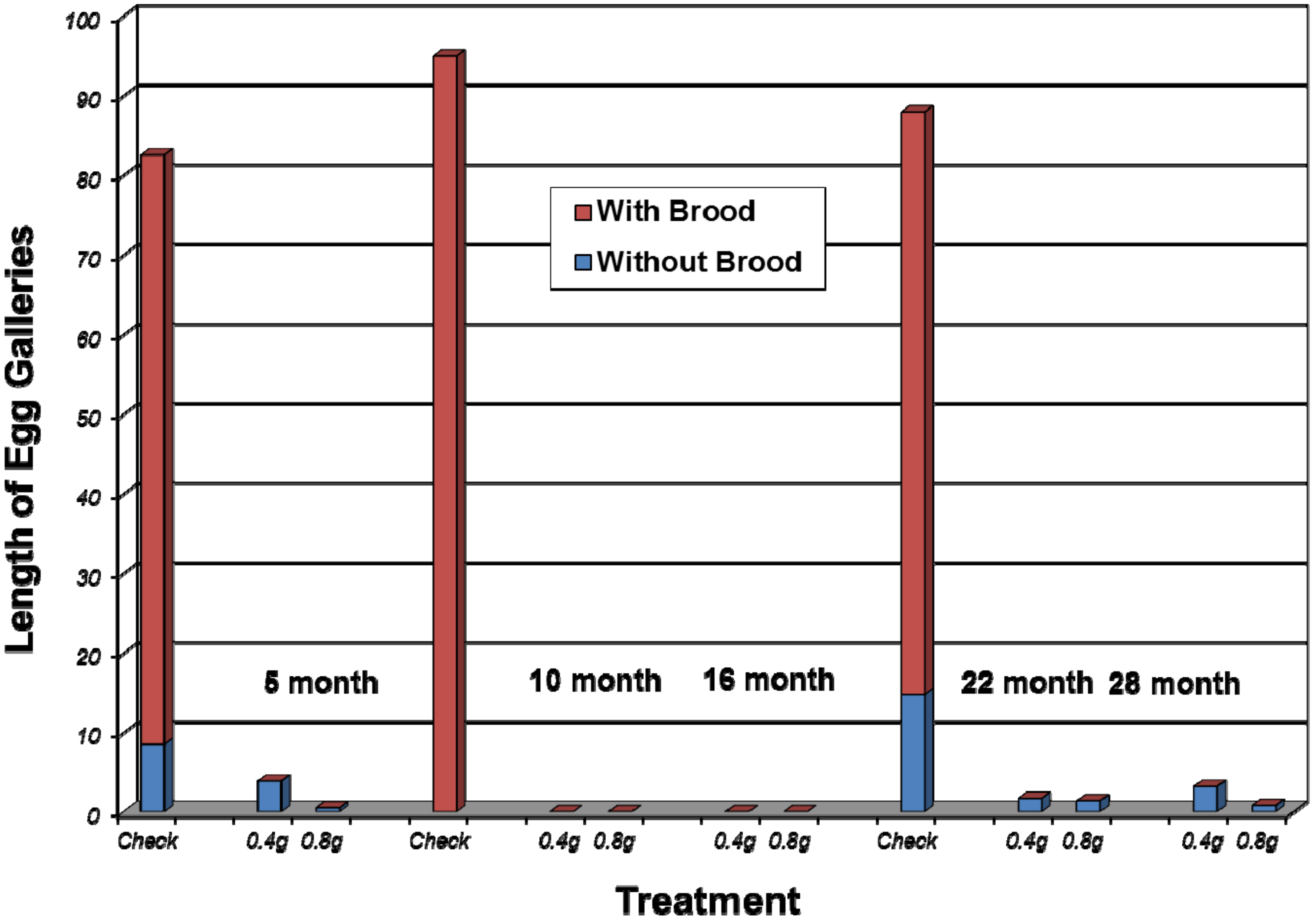


Figure 12. Mean length egg galleries (with and without brood) constructed by *Ips* engraver beetles (per 1000 cm^2) in loblolly pine bolts cut 5 to 28 months after injection with two rates of abamectin using the Tree IV Injection System; Lufkin, TX, 2008 - 2010

Table 27: Extent of feeding by cerambycid larvae (per 1000 cm^2) in loblolly pine bolts cut 5 to 28 months after trunk injection with abamectin using the Tree IV injection systems; Lufkin, Texas: 2008 - 2010.

Evaluation period	Season/Yr. Injected	Treatment	N	No. of cerambycid egg niches on bark	Percent phloem area consumed by larvae
5 month post-injection (Sept '08)	Spring 2008	Aba 0.8 g AI	11	4.3	0.1 *
		Aba 0.4 g AI	9	6.3	1.3 *
		Check	11	7.9	10.1
10 month post-injection (Aug. '09)	Fall 2008	Aba 0.8 g AI	9	1.7	0.0 *
		Aba 0.4 g AI	8	1.9	0.0 *
16 month post-injection (Aug. '09)	Spring 2008	Aba 0.8 g AI	10	0.9 *	0.0 *
		Aba 0.4 g AI	10	3.6	0.0 *
		Check	10	4.4	7.7
22 month post-injection (Aug. '10)	Fall 2008	Aba 0.8 g AI	10	7.9	0.0 *
		Aba 0.4 g AI	10	5.6	0.1 *
28 month post-injection (Aug. '10)	Spring 2008	Aba 0.8 g AI	10	5.9	0.0 *
		Aba 0.4 g AI	10	8.2	0.0 *
		Check	10	6.8	22.0

* Means followed by an asterisk are not significantly different from the check at the 5% level based on Fisher's Protected LSD.

Table 28: Attack success and gallery construction of *Ips* engraver beetles on loblolly pine bolts cut 10 to 22 months after trunk injection with fipronil using the Tree IV injection system; Lufkin, Texas: 2009 and 2010.

				Mean # of nuptial chambers without egg galleries		Mean # of nuptial chambers with egg galleries		
Evaluation period	Season/Yr. Injected	Treatment	N	No.	% of total	No.	% of total	Mean total # of nuptial chambers
10 month post-injection (Aug. '09)	Fall 2008	Fip 0.8 g AI	9	6.0 *	100	0.0 *	0	6.0
		Fip 0.4 g AI	10	4.4 *	96	0.2 *	4	4.6
		Check	10	0.8	19	3.2	81	4.0
22 month post-injection (Aug. '10)	Fall 2008	Fip 0.8 g AI	10	2.6 *	79	0.7 *	21	3.3
		Fip 0.4 g AI	10	2.5 *	81	0.6 *	19	3.1
		Check	10	0.2	6	2.5	94	2.6

* Means followed by an asterisk are not significantly different from the check at the 5% level based on Fisher's Protected LSD.

Table 29: Mean number of egg galleries constructed by *Ips* engraver beetles (per 1000 cm^2) in loblolly pine bolts cut 10 to 22 months after trunk injection with fipronil using the Tree IV injection system; Lufkin, Texas: 2009 and 2010.

				Number of egg galleries				
				Without larvae		With larvae		
Evaluation period	Season/Yr. Injected	Treatment	N	No.	% of total	No.	% of Total	Total #
10 month post-injection (Aug. '09)	Fall 2008	Fip 0.8 g AI	9	0.0	#####	0.0 *	#####	0.0 *
		Fip 0.4 g AI	10	0.2	100	0.0 *	0	0.2 *
		Check	10	0.0	0	9.4	100	9.4
22 month post-injection (Aug. '10)	Fall 2008	Fip 0.8 g AI	10	0.6	86	0.1 *	14	0.7 *
		Fip 0.4 g AI	10	1.3	100	0.0 *	0	1.3 *
		Check	10	1.2	21	4.5	79	5.7

* Means followed by an asterisk are not significantly different from the check at the 5% level based on Fisher's Protected LSD.

Table 30: Mean length of egg galleries constructed by *Ips* engraver beetles (per 1000 cm^2) in loblolly pine bolts cut 10 to 22 months after trunk injection with fipronil using the Tree IV injection system; Lufkin, Texas: 2009 and 2010.

				Length of egg galleries				
				Without larvae		With larvae		
Evaluation period	Season/Yr. Injected	Treatment	N	cm	% of Total	cm	% of Total	Total length
10 month post-injection (Aug. '09)	Fall 2008	Fip 0.8 g AI	9	0.0	#####	0.0 *	#####	0.0 *
		Fip 0.4 g AI	10	0.8	100	0.0 *	0	0.8 *
		Check	10	0.0	0	94.9	100	94.9
22 month post-injection (Aug. '10)	Fall 2008	Fip 0.8 g AI	10	4.2	525	0.8 *	16	5.0 *
		Fip 0.4 g AI	10	6.5	100	0.0 *	0	6.5 *
		Check	10	14.7	20	73.2	83	87.9

* Means followed by an asterisk are not significantly different from the check at the 5% level based on Fisher's Protected LSD.

Table 31: Extent of feeding by cerambycid larvae (per 1000 cm^2) in loblolly pine bolts cut 10 to 22 months after trunk injection with fipronil using the Tree IV injection systems; Lufkin, Texas: 2009 and 2010.

Evaluation period	Season/Yr. Injected	Treatment	N	No. of cerambycid egg niches on bark	Percent phloem area consumed by larvae
10 month post-injection (Aug. '09)	Fall 2008	Fip 0.8 g AI	9	6.2	0.0 *
		Fip 0.4 g AI	10	4.7	0.0 *
		Check	10	4.4	7.7
22 month post-injection (Aug. '10)	Fall 2008	Fip 0.8 g AI	10	6.6	0.3 *
		Fip 0.4 g AI	10	6.3	1.0 *
		Check	10	6.8	22.0

* Means followed by an asterisk are not significantly different from the check at the 5% level based on Fisher's Protected LSD.

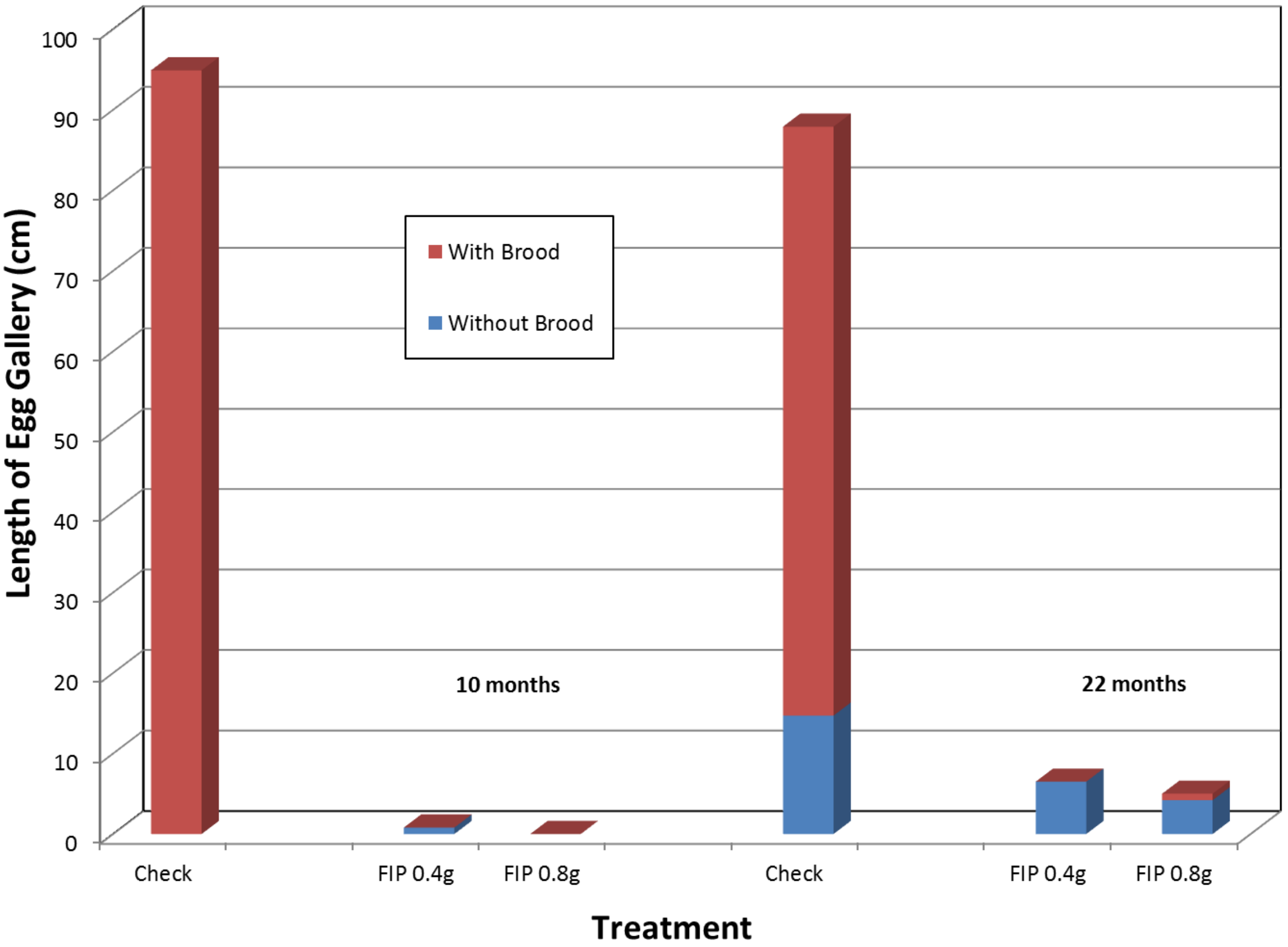


Figure 13. Effect of two fipronil injection treatments on *Ips* engraver beetle attack success 10 to 22 months after injection expressed as length of egg galleries with and without brood, Diboll, TX: 2009 - 2010.

SYSTEMIC PESTICIDE INJECTION TRIALS

Emamectin Benzoate or Abamectin Combined with Fungicide for Protection of High-Value Southern and Western Conifers from Bark Beetles and Blue Stain Fungi – Alabama and Utah

Highlights:

- The FPMC evaluated the efficacy of emamectin benzoate or abamectin alone or combined with fungicide for preventing mortality of conifers by *Dendroctonus* bark beetles (Coleoptera: Curculionidae, Scolytinae) in Alabama and Utah in 2010.
- Results indicate that tree injections that included emamectin benzoate are still effective in reducing/preventing tree mortality by southern pine beetle in the second year after treatment. The addition of a propiconazole/thiabendazole mix did not improve tree survival.
- The injection trial in Utah showed that tree injections that included emamectin benzoate are largely effective in reducing/preventing lodgepole pine mortality by mountain pine beetle in the first year after treatment. Efficacy of abamectin and abamectin + fungicide as preventative treatments will be determined in 2011.

Justification: Bark beetles of the genus *Dendroctonus* (Coleoptera: Curculionidae, Scolytinae) such as the southern pine beetle (SPB), *D. frontalis*, and mountain pine beetle (MPB), *D. ponderosae*, are responsible for extensive conifer mortality throughout North America. These species do not just affect the timber industry; they also have a significant impact on recreation, water, and wildlife resources as well as residential property values.

In 2004, the FPMC conducted an injection trial in East Texas to evaluate the potential efficacy of several reported systemic insecticides, including emamectin benzoate, fipronil, imidacloprid and dinotefuran, for protection of loblolly pine against *Ips* engraver beetles. Emamectin benzoate injections had been found to be highly effective (4+ years) against both pinewood nematode, *Bursaphelenchus xylophilis*, and coneworms, *Dioryctria* spp. The results from the 2004 trials with *Ips* bark beetles showed that emamectin benzoate was highly effective in preventing both the successful colonization of treated bolts 3 and 5 months after tree injection and the mortality of standing trees (see 2004 Accomplishment Report, Grosman et al., 2006). Similarly, abamectin was found to be effective against *Ips* spp. in a 2008 trial. Trials are needed to confirm efficacy against SPB and MPB and other bark beetle species as well as to determine duration of treatment efficacy.

Objectives: 1) Evaluate the efficacy of systemic injections of emamectin benzoate alone or combined with fungicide or abamectin for preventing mortality of conifers found in the southeastern and western regions of the United States by *Dendroctonus* bark beetles and blue stain fungi; 2) evaluate effect of injection timing on treatment efficacy, and 3) determine the duration of treatment efficacy.

Cooperators:

Dr. Steve Clarke	USDA Forest Service – FHP R8, Lufkin, Texas
Dr. Christopher Fettig	USDA Forest Service – PSW Research Station, Davis, CA
Dr. Steve Munson	USDA Forest Service – FHP R4, Ogden, Utah
Dr. David Cox	Syngenta, Modesta, CA
Ms. Marianne Waindle	Mauget, Arcadia, CA
Mr. Joseph Doccola	Arborjet, Inc., Worchester, MA

Study Sites: The study has/is being conducted at 3 sites:

1) Talladega National Forest, Oakmulgee Ranger District in Bibbs and Perry Co., Alabama with SPB attacking loblolly pine,
2) Uinta-Wasatch-Cache National Forest, Mountain View-Evanston Ranger District, Utah, with MPB attacking lodgepole pine.

Insecticides:

Emamectin benzoate (TREE-äge™, Arborjet Inc.) – an avermectin derivative
Abamectin (Abacide® 2, JJ Mauget) – a mixture of avermectin B1a and B1b; fermentation products from soil bacterium *Streptomyces avermitilis*
Thiabendazole - a systemic benzimidazole fungicide
Propiconazole – a systemic triazole fungicide
Tebuconazole (Tebuject™ 16, Mauget Inc.) – another triazole fungicide

Research Approach:

The treatments by trial included:

Trial 1

1) Emamectin benzoate (0.4g AI per inch) injection at 10 ml per inch DBH in April 2009,
2) Thiabendazole (13%) + Propiconazole (7%) (1:1) injection at 10 ml per inch DBH,
3) Emamectin benzoate + Thiabendazole + Propiconazole (2:1:1) injection at 20 ml per inch DBH,
4) Untreated (control) - used to assess beetle pressure during each summer (2009 - 2010)

Trial 2

1) Emamectin benzoate (0.4g AI per inch) injection at 10 ml per inch DBH in June 2009,
2) Emamectin benzoate (0.4g AI per inch) injection at 10 ml per inch DBH in September 2009,
3) Emamectin benzoate + Propiconazole injection at 20 ml per inch DBH in June 2009,
4) Emamectin benzoate + Propiconazole injection at 20 ml per inch DBH in September 2009,
5) Abamectin (0.4g AI per inch) injection at 20 ml per inch DBH in September 2009,
6) Abamectin (0.4g AI per inch) injection at 20 ml per inch DBH + Tebuconazole (0.4g AI per inch) injection at 6 ml per inch DBH in September 2009,
7) Untreated (control) - used to assess beetle pressure during each summer (2009 - 2010)

Table 28. Scheduled injection, baiting and evaluation dates for three *Dendroctonus* bark beetle trials.

	SPB (AL)	MPB (UT)
Project Leader(s)	Grosman & Clarke	Fettig
Injection Dates	Apr-09	Apr-09 Sep-09
Baiting Period	May - Jun 2009 Apr - Jun 2010	Jul - Aug 2009 Jul - Aug 2010
Prelim Evaluation	Jun - Nov 2009 May - Nov 2010	Oct 2009 Oct 2010
Final Evaluation	Dec. 2009 Dec. 2010	Jun 2010 Jun 2010

SPB = Southern pine beetle; MPB = Mountain pine beetle

Each insecticide (injection or spray) treatment was applied to 15-35 randomly-assigned trees. A similar number of trees was used for each set of untreated checks (2 sets (by year) total). Test trees were located in areas with recent beetle activity, spaced >100m apart, were 23 to 52 cm dbh, and were within 75m of an access road to facilitate treatment.

Each systemic insecticide treatment was injected using the Arborjet Tree IV™ microinfusion system (Arborjet, Inc. Woburn, MA) into 4-8 points 0.3 m above the ground. The injected trees were generally allowed 1-2 months (depending on water availability) to translocate chemicals prior to being challenged by the application of synthetic pheromone baits. Due to the short season and high elevation, the trees in Utah were not baited until 2009 (Table 28). In Utah, two sets were injected in June 2009 and two other sets were injected in September 2009

All test trees and the first set of untreated check trees in AL and UT were baited with appropriate species-specific lures (Phero Tech Inc., Delta, BC or Synergy Semiochemical, Delta, BC) for 2 to 4 weeks in 2009. The surviving treated trees in each treatment (if there were no more than 6 killed by the bark beetle challenge), and the second set of check trees were baited again for the same length of time in 2010.

The only criterion used to determine the effectiveness of the insecticide treatment was/will be whether or not individual trees succumb to attack by bark beetles. Tree mortality was/will be assessed in August for multiple, consecutive years until efficacy is diminished. The period between pheromone removal and mortality assessment was/will be sufficient for trees to "fade," an irreversible symptom of pending mortality. Presence of species-specific bark beetle galleries will be verified in each tree classified as dead or dying.

Treatments were/will be considered to have sufficient beetle pressure if ≥60% of the untreated control trees dies from beetle attack during each year. Insecticide treatments were/will be considered efficacious if <7 treated trees die as a result of bark beetle attacks. These criteria were established based on a sample size of 30 to 35 trees/treatment and the test of the null hypothesis, Ho:S (survival ≥ 90%). These parameters provide a conservative binomial test ($\alpha = 0.05$) to reject Ho when more than six trees die from bark beetle attack (Shea et al., 1984).

Results:

Southern pine beetle on loblolly pine (AL) – Trial 1

2009 at Oakmulgee NF - The study trees were baited with the three-component bait (frontalin, turpentine and endo-brevicomin) from the start (May). The results showed nearly 45% (13 of 29) of the check trees exhibited fading crowns by December 2009 (Figure 14). In contrast, 3% each of the EB and EB plus fungicide-treated trees had faded. The tree mortality (46%) for the fungicide only treatment did not differ substantially from mortality among check trees. All dead trees were cut down to determine the cause of tree mortality. As in the past, mortality of check trees was caused by a combination of SPB activity and blue-stain fungal infection (Table 32). SPB was not successful in trees injected with EB. Although other treatment trees also had blue stain fungi, the cross sectional area covered by fungi was somewhat reduced compared to checks.

2010 at Oakmulgee NF - The study trees were baited with the three-component bait (frontalin, turpentine and endo-brevicomin) from the start (April). The results showed over 41% (12 of 29) of the check trees exhibited fading crowns by December 2010 (Figure 14). In contrast, 3% of the EB trees and7% of the EB plus fungicide-treated trees had faded. The tree mortality (25%) for fungicide only treatment did not differ substantially from mortality among check trees.

Mountain pine beetle on lodgepole pine (UT) – Trial 2

2009 at Uinta-Wasatch-Cache NF - Nearly all baited trees were heavily attacked by MPB within 3 weeks. A final assessment in September 2010 showed heavy mortality (83%, 25 of 30) of untreated lodgepole pine trees (Figure 15). Mortality of treated (EB alone and EB + fungicide) trees were both 33% and thus above the 20% threshold.

2010 at Uinta-Wasatch-Cache NF - A preliminary assessment of tree mortality was conducted in September 2010. Mortality of EB treated trees (fall) was low (<6%) while that of abamectin-treated trees appeared to be higher (>23%) (Figure 15). Final assessment is planned for summer 2011.

Conclusions:

The results of trials presented above indicate that emamectin benzoate injection treatments can provide good protection against southern pine beetle, but is marginal for mountain pine beetle. It appears that the addition of a fungicide may reduce the success of blue stain fungi colonization. It is not yet apparent if the combination treatment improved protection compared to EB alone.

The AL and UT trials will be monitored in 2011 to evaluate the duration of efficacy of combination treatments of emamectin benzoate and fungicide and combination treatments of abamectin and fungicide at the Utah site.

Acknowledgements: Many thanks go to our cooperators: Chris Fettig, Steve Clarke, Steve Munson, Meg Halford, Cindy Ragland, Jim Meeker and Tim Haley of the U.S. Forest Service for their efforts on the projects. We appreciate the chemical donations and injection equipment loans made by Arborjet, Inc, BASF, and Syngenta and field assistance of Bill Upton (Texas Forest Service) and Chris Haleys, Wood Johnson, and Roger Menard (U.S. Forest Service). These trials were supported by funds from the FPMC, Southern Pine Beetle Initiative, FS-PIAP Grant to C. Fettig, BASF and Syngenta.

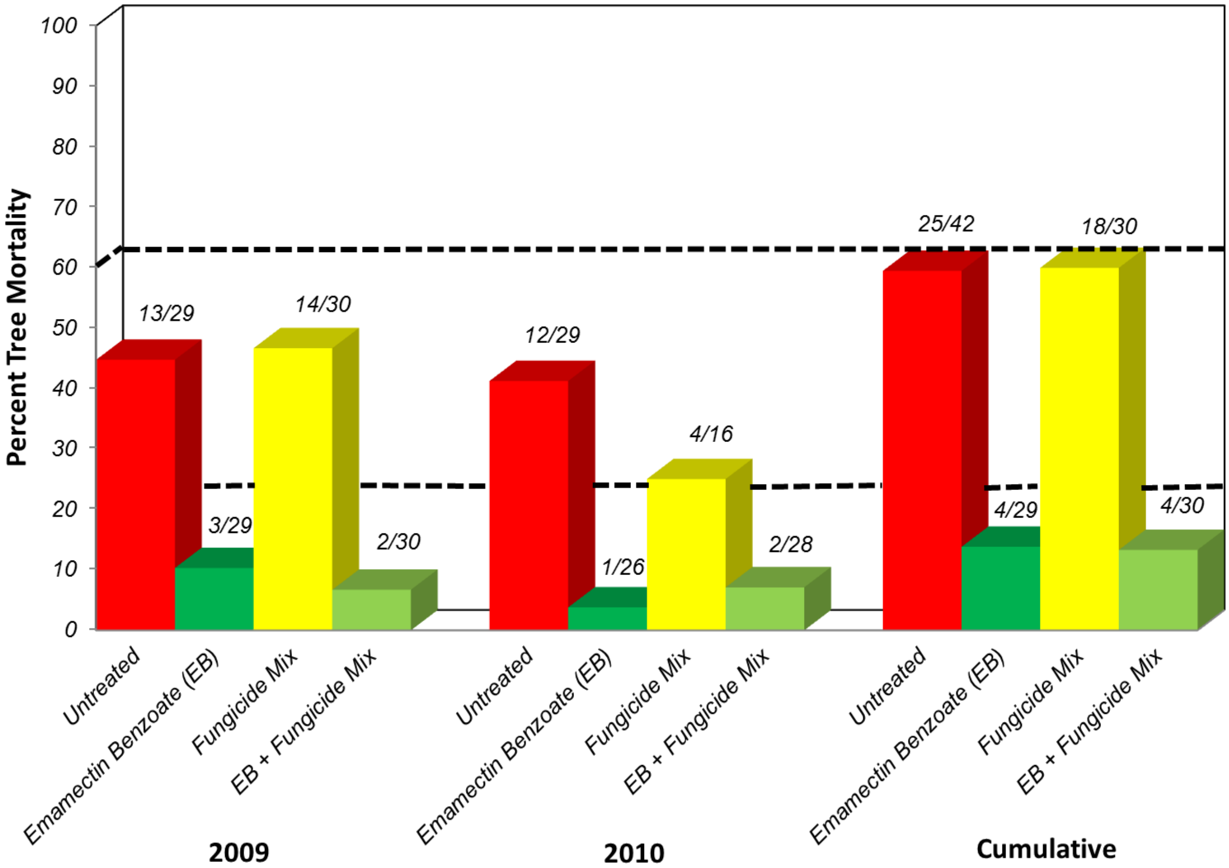


Figure 14. Effects of emamectin benzoate injection treatments on loblolly pine mortality caused by southern pine beetle, Talladega National Forest, AL, in 2009 and 2010. The dashed line at 60% cumulative mortality is the level of control tree mortality necessary for a valid test; the dashed line at 20% cumulative mortality is the maximum allowable mortality of treatments to be considered efficacious.

Table 32. Effects of emamectin benzoate and fungicide injection treatments on Mean (± SE) of success of bark beetle, cerambycids and blue stain colonization in loblolly pine, Talladega National Forest, AL - 2009.

Treatment	N	Length (cm) of Bark Beetle Galleries	Cerambycid Feeding Area (cm^2)	Percent cross section covered with Blue stain Fungi
Emamectin benzoate (EB)	1	0.0 **a**	0.0 **a**	55.0 **ab**
Fungicide	12	42.8 **b**	26.6 **b**	51.4 **a**
EB + Fungicide	1	0.0 **a**	0.0 **a**	57.0 **ab**
Check	14	56.3 **b**	39.4 **b**	87.0 **b**

† Means followed by the same letter in each column of the same site are not significantly different at the 5% level based on Fisher's Protected LSD.

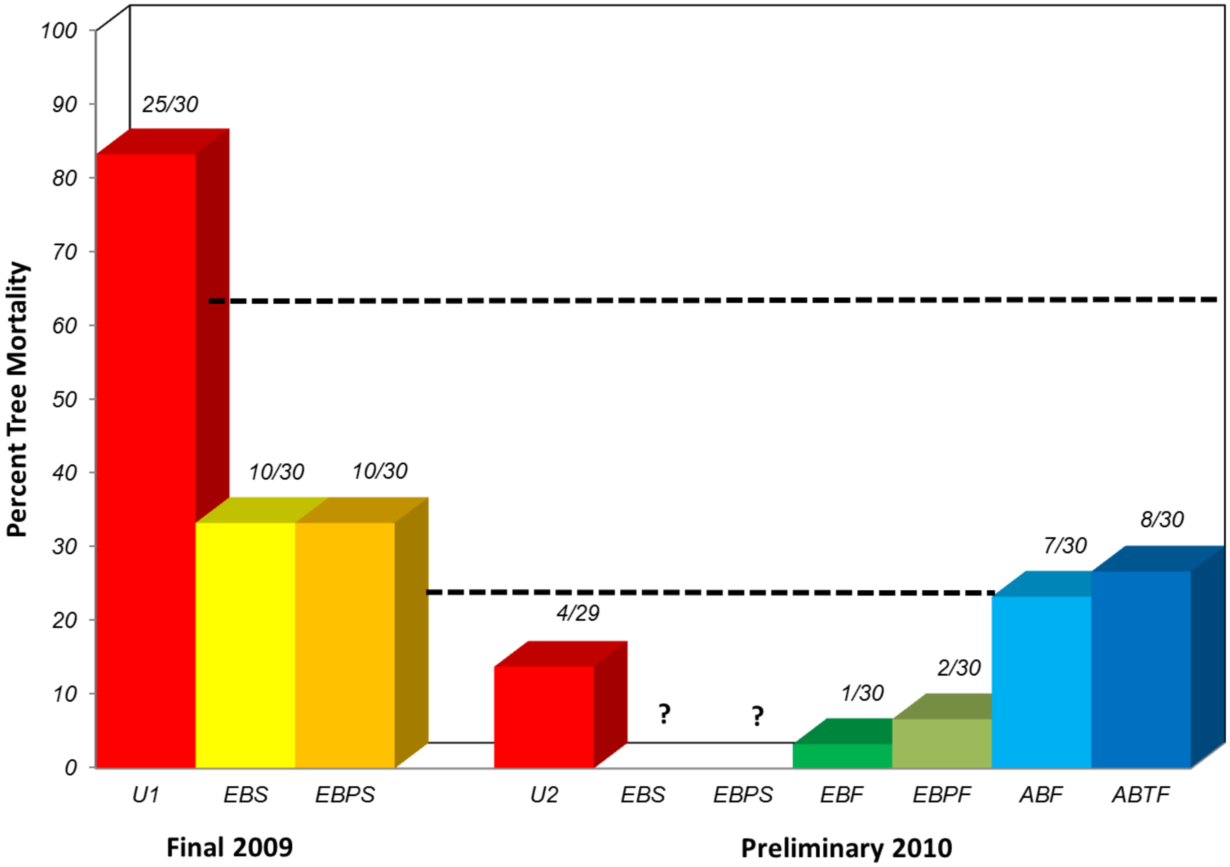


Figure 15. Effects of emamectin benzoate and abamectin injection treatments on lodgepole pine mortality caused by mountain pine beetle, Uinta-Wasatch-Cache National Forest, UT, in 2009 and 2010. The dashed line at 60% cumulative mortality is the level of control tree mortality necessary for a valid test; the dashed line at 20% cumulative mortality is the maximum allowable mortality of treatments to be considered efficacious.

SYSTEMIC PESTICIDE INJECTION TRIALS

Evaluation of Emamectin Benzoate (TREE-äge™) for Protection of Trees Against Invasive Insect Pests

Highlights:

- The emamectin benzoate treatment significantly reduced the success of chalcid wasps in Afghan pines during the second year after treatment.
- Data suggests that EB-treated western soapberry trees infested with the invasive soapberry borer, *Agrilus prionurus* (Coleoptera: Buprestidae) were healthier compared to checks by the end of 2010.

Justification: Injection trials conducted by the Forest Pest Management Cooperative, Arborjet Inc. (Woburn, MA) and others from 1999 – 2008 have shown that emamectin benzoate (EB, TREE-äge™), injected into conifers and hardwoods, is highly effective against coneworm, bark beetles, wood borers, forest tent caterpillar and winter moth. Syngenta submitted TREE-äge™ for registration by EPA in January 2008. Partial approval has been granted for use on ash against emerald ash borer (EAB). It is of interest to know if the Tree-äge™ formulation is effective in preventing/reducing damage by new pests, such as an unnamed chalcid wasp and the soapberry borer, a close relative of EAB.

Objectives: 1) To determine the efficacy of TREE-äge™ for protecting individual afghan pines and western soapberry trees from damage and/or mortality attributed to different invasive insect pests; and 2) To determine the duration of protection provided by TREE-äge™ against invasive insect pests.

Cooperators

Mr. Oscar Mestas	Urban Forester, Texas Forest Service, El Paso, TX
Mr. Randy Myers	Urban Forester, Midland, TX
Mr. Tom French	Private landowner, Rosharon, TX
Ms. Dennis Moore	City Forester, Allen, TX
Mr. Chad Krajca	District Park Supervisor, Mesquite, TX
Ms. Kim Knopp	Park Ranger, Yegua Creek Park, Brenham, TX
Mr. John London	Park Ranger, Fanthrop Inn State Historical Site, Anderson, TX
Ms. Kathy Cantu	Private Landowner, Belton, TX
Mr. Keith Martin	County Arborist, Southlake and Colleyville, TX
Mr. Patrick Haigh	TXDOT Superintendent and private landowner, Rockwall, Mesquite, and Forney, TX
Dr. and Mrs. Aaron Tucker	Private landowners, Rockport, TX
Dr. David Cox	Syngenta, Modesta, CA
Mr. Joseph Doccola	Arborjet, Inc., Worchester, MA

Study Sites: The trials are being conducted at numerous sites:

1) Skyline Park, El Paso, TX with chalcid wasps attacking Afghan pine,
2) Municipal property, Midland, TX with chalcid wasps attacking Afghan pine,
3) Private and municipal property in or near Rosharon, Allen, Mesquite, Anderson, Belton, Colleyville, Southlake, Forney, Rockwall, and Rockport, TX with soapberry borer (SBB) attacking western soapberry,

Research Approach:

Treatments by trial included:

Trial 1 (Chalcid)

1) Emamectin benzoate (0.4g AI per inch; TREE-äge™, Arborjet Inc.) trunk injection at 10 ml per inch DBH in March 2009,
2) Imidacloprid (8.7g AI tree; Merit 75 WSP, Bayer.) soil injection at 74 gal mix in 4-8 holes around drip line of tree,
3) Untreated (control)

Trial 2 (Soapberry Borer)

1) Emamectin benzoate (0.4g AI per inch; TREE-äge™, Arborjet Inc.) trunk injection at 10 ml per inch DBH in June 2009 and June, July and September, 2010,
2) Untreated (control)

Trial 1: This study is being conducted in an El Paso and Midland, TX. A number of afghan pine (age and size unknown) at each location have been under attack by insect (chacid wasp?) pests for several years. Test trees (10 - 15) were selected in early December 2008 in El Paso and in early March in Midland. Five (5) were injected with a standard rate (10 ml per inch diameter) of TREE-äge™ in the spring (late March) in each location. Five (5) trees were treated with imidacloprid via soil injection in El Paso only. Five trees serve as untreated controls at each location.

The imidacloprid application was performed (Dec. 2008 – Jan. 2009) by injecting the dilution about 12 inches into the ground with 45 lbs. PSI using a grid of 4-8 holes around the drip line in a zig-zag pattern. Prior to the injection of chemical the area around the tree was irrigated for several days and again after the irrigation process.

The TREE-äge™ treatment was injected using the Arborjet Tree IV™ microinfusion system (Arborjet, Inc. Woburn, MA) into 4 cardinal points 0.3 m above the ground. First, a 3/8" diameter hole was drilled horizontally at each point. An Arbor –plug was installed into each hole. The Tree IV needle was inserted into the plug. Under pressure (60 psi), the TREE-äge™ product was pumped into the chamber behind the plug and then out into the xylem tissue. The injected trees were allowed five months to translocate chemicals before the treatments were evaluated for efficacy.

In April 2009 (just after treatment) and late September 2009 and 2010, 3-4' long branches were collected from three heights (low, middle and top crown) on each study tree. In the laboratory, 2-3 inch sections were clipped off from each branch (12 inch total per branch). The diameter at each section was measured. The bark was peeled from the branch sections and the number of live and dead larvae, live and dead adults, current and last year's adult emergence holes were recorded. The number of chalcids (larvae or adult) per 100 cm^2 of branch was calculated.

Trial 2: This study is being conducted at numerous locations in Texas (Rosharon,TX, near Houston and Allen and Mesquite, TX near Dallas). Several (1 – 30) western soapberry (2 – 18" DBH) were selected in each location. Four to eight trees were injected with a standard rate (10 ml per inch diameter) of TREE-äge™ in the summer (late June and early July) using a QUIK-jet injection system (Arborjet, Inc. Woburn, MA). The trunk injection procedure was generally the same as that described for the previous trial. A similar number of trees serve as untreated controls at each location.

All study trees were evaluated in July and November, 2010 for relative health. Additional evaluations are planned for summer and fall 2011 and 2012.

Tree health and survival was evaluated in at the time of treatment application as well as July and November 2010 and, if warrented, 2011 and 2012 using the following ranking criteria.

Health Condition:

1=Excellent	Full crown, good foliage, no epicormic branches, no apparent SBB attacks
2=Good	Mostly full crown, a few SBB attacks, no epicormic branches
3=Fair	Thinning crown; several SBB attacks, a few epicormic branches
4=Poor	Moderately thin crown, many SBB attacks, several epicormic branches
5=Near Death	Mostly dead crown; many epicormic branches; bark starting to flake
6=Dead	No leaves, many areas of flaking bark

Data was analyzed by GLM and the Fisher's Protected LSD test using the Statview statistical program.

Results:

Trial 1: Chalcid infestation levels were significantly higher in the upper crown of untreated Afghan pines compared to lower crown levels (Figure 16). Emamectin benzoate significantly reduced the number of live chalcid larvae in branches at both sites compared to the checks (Figures 17 and 18). Imidacloprid did not affect chalcid levels compared to checks in El Paso.

Trial 2: In 2009, efficacy of EB treatment on SBB damage was difficult to evaluate, even after 5 months post treatment as no tree mortality occurred at any sites as of December. Some cursory observations indicate that SBB attacks (larval galleries) on several EB-treated trees appear to be healing. Also, EB-treated trees tended to have more leaves at the end of the growing season compared to untreated checks.

In 2010, efficacy of EB treatment from 2009 has become more obvious, particularly at the Mesquite park. All the EB-treated trees are alive and well, whereas the checks are nearly dead or dead (Figure 19). Observations at other sites indicate that SBB attacks (larval galleries) on several EB-treated trees appear to be healing. Also, EB-treated trees tended to have more leaves at the end of the growing season compared to untreated checks.

Conclusions:

The EB treatment significantly reduced the success of chalcid wasps in Afghan pines during the first and second year. Data suggests that EB-treated western soapberry are healthier compared to checks. The duration of treatment efficacy will be further evaluated in 2011.

Acknowledgements: Many thanks go to our cooperators: Oscar Mestas, Randy Myers, Tom French, Dennis Moore, and Chad Krajca for their efforts on the projects. We appreciate the chemical donations and injection equipment loans made by Arborjet, Inc and Syngenta and field and laboratory assistance of TFS employees Bill Upton, Billi Kavanagh, Larry Spivey, James Fox and Penny Whisnent. These trials were supported by funds from the FPMC.

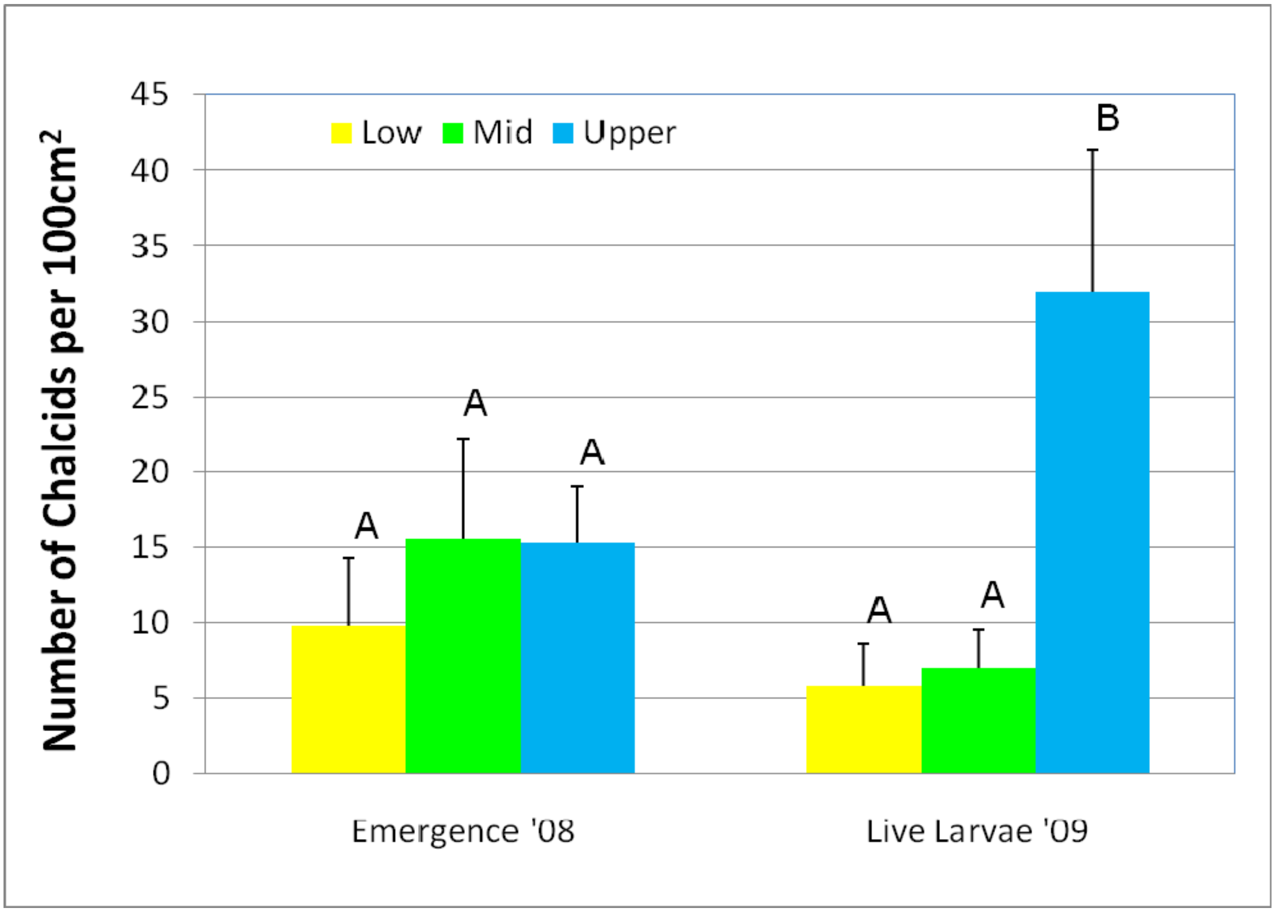


Figure 16. Effects of crown level on number of chalcid adults emerging in 2008 and live larvae found in branches From El Paso and Midland, TX in 2009.

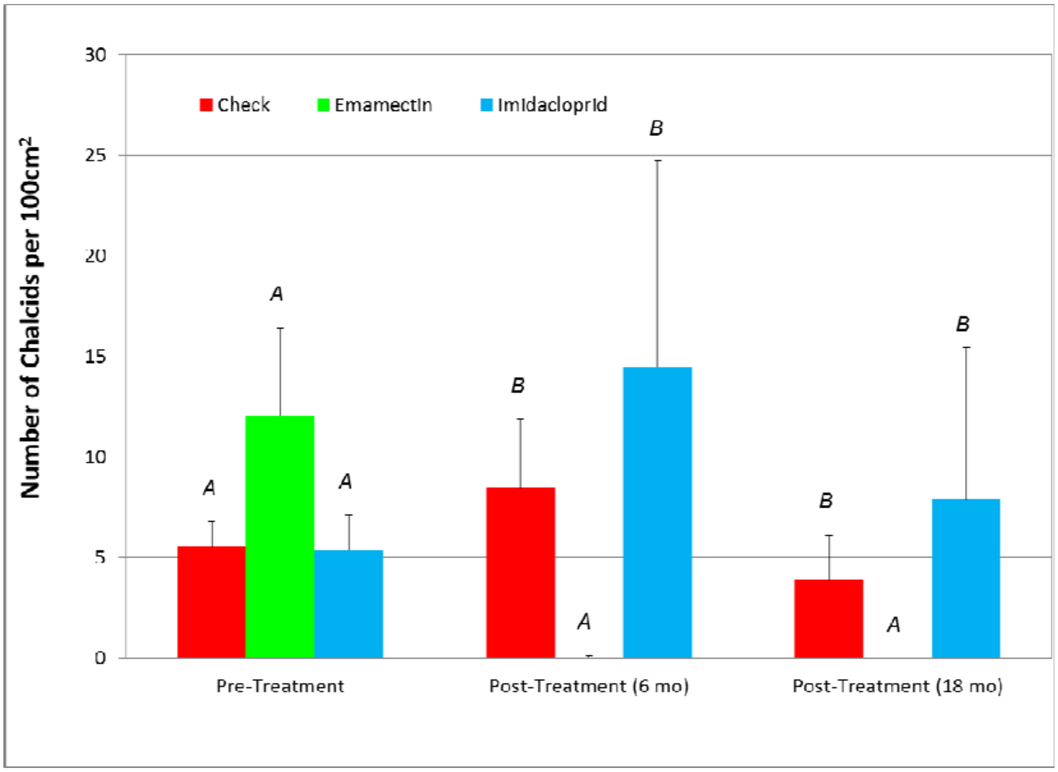


Figure 17. Effects of treatment on number of chalcid larvae present in Afghan pine branches from El Paso, TX, 2009 and 2010.

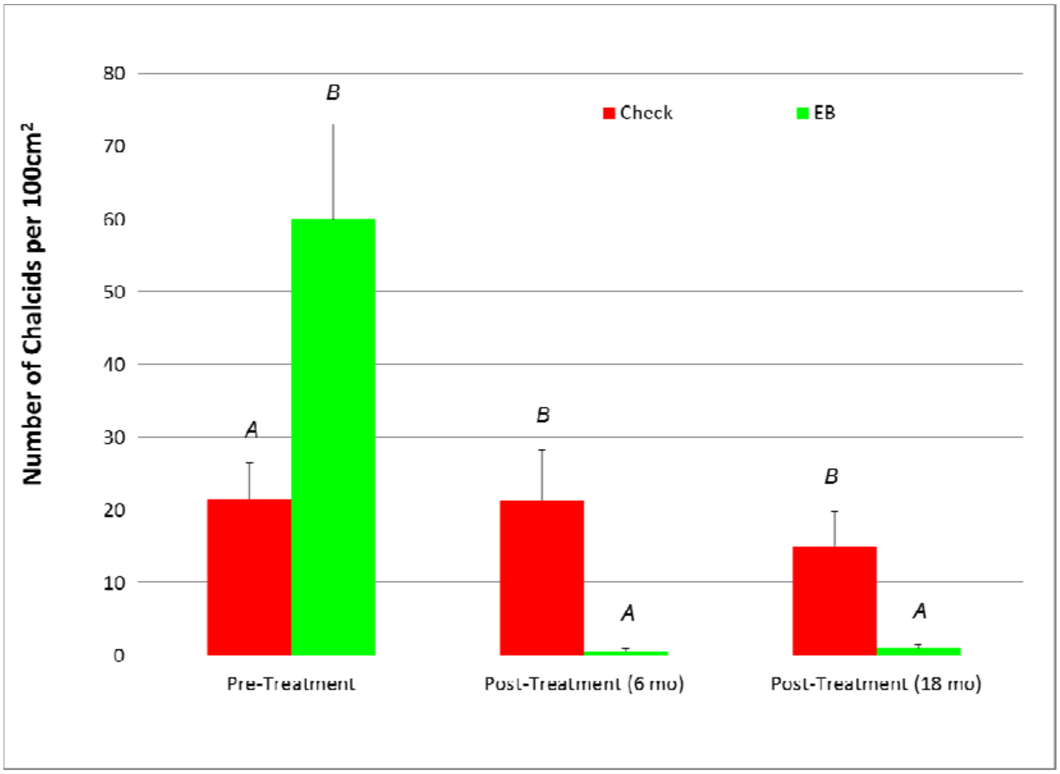


Figure 18. Effects of treatment on number of chalcid larvae present in Afghan pine branches from Midland, TX, 2009 and 2010.

Figure 19. Effects of EB treatments (2009 and 2010) on health of western soapberry in central Texas, 2009 and 2010.

SYSTEMIC PESTICIDE INJECTION TRIALS

Summary and Registration Status of Tested Systemic Insecticides and Fungicides

One of the initial goals of the Forest Pest Management Cooperative was to develop alternative control options for cone and seed insects in light of the potential loss of registered foliar pesticides (e.g. Guthion®). Individual tree injections in seed orchards offer several advantages. Control efforts can be allocated to clones on the basis of inherent susceptibility to insect attacks, genetic worth, and high potential for seed production. With these criteria, only 10 – 25% of the ramets in an orchard might need to be protected with insecticides. In turn, the pesticide load (amount of pesticide per acre) produced by conventional application techniques could be substantially reduced. Potential environmental concerns from insecticides in runoff water could be virtually eliminated because insecticides would be contained within the tree. Specific situations where systemic injections may be particularly useful include protecting seeds on trees with control pollinated crosses, protecting selected ramets of genetically-valued clones in early-generation orchards after emphasis shifts to newer orchards, and providing insect control in orchards located in environmentally-sensitive sites where conventional air and ground sprays may be hazardous or prohibited.

Protection of individual trees from bark beetles has historically involved insecticide applications to the tree bole using hydraulic sprayers. However, this control option can be expensive, time-consuming, of high risk for worker exposure and drift, and detrimental to natural enemies. The use of a newly-developed injection technology to deliver systemic insecticides could reduce or eliminate many of the limitations associated with hydraulic spray applications.

<u>Insecticides</u>

Emamectin Benzoate (EB) - Over a 6-year period, emamectin benzoate (Arise SL®), injected as part of the initial Seed Orchard Duration trial, exhibited excellent protection in pine seed orchards against coneworms, with a mean reduction in damage of 80% compared to checks. The data suggest that a single injection of EB can protect trees against coneworms for 72 months or longer. A second injection is not necessary during the second growing season to improve efficacy. EB has not been as effective against seed bugs. Single injections are capable of significantly reducing seed bug damage, but only for about 18 months. The work by the FPMC has proven that EB is highly effective in protecting cone crops. Unfortunately, because seed orchard use constitutes a very small market (only ~10,000 acres in the South), the primary chemical manufacturer, Syngenta, had been reluctant to support an injection use registration in the U.S. for seed orchards alone.

Since 2002, an attempt had being made to expand the potential forestry market for EB through trials with other tree and pest species. In 2004, injected EB (Denim®) was tested for efficacy against southern pine engraver beetles. EB was found to be highly effective in preventing the colonization and mortality of stressed loblolly pine by southern pine engraver beetles (see 2004 Annual Report, Grosman et al. 2006).

In light of the large potential market for EB, particularly as it relates to protection of high-value trees from bark beetles, Syngenta has shown considerably more interest in pursuing registration of this chemical for injection use. Unfortunately, the Denim® formulation had several negative characteristics that limited its potential use as an injectable formulation. Syngenta reached an agreement with Arborjet, Inc. during the winter of 2004/2005 to develop a new injectable formulation of EB. Arborjet created a non-toxic, low viscosity formulation for injection use (Joe Doccola, Arborjet™, personal communication).

Several additional FPMC trials were established in 2005 - 2008 with some ongoing in 2009 - 2010, to evaluate the new formulation of EB for 1) efficacy against cone and seed insects in loblolly pine, slash pine, and Douglas-fir seed orchards, 2) efficacy of different rates and duration against *Ips* engraver beetles, 3) efficacy against aggressive *Dendroctonus* bark beetles in the South (southern pine beetle) and the West (mountain pine beetle, western pine beetle and spruce beetle); 4) efficacy against different pests of oak; and 5) efficacy against two invasive insect pests in Texas. All trials showed that the new EB formulation could be quickly injected into trees, was non-toxic, and, where results were available, effective against different species of coneworms, bark beetles, hardwood pests, and a chalcid wasp; in some cases, for two or more consecutive years. Arborjet also has ongoing trials to test the new formulation for control of emerald ash borer, Asian longhorned beetle, forest tent caterpillar, gypsy moth, winter moth, hemlock wooly adelgid and red gum lerp psyllid.

In light of these successes, Syngenta and Arborjet conducted the required toxicology tests and submitted a request to EPA in January 2008 for full label registration. The product is called "TREE-äge." In the meantime, requests were made and approved in 2008 for 24C (Special Local Need) registration for use against emerald ash borer in IL, IN, MD, MI, MN, MO, OH, PA, VA, WI and WV. EPA did approve the Section 3 use of TREE-äge in ash for protection against EAB in July 2008, but requested additional data to support use in other sites (i.e., seed orchards and conifers). **In December 2010, EPA approved the extension of the TREE-äge® label to include use of EB for "control of mature and immature arthropod pests of deciduous, coniferous and palm trees, including, but not limited to, those growing in residential and commercial landscapes, parks, plantations, seed orchards, and forested sites (in private, municipal, state, tribal and national areas)."** Approval of the final label is required at the state level as well. As of March 2011, 30 states including TX, OK, FL, NC, SC and VA have approved the full label. Availability of TREE-äge® in the remaining southern states is expected by late spring 2011.

TREE-äge® is available in 1-liter containers from several distributors including Arborjet Inc., Rainbow Treecare, and John Deer Landscapes (more to come). Arborjet has quoted a price of $525 per liter (discounts are available when purchasing a case of 8 liters or more). Thus, the cost to treat a 10 inch DBH tree at a medium rate (0.2 g AI per inch DBH) would be about $28 while a treatment of a large (25 inch DBH) tree would be about $68 (labor excluded). **NOTE: TREE-äge® insecticide is a Restricted Use Pesticide and must only be sold to and used by a state certified pesticide applicator or by persons under their direct supervision.** It is important that all users read the label and follow all precautions and guidelines.

Fipronil – In light of the discovery that fipronil had systemic activity in loblolly pine against pine tip moth in 2002 (see 2003 Annual Report), an experimental emulsifiable concentrate (EC) formulation of fipronil was injected into trees as part of a seed orchard trial (2003) and a bark beetle trial (2004). The EC formulation reduced overall coneworm damage by 80% and was highly effective in preventing the colonization and mortality of stressed loblolly pine by southern pine engraver beetles (*Ips* spp.) (see 2004 Annual Report). Although this formulation had not been found to cause stem necrosis in injected trees, BASF elected to develop and test several new formulations of fipronil for injection use. These were available for comparison with the new formulation of EB in the three 2005 FPMC trials mentioned above. Although fipronil tends to require more time to move throughout the tree, it proved nearly as effective as EB in most trials.

The BAS 350 UB formulation of fipronil, developed by BASF in 2005, requires the addition of methanol to improve uptake of the chemical by trees. This would be undesirable when sold for commercial use. Thus, BASF developed three new formulations (PW, PS and UK) that already contain a solvent and is injection ready. These formulations were tested in 2007 and found to be highly and equally effective against *Ips* bark beetles. Additional trials were established in the West to test fipronil against western and mountain pine beetles. Unfortunately, the results were less effective than expected. Again timing and temperatures appeared to play a role in the reduced activity. BASF decided not to submit an application to EPA for registration of fipronil for use as a tree injection treatment. Mauget is now interested in this chemical and is working with the FPMC to conduct additional tests. Initial results show again that fipronil is highly effective in preventing the successful colonization of pine by *Ips* engraver beetles.

Imidacloprid – Imidacloprid is another neonictinoid chemical tested by the FPMC in seed orchard trials at low (2ml, Pointer® w/ Wedgle Tip injector in 1997) and high (30 ml, Admire® w/ STIT injector in 1999-2000) volumes. Generally, low volume injections were ineffective against coneworms and seed bugs. High volume injections of imidacloprid did significantly reduce coneworm damage (45%), but were not nearly as effective as EB (94%) in the first year after injection. In contrast, imidacloprid was more effective against seed bugs (82% reduction) than was EB (34% reduction). However, there was considerable variability in the efficacy against both groups of pests. As observed with thiamethoxam, imidacloprid efficacy against both coneworms and seed bugs declined markedly in the second year.

Protection against seed bugs, but not coneworms, improved significantly with a second injection of imidacloprid in 2000 (see 2000 Annual Report). This suggests that yearly injections of imidacloprid are needed for optimal protection against seed bugs. Again, the cost (manpower and excessive tree wounding) makes yearly injections problematic. In addition, imidacloprid has a low solubility in water (0.4g/L). Thus, mixing currently-registered products (Merit® and Admire®) in water to create an injectable solution at an effective concentration is difficult. For these reasons, we elected to discontinue our evaluation of imidacloprid after 2000. Recently, Arborjet has developed a new formulation of 5% injectable imidacloprid (IMA-jet™). Trials have been established in 2007 - 2009 to evaluate this formulation alone or combined with their new formulation of EB or abamectin. IMA-jet™ can significantly reduce seed bug damage but had no significant effect against coneworm and efficacy was not enhanced by EB. The effects declined markedly in the second year after injection.

Dinotefuran - Dinotefuran (Valent) is a "3rd generation" neonicotinoid insecticide with primary activity against sucking insects as well as Coleoptera (beetles). Although dinotefuran (0.2g/inch DBH) was not found to be active against bark beetles in our 2004 trial, it was found by Arborjet (at 0.4g/inch DBH) to be as effective as imidacloprid against emerald ash borer (Joe Doccola, Arborjet, personnel communication). One advantage dinotefuran has over imidacloprid is that it is 100X more water soluble (40g/L vs 0.4g/L). Thus, higher concentrations can be developed that translocate more quickly compared to imidacloprid. Arborjet, working in cooperation with Valent, developed a formulation of dinotefuran that may be combined with EB for seed orchard use. The trial in 2007 and 2008 showed that this chemical can reduce seed bug damage but had little effect against coneworms. New trials initiated in 2010 again indicate dinotefuran alone has good activity against seed bugs but little or no activity against coneworns. The combined dinotefuran +EB treatment was effective against coneworm, but no more effective than EB alone.

Nemadectin - Nemadectin (Fort Dodge Animal Health) is a fermentation product of *Streptomyces cyanogriseus noncyanogenus* and closely related to EB. A preliminary trial was conducted in 2005 to determine if nemadectin has similar efficacy against bark beetles. The results suggest some activity, but treatment and evaluation earlier in the year should provide more conclusive evidence. Additional tests initiated in 2006 confirmed that nemadectin has moderate activity against *Ips* engraver beetles. The trial was continued through 2008 and showed that nemadectin at the highest rate (0.4 g AI / inch DBH.) had very good efficacy against *Ips* engravers and wood borers 28 months after injection. Fort Dodge Animal Health indicated they planned to sell the use rights to another company who would then submit for EPA registration. No progress has been made on this registration since 2008.

Abamectin – Abamectin (Syngenta) is an avermectin derivative closely related to EB. A preliminary trial was initiated in 2008 in cooperation with Mauget Co. to determine if abamectin has similar efficacy against bark beetles. The results indicate that abamectin is very active against *Ips* engraver beetles and wood borers for two growing seasons. Seed orchard trials were established in 2008 at the Yulee, FL and in 2010 at Woodville, TX. The Florida results indicate no initial activity against coneworms and/or seed bugs, whereas abamectin was very effective against coneworm at Woodville. The *Ips* trial and TX seed orchard trial will be extended through 2011 to further evaluate efficacy duration.

Chlorantraniliprole (Acelepyrn, DuPont) - Chlorantraniliprole is an anthranilic diamide insecticide with reported activity against moths, beetles, caterpillars, etc. The seed orchard trial established in 2010 at Woodville, TX indicates that this chemical is active against coneworms, but not seed bugs.

Fungicides

Propiconazole - Propiconazole is a systemic triazole fungicide with a broad range of activity - used agriculturally on grasses grown for seed, mushrooms, corn, wild rice, peanuts, almonds, sorghum, oats, pecans, apricots, peaches, nectarines, plums and prunes, as well as to protect oaks against oak wilt disease. Propiconazole is considered to be fungistatic or growth inhibiting rather than fungicidal or lethal to target fungi.

Thiabendazole - Thiabendazole is a systemic benzimidazole fungicide used to control fruit and vegetable diseases such as mold, rot, blight and stain, as well as a prophylactic treatment for Dutch Elm disease. Thiabendazole has both fungistatic and fungicidal properties.

A trial was initiated in 2009 in cooperation with Arborjet to determine if the combination of an EB plus propiconazole + thiabendazole (below) mix treatment would improve survival of baited pine after SPB attack compared to EB alone. The results suggest that addition of the fungicide mix does not improve survival of pines. The trial will be extended through 2011. An additional trial was initiated in the fall 2009 in cooperation with Dr. Lori Eckhardt, Auburn University, to determine to what extent the fungicide mix would affect growth of *Leptographium* species on media in the laboratory or in the host in the field. The results indicate that the fungicide mix was highly effective in inhibiting growth of five *Leptographium* spp. in laboratory media but did not affect growth of *Leptographium* spp. in longleaf pine roots and stems.

Another trial was initiated in 2009 in Utah to determine if EB combined with propiconazole only would improve survival of baited lodgepole pine after MPB attack. So far, the results again indicate that the addition of propiconazole does not improve survival of pine .

Tebuconazole – Tebuconazole is another triazole fungicide used agriculturally to treat a wide range of plant pathogenic fungi. In the same Utah trial (mentioned above), abamectin was combined with tebuconazole. Results are pending.

REGENERATION WEEVILS

Evaluation of Arctic™ and OnyxPro™ for Protection of Pine Seedlings Against Pine Regeneration Weevils

Highlights:

- Two insecticides, Arctic™ and OnyxPro™, were evaluated for their ability to protect pine seedlings against regeneration weevils for 12 months post treatment.
- Arctic™ (permethrin) with and without a spreader sticker was highly effective in causing weevil mortality for 9 months and/or in reducing feeding by weevils for the full 12 months.
- OnyxPro™ caused limited weevil mortality during the first 5 weeks after seedling treatment, but significantly reduced weevil feeding compared to checks for up to 7 months.

Justification: The pales weevil, *Hylobius pales*, and pitch-eating weevil, *Pachylobius picivorus*, are two of the most serious insect pests of pine seedlings in the eastern United States. Adult weevils of both species are attracted to freshly-harvested pine sites where they breed in logging slash, stumps, and old root systems. Seedlings planted in freshly-logged areas are injured or killed by adult weevils that feed on the stem bark. It is not uncommon to have 30 to 60 percent weevil-caused mortality among first-year pine seedlings in the South, and mortality of 90 percent or more has been recorded.

One strategy to reduce losses caused by reproduction weevils is the use of seedling protective treatments. Pounce® 3.2EC (permethrin, FMC) had been used extensively through the 1990s. The longevity of Pounce on treated seedlings was evaluated by the FPMC in 1998. Overall, the chemical caused better than 50% weevil mortality even after exposure to seedlings treated nearly four months earlier. It is clear that when seedlings were thoroughly covered with Pounce®, they could be protected from weevils for as long as six months post-treatment. In addition, measurement of feeding areas on treated and untreated seedling sections showed that Pounce® was capable of significantly reducing the amount of feeding damage for eight months or longer.

FMC discontinued production of the EC formulation of Pounce® in 2005. Waylay™ and Arctic™ (permethrin, Winfield Solutions) were registered in 2006 to replaced Pounce®. Both of these new products contained similar concentrations of the active ingredient, but differ somewhat in their inert ingredients. Unfortunately, applicators have indicated that the Waylay™ or Arctic™ treatments have not performed (repellency/duration) as well as Pounce® (Note: Waylay™ was discontinued in 2008). We were interested to know if the addition of a spreader/sticker to an Arctic™ solution would improve duration of protection of seedlings against weevils. Additionally, another product, OnyxPro™ (bifenthrin, FMC) is already registered for use in nurseries but has not been tested for effectiveness and duration of protection when applied to pine seedlings in nursery beds.

Objectives:

1) Determine the efficacy and duration of Arctic™ (permethrin) alone or combined with a spreader/sticker and OnyxPro™ (bifenthrin) in reducing weevil-caused feeding damage and seedling mortality.

2) Determine the longevity of Arctic™ and OnyxPro™ residuals on treated pine seedlings.

Cooperators:

Mr. Shannon Stewart	ArborGen, Livingston, TX
Mr. Robert Cossar	Winfield Solutions, Crossett, AR
Mr. Brian Mount	FMC, Warren, AR

Insecticide:

Arctic™ 3.2 EC (permethrin) – pyrethroid insecticide
OnyxPro™ (bifenthrin) – pyrethroid insecticide.
Complex™ – self-emulsifiable spreader sticker and non-ionic surfactant

Research Approach:

The treatments included:

1) Arctic™ applied once to pine seedlings at 2 quarts / 100,000 seedlings just prior to lifting.
2) Arctic™ + Complex™ (spreader/sticker) applied once to pine seedlings at 2 quarts. / 100,000 seedlings just prior to lifting.
3) OnyxPro™ applied once to pine seedlings at 0.32 oz. / 1000 sq ft just prior to lifting.
4) Check

A laboratory colony, consisting of pales weevils only, was established during the winter of 2009. Weevils, from the field, were collected once a week using pit traps baited with a 5:1 mix of ethanol and turpentine and set up in recently harvested tracts. In the laboratory, collected weevils were maintained in clear plastic containers containing a layer of vermiculite, split bolts, and foliage. The plant material and vermiculite were changed every two weeks.

Two hundred seedlings (50 Arctic™-treated, 50 Arctic™ + Complex™-treated, 50 OnyxPro™-treated, and 50 untreated) were obtained from the ArborGen's Livingston Nursery in mid-October, 2009. Seedlings (other than checks) were treated prior to lifting with Arctic™ 3.2 EC per label recommendations (2 qt / 100,000 seedlings) or OnyxPro™ (13.9 oz / acre). All seedlings were planted in 3 gal pots (8 seedlings per pot; treatments separated) and placed outside for exposure to the elements (Fig. 20). The soil was a 3:1 mix of plantation soil and potting soil. The seedlings were watered as needed.

Figure 20. Treated and untreated loblolly pine seedlings used for weevil trial.

One week after treatment and then once every month or two thereafter for 12 months, 20 seedlings (5 Arctic™ -treated, 5 Artic™ + Complex™-untreated, 5 OnyxPro™ -treated, and 5 untreated) were pulled and the above-ground stem of each seedling clipped into 5 cm twig segments. Each twig was placed in an individual moistened paper sleeve and placed separately in a petri dish. One weevil, starved for 24 hours, was placed in each dish (Fig. 21). All dishes were placed in a dark room (temperature: ~70 ^{o}F) for 48 h. Paper towels sleeves were remoistened after 24 h. The number of dead weevils and an estimate of weevil feeding on cambial tissue were made after 24, 48 and 72 h for each twig. The amount of feeding was measured with a transparent grid of 2 mm^2 squares transposed over the feeding sites on the twigs. Each treatment was replicated 10 times for both male and females, on each of nine separate testing periods.

Figure 21. Single pales weevil adult exposed to treated loblolly pine twig.

Results:

Preliminary laboratory experiments showed no significant differences between the weevil species or sexes in the amount of feeding per 24 hours or susceptibility to Arctic™ and OnyxPro™. Therefore, species and sex data were pooled. Subsequent evaluations of Arctic™ and OnyxPro™ longevity on treated seedlings in the laboratory showed that, overall, treatments containing Arctic™ caused 100% weevil mortality even after exposure to seedlings treated 7 months earlier (Figure 22, Table 33). Onyx Pro™ caused no mortality after 5 weeks post treatment. Differences in feeding areas on treated and untreated seedlings were evidence that Arctic® and OnyxPro™ significantly reduced the amount of feeding damage by weevils for at least 12 months (Figure 23, Table 34).

Conclusions:

This trial confirmed that Arctic™ (permethrin) provides excellent, extended protection of pine seedlings against regeneration weevils. The addition of a spreader/sticker does not enhance protection. **It is important that applicators take care to completely cover seedlings with the chemical to ensure maximum protection**. The FPMC recommends the use of a bar in front of the sprayer heads to bend the seedling to expose the stems to spray in the nursery. Two passes along the seedling bed (one in each direction) should be made for maximum insecticide coverage.

Acknowledgements: We thank ArborGen for providing seedlings for the project. We appreciate the chemical donations and injection equipment loans made by FMC and Winfield Solutions.

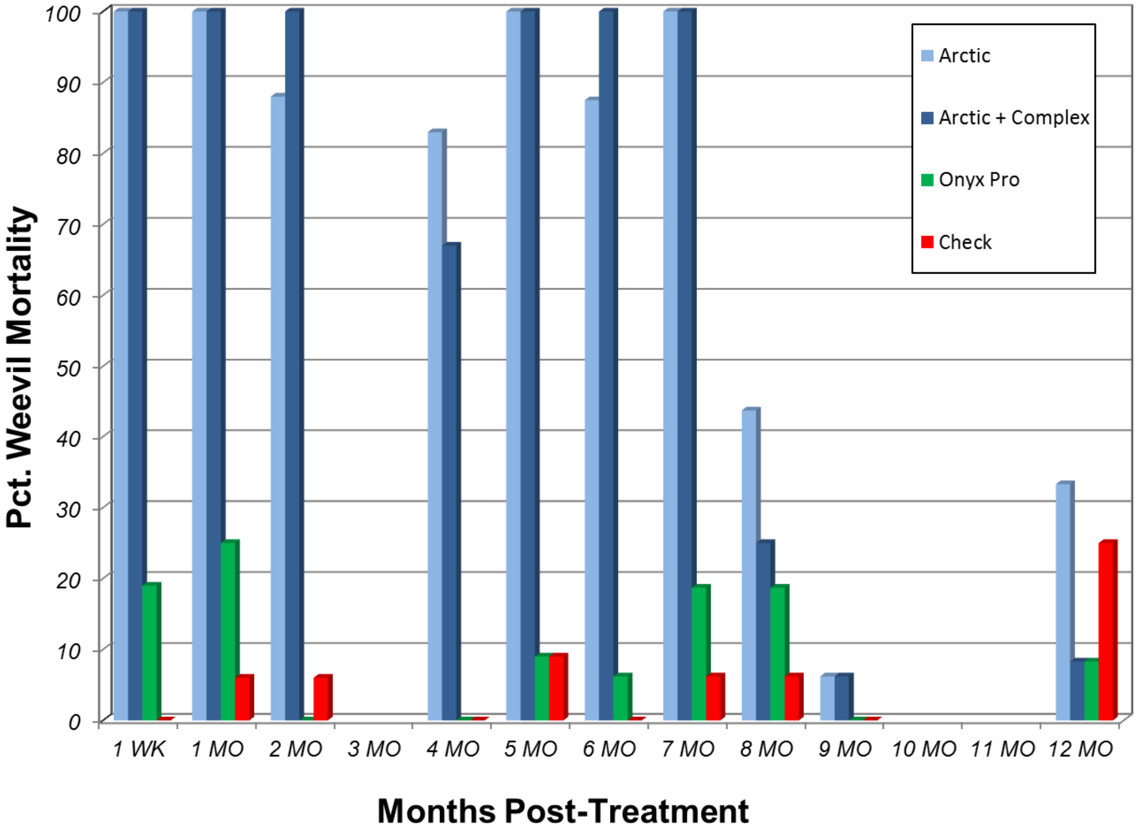


Figure 22. Mean weevil mortality (%) after exposure to insecticide treated and untreated loblolly pine seedling twigs, 2010.

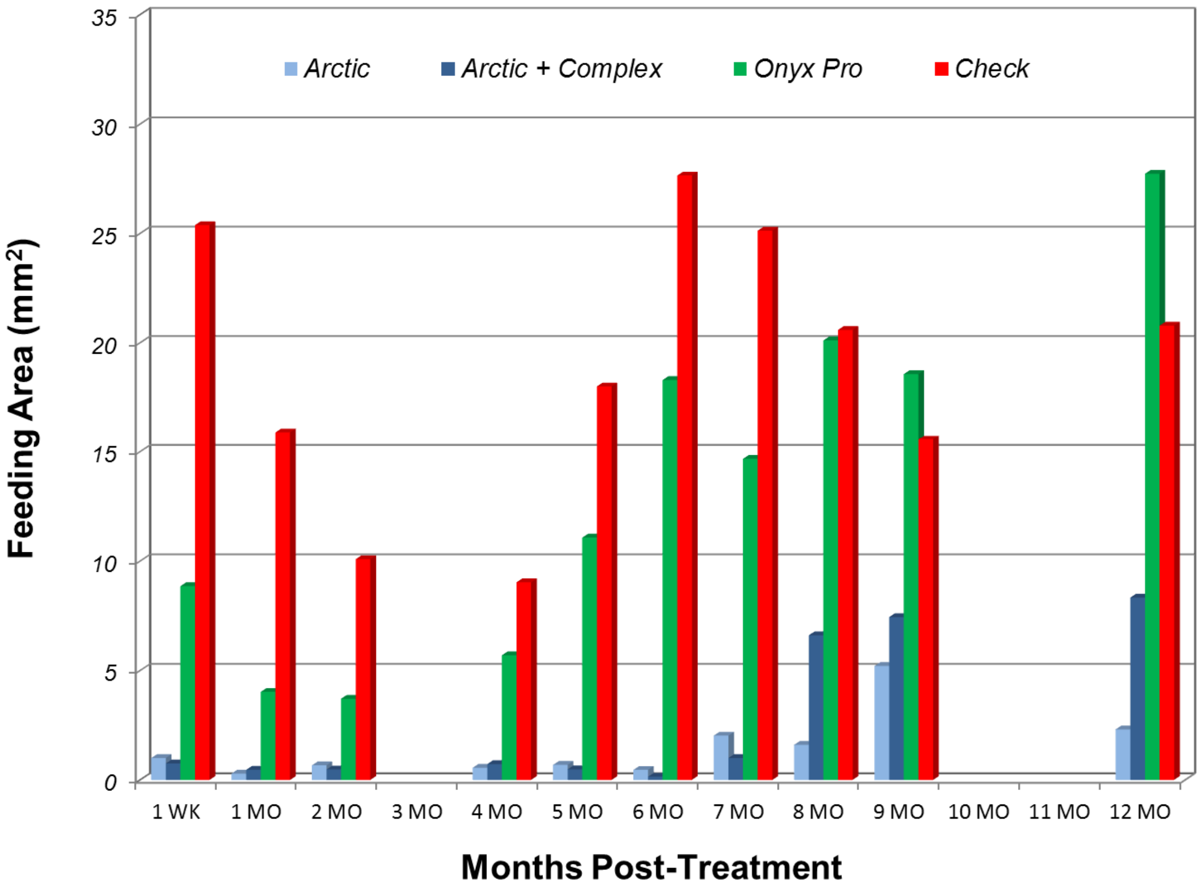


Figure 23. Mean weevil feeding area (mm^2) after exposure to insecticide treated and untreated loblolly pine seedling twigs, 2010.

Table 33. Mortality of pales weevils after exposure to Arctic™ and Onyx Pro™-treated pine seedlings from Arborgen's Livingston, TX, Nursery[a], 2010.

	Percent Mortality after:									
Treatment	1 week	1 month	2 months	4 months	5 months	6 months	7 months	8 months	9 months	12 months
Arctic™	100 c†	100 c	88 b	83 b	100 b	88 b	100 b	44 b	6 a	33 a
Arctic™ + Complex™	100 c	100 c	100 b	67 b	100 b	100 b	100 b	25 ab	6 a	8 a
Onyx Pro™	19 b	25 b	0 a	0 a	9 a	6 a	19 a	19 ab	0 a	8 a
Check	0 a	6 a	6 a	0 a	9 a	0 a	6 a	6 a	0 a	25 a

[a] Pine seedlings were treated November 3, 2009 using backpack sprayers.

† Means followed by the same letter in each column of the same site are not significantly different at the 5% level based on Fisher's Protected LSD.

Table 34. Feeding area by pales weevils after exposure to Arctic™ and Onyx Pro™-treated pine seedlings from Arborgen's Livingston, TX, Nursery[a], 2010.

	Mean Feeding Area (mm^2) per 24 hrs:									
Treatment	1 week	1 month	2 months	4 months	5 months	6 months	7 months	8 months	9 months	12 months
Arctic	1.00 a†	0.29 a	0.67 a	0.56 a	0.69 a	0.46 a	2.02 a	1.60 a	5.21 a	2.31 a
Arctic + Complex	0.75 a	0.46 a	0.48 a	0.72 a	0.48 a	0.15 a	1.00 a	6.60 a	7.44 a	8.33 a
Onyx Pro	8.85 b	4.02 ab	3.71 b	5.69 b	11.07 b	18.29 b	14.67 b	20.10 b	18.56 b	27.72 b
Check	25.38 c	15.90 b	10.08 c	9.03 c	18.00 c	27.65 b	25.13 c	20.58 b	15.56 b	20.78 b

[a] Pine seedlings were treated November 3, 2009 using backpack sprayers.

† Means followed by the same letter in each column of the same site are not significantly different at the 5% level based on Fisher's Protected LSD.

PINE TIP MOTH TRIALS

Impact Study – Western Gulf Region

Highlights:

- Four new Nantucket pine tip moth impact plots were established in 2010, bringing the total to 110 plots established since 2001.
- Tip moth damage levels on first-year check trees increased to 26% in 2010. Damage levels on second-year check trees, established in 2009, increased to high levels (59%).
- The application of PTM™ on first year trees provided excellent protection; damage was reduced by 87% in 2010 (by an average of 91% over the past two years).
- Protected trees experienced significantly improved tree growth compared to check trees at all tip moth damage levels. Growth differences between protected and checks trees increased as damage levels on check trees increased.
- Mr. Trevor Walker has nearly completed his data impact and economic analyses.

Objectives: 1) Evaluate the impact of pine tip moth infestation on height, diameter, volume growth and form of loblolly pine in the Western Gulf Region and 2) identify a pine tip moth infestation threshold that justifies control treatment.

Cooperators:

Mr. Conner Fristoe	Plum Creek Timber Co., Crossett, AR
Dr. Nick Chappell	Potlatch Forest Holdings, Warren, AR
Mr. Peter Birks	Weyerhaeuser Co., Columbus, MS
Mr. Bill Stansfield	The Campbell Group, Diboll, TX
Mr. Jeff Hall	Forest Investment Associates, Jackson, MS
Mr. Trevor Walker	Stephen F. Austin State University, Nacogdoches, TX
Dr. Dean Coble	Stephen F. Austin State University, Nacogdoches, TX

Study Sites: Several FPMC members have established 10 or more impact study sites by 2010. In most plantation sites, one to two areas were selected and divided into 2 plots each – with each plot containing 126 trees (9 rows X 14 trees). Tip moth populations were monitored on TFS sites in East Texas.

Insecticide:

Mimic® 2F (tebufenozide; molting stimulant specific to Lepidoptera) used through 2008.
PTM™ Insecticide (fipronil) – used since 2009.

Design: 76 sites X 1-2 plots X 2 treatments X 50 trees = 10,100 monitored trees.

Treatments:

1) Mimic® 2F applied once per generation at 0.08 oz. / gal. on first- and second-year sites through 2008, or
   PTM™ dilution applied just after planting (5.6 ml PTM™ in 54 ml water per seedling) on first–year sites.
2) Check

Application Methods: Treatments were randomly assigned to each plot pair at the establishment of each site. Pesticides were applied by backpack sprayer or spray bottle (Mimic®) or soil injector applicator (PTM™) to all 126 trees within the designated treatment area on second- and first-year sites, respectively. Mimic® application dates were based on optimal spray period predictions for locations near each study site (Fettig et al. 2003), generally every 7-8 weeks starting in late February and ending in late September. PTM™ treatments consisted of a single application at or just after planting.

Tip Moth Damage Survey: Tip moth infestation levels were determined by surveying the internal 50 trees within each plot during the pupal stage of each tip moth generation for the first two years after establishment. Each tree was ranked according to the extent of tip moth damage including: 1) tree identified as 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. Trees also were surveyed a final time in November or December. At this time, data also were collected on tree height and diameter at 15 cm (6 in) above the ground. Tree height, diameter at breast height (DBH) and form data were collected on third-year and fifth-year sites. Tree form was evaluated based on number of forks occurring on each tree: 0 = no forks, 1 = one fork, 2 = two to four forks and 3 = five or more forks. A fork is defined by the presence of a lateral branch that is more than half the diameter of the main stem at its base.

Data Analysis: Trevor Walker, graduate student at Stephen F. Austin State University, has provided the following outline for data analysis:

A) Dominant height equation modifier:
    Relate tree growth impact to infestation level (Hedden paper):
        Predictor variables - Years since treatment, identify others in
            Hazard-rating part of study
B) Economic simulation:
    Determine *willingness to pay* (Asaro 2006) for treatment:
    Assume:
        Real price increase and consumer price index
        Fluctuate levels of, or numerically solve - price per unit of forest product, alternative rate of return.

Results: Figure 24 shows the mean number of pine tip moths captured in traps per day at several one- to three-year-old sites surrounding Lufkin, TX from 2001- 2007. The optimal spray periods in East Texas (near Lufkin) for the first four generations were predicted to be March 22-26, May 21-25, July 10-14, and Aug 19-23 (Fettig et al. 2003). Based on previous years trap data (Figure 21), a fifth spray period was calculated to be September 29 to October 3. In contrast, optimal spray periods for southern Arkansas sites (near Crossett) should be April 6-10, June 5-9, July 30-August 3, and Sept. 13-17.

The new impact plots established in 2009 (3) and 2010 (4), brought the total number of plots established since 2001 to 110. The use of PTM™ on these sites resulted in better protection (Table 35). Figure 25 shows the distribution of the 110 first- through ninth-year impact study sites in the Western Gulf Region.

Group 1 - Tenth-year sites (12):
Trees on these sites were measured in 2010.

Group 2 - Ninth-year sites (4):
Trees on these sites were not measured in 2010.

Group 3 - Eighth-year sites (8 new; 24 total):
Trees on these sites were measured in 2010.

Group 4 - Seventh-year sites (2 new; 26 total):
Trees on these sites were not measured in 2010.

Group 5 - Sixth-year sites (6 new; 40 total):
Trees on these sites were not measured in 2010.

Group 6 - Fifth-year sites (22 new; 64 total):
Trees on these sites were measured in 2010.

Group 7 - Fourth-year sites (13 new; 88 total)
Trees on these sites were not measured in 2010.

Group 8 - Third-year sites (15 new; 103 total):
Trees on these sites were measured in 2010.

Group 9 - Second-year sites (3 new; 106 total):
Tip moth infestation levels on untreated second-year trees were more than 2X higher (59% of shoots infested) in 2010 compared to similar aged trees in 2009 (25% of shoots infested) (Table 35). Overall protection of second-year trees was better, but not great, with PTM™ (applied in 2009) reducing damage to shoots by only 72%. Combined, these factors have resulted in smaller than expected gains in the height (10%), diameter (8%) and volume (23%) of protected trees compared to check trees (Table 36, Figures 26-28).

Group 10 - First-year sites (4 new; 110 total):
Overall, tip moth infestation levels on untreated first-year seedlings were generally higher (26% of shoots infested) in 2010 compared to 2009 levels (21% of shoots infested) (Table 35). PTM™ protection was again better in 2010 compared to previous results with Mimic®. Overall, the soil injection treatments reduced damage by 87%; reductions in damage were above 75% on all three sites. PTM™-treated trees on each site showed significant gains in height, diameter, and volume compared to untreated check trees. Overall, protected (Mimic®/ PTM™) seedlings saw gains in height, diameter and volume of only 10%, 8% and 28%, respectively, compared to check trees (Table 36, Figures 26-28).

Conclusions: Overall, tip moth populations and damage levels were very high in 2010 compared to previous years (2001 – 2009). Although close to average rainfall was received in 2009, the extensive drought conditions that occurred in the Western Gulf Region through 2005, most of 2006, 2007 and 2010 and periodically since then may have allowed tip moth populations to build. A single application of PTM™ was able to significantly reduce tip moth infestation levels on two-year-old sites in 2010. Whereas, Mimic® treatments did significantly improve tree growth on first-year sites in 2001, 2003, 2005 and 2006 and second-year sites in 2002, 2005 and 2006, they did not improve tree growth on first-year sites in 2002 or second-year sites in 2003. One reason may be that tip moth populations were too low (below some threshold) to impact the growth of untreated trees on first and second-year sites in 2002 and 2003, respectively. In contrast, tip moth populations were apparently high enough on second-year sites to significantly impact growth of unprotected trees. Analysis of data from 76 sites containing loblolly pine 3 years of age or older showed that two-year mean tip moth damage levels (percent shoots infested) of less than 10% can still significantly impact tree growth in a given year.

The question remains, at what damage level does protection treatments become cost effective in forest plantations? Data are being evaluated by Mr. Trevor Walker, biometrician graduate student, to answer this question.

Given the disparity in tip moth population levels over the past three years, it is suggested that additional impact sites be established in 2011. If additional impact sites are to be installed, we recommend that PTM™ Insecticide be used and applied at planting to protect trees for 2+ years. Also, it is important to monitor tip moth damage and impact on 3rd-, 5th, 8th and 10th-year sites in 2011.

Acknowledgments: We greatly appreciate the efforts of Peter Burk (Weyerhaeuser), Al Cook (independent contractor for International Paper and Plum Creek), Nick Chappell (Potlatch), Conner Fristoe (Plum Creek), Bill Stansfield (Campbell Group), and Jimmy Murphy and Rodney Schroeder (American Forest Management, contractor for Forest Investment Associates), for establishing, spraying and monitoring the impact plots. Many thanks go to Trevor Walker and Dean Coble, SFASU, for work on the analysis of the impact data.

References:

Fettig, C.J., K.W. McCravy and C.W. Berisford. 2000. Effects of Nantucket pine tip moth insecticide spray schedules on loblolly pine seedlings. So. J. Appl. For. 24(2):106 – 111.

Fettig, C.J., J.T. Nowak, D.M. Grosman and C.W. Berisford. 2003. Nantucket pine tip moth phenology and timing of insecticide spray applications in the Western Gulf Region. USDA Forest Service So. Res. Stat. Res. Pap. SRS-32. 13pp.

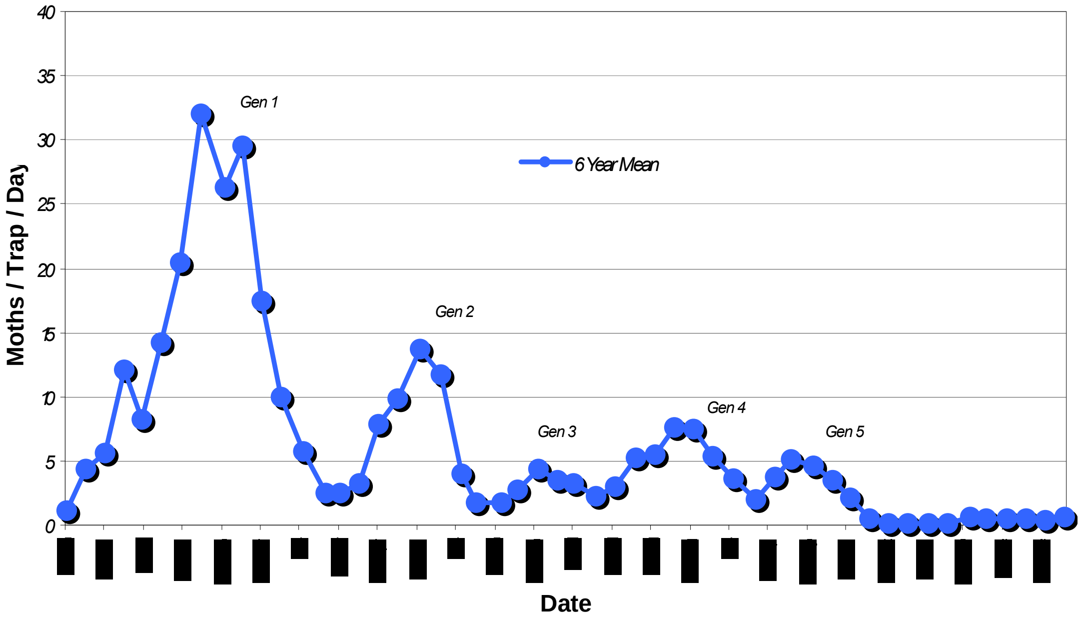


Figure 24. Mean number of pine tip moth adults captured per trap per day in the Lufkin, TX area (2001 - 2010).

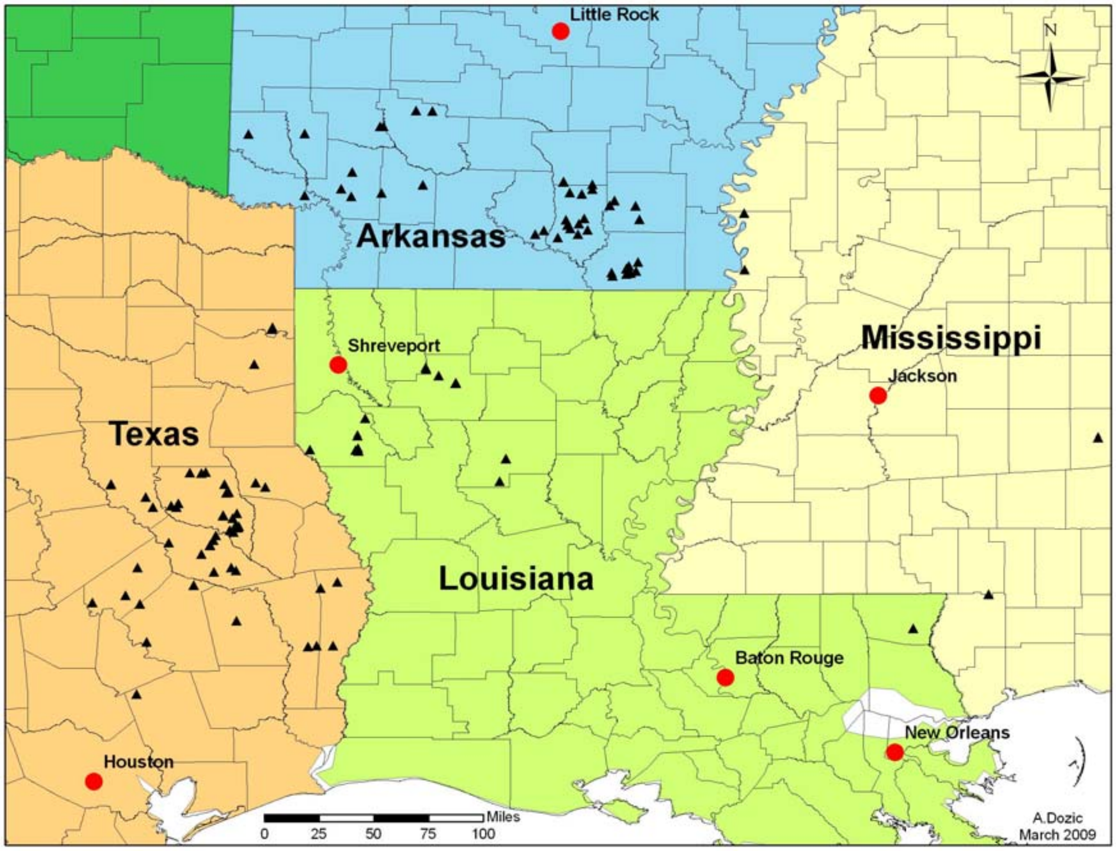


Figure 25. Distribution of 110 one- to five-year old impact sites (▲) from 2001 – 2010 in the Western Gulf Region.

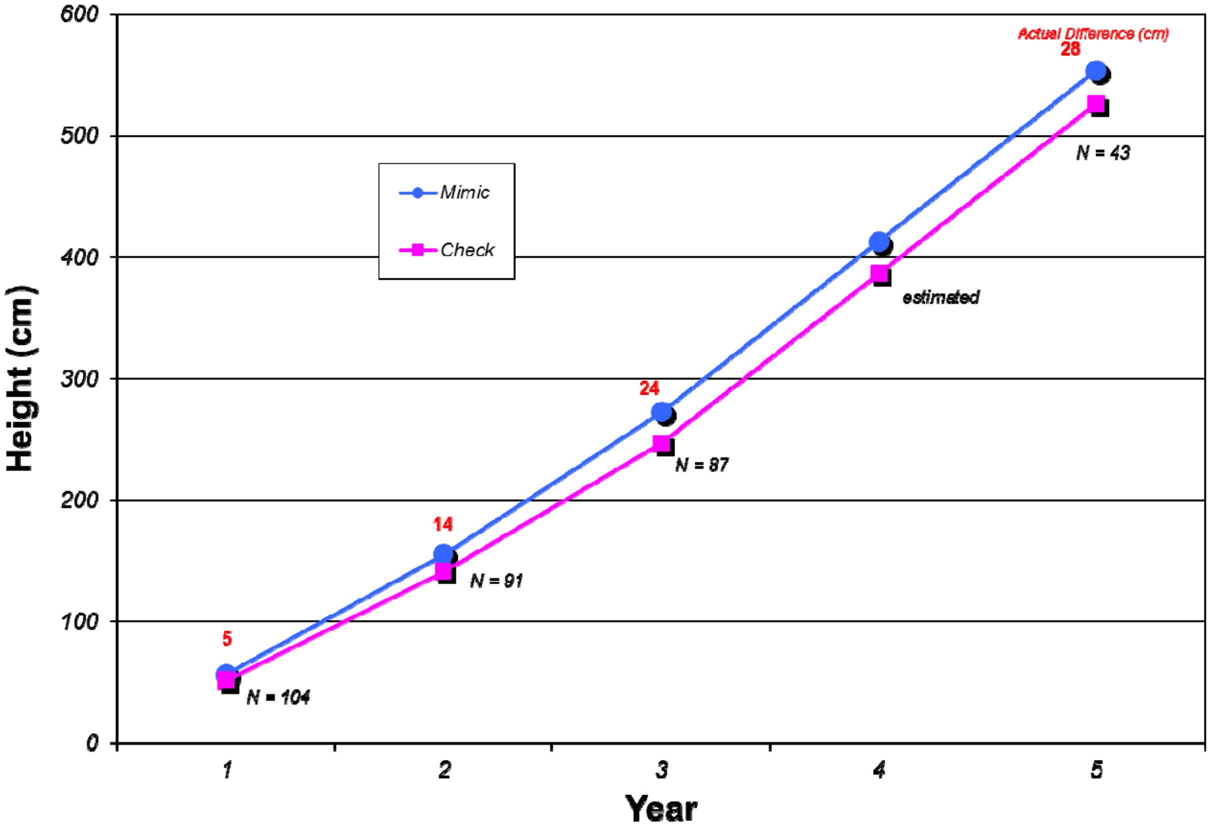


Figure 26. Mean height (cm) of one- to five-year old loblolly pine treated with Mimic® or PTM™ compared to untreated trees on all Western Gulf sites: 2001 – 2010.

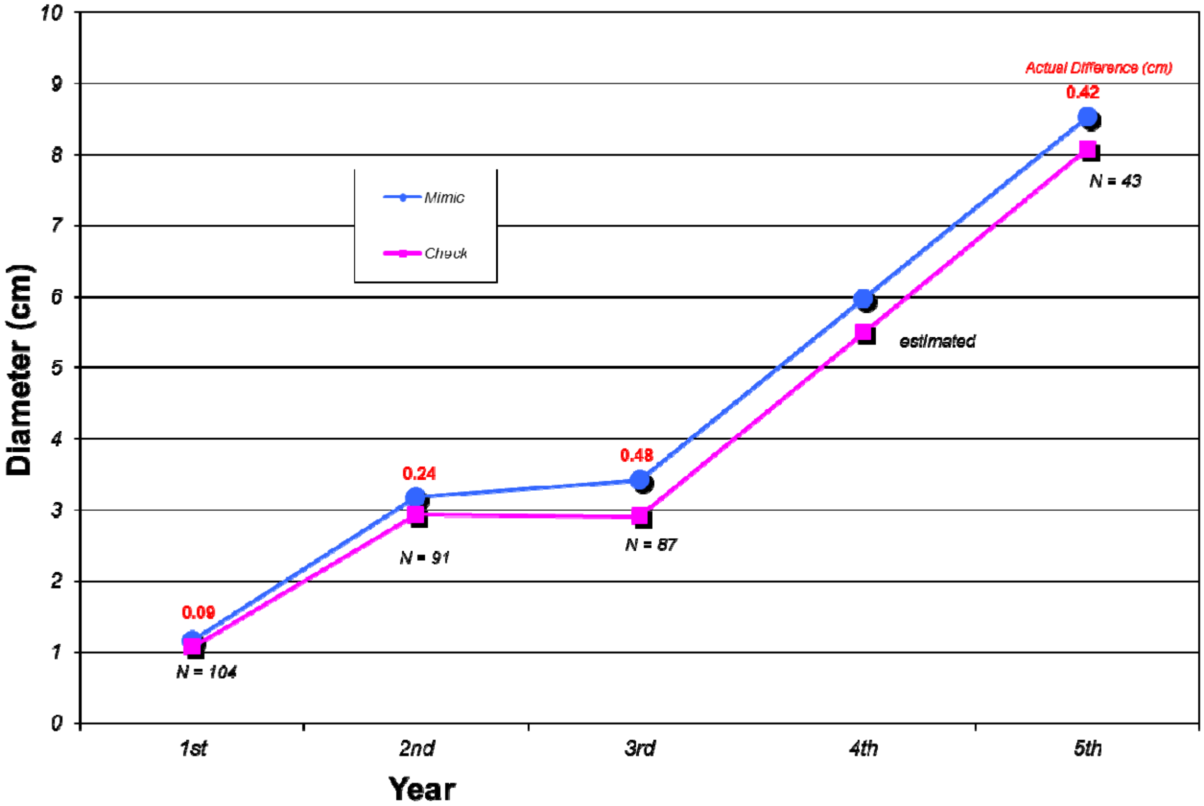


Figure 27. Mean diameter (cm) of one- to five-year old loblolly pine treated with Mimic® or PTM™ compared to untreated trees on all Western Gulf sites: 2001 – 2010.

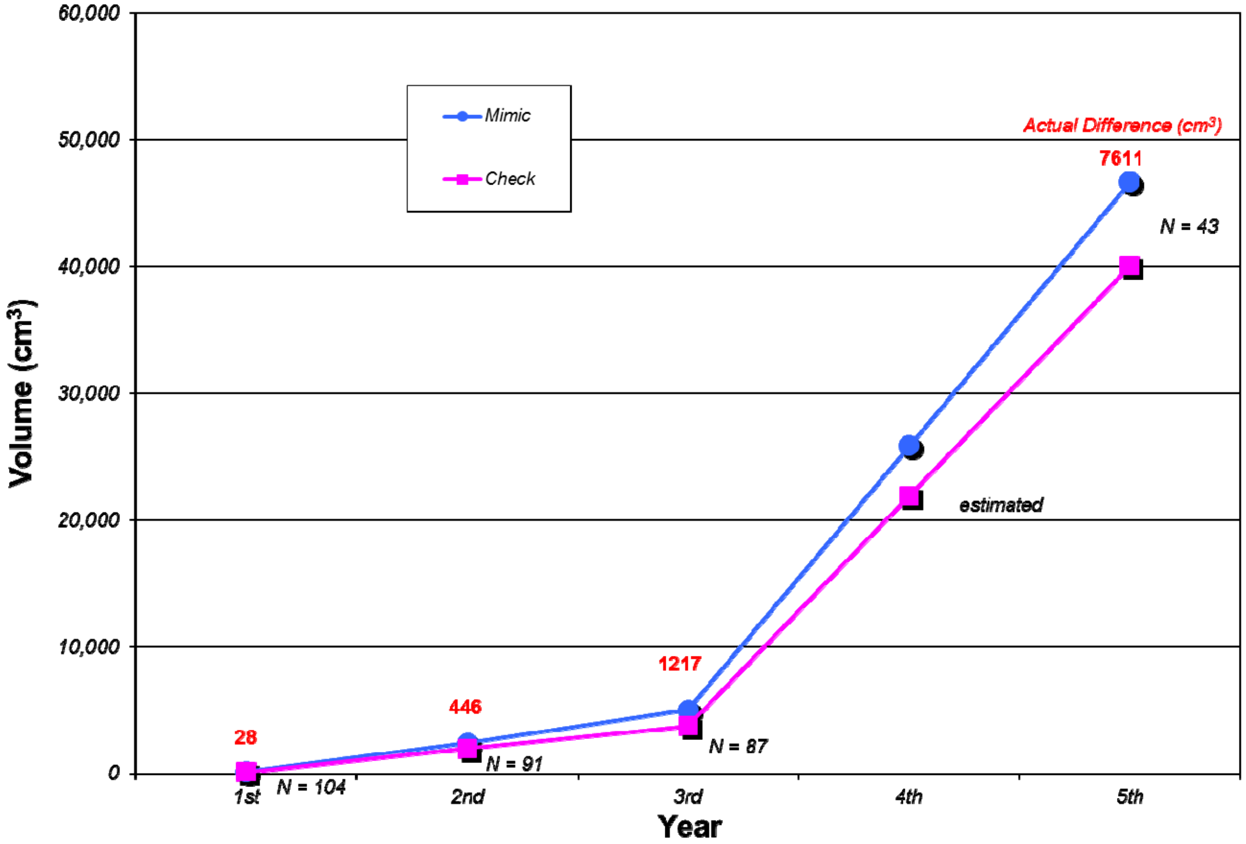


Figure 28. Mean volume index (cm^3) of one- to five-year old loblolly pine treated with Mimic® or PTM™ compared to untreated trees on all Western Gulf sites: 2001 – 2010.

Table 35: Mean percent of pine shoots (in top whorl) infested by pine tip moth on one- and two-year old loblolly pine trees following treatment with Mimic® after each generation in year 1 and 2, or PTM™ in year 1 (2009 and 2010); Arkansas, Lousiana, Mississippi and Texas sites, 2001 - 2010.

	Planted 2001		Planted 2002		Planted 2003		Planted 2004		Planted 2005		Planted 2006	
	(N =16)		(N=7)	(N=4)	(N=10)	(N=9)	(N= 8)	(N= 5)	(N= 6)		(N=29)	(N=22)
Treatment	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2
Mimic®	1.8	3.8	1.5	3.8	1.2	1.2	1.4	1.8	3.0	7.2	5.0	13.2
Check	23.0	21.9	7.5	15.5	12.2	12.0	10.3	15.6	13.2	15.7	14.0	26.0
% Reduction	92	83	80	75	90	90	87	88	78	54	65	49

	Planted 2007		Planted 2008		Planted 2009		Planted 2010		Mean	Mean
	(N= 13)		(N=15)		(N= 3)		(N= 4)		Year 1	Year 2
Treatment	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	(N=110)	(N=96)
Mimic®	15.5	17.1	4.4	7.7	0.6	16.7	3.3		5.1	8.8
Check	24.0	47.9	24.0	25.0	20.6	58.9	25.5		18.1	26.2
% Reduction	35	64	82	69	97	72	87		**72**	**66**

Table 36: Mean tree height, diameter and volume index and percent growth gain and actual difference in growth of one-, two-, three- and five-year old loblolly pine following treatment with Mimic® after each generation in year 1 and 2; Arkansas, Lousiana, Mississippi and Texas, 2001 - 2010.

	Mean			
Treatment	Year 1 (N= 9516 trees on 104 sites)	Year 2 (N= 8560 trees on 91 sites)	Year 3 (N= 8165 trees on 87 sites)	Year 5 (N= 4104 trees on 43 sites)
	Height (cm)			
Mimic®	56.6	154	265	542
Check	51.3	141	241	514
Actual Diff. In Growth (cm)	5	14	24	28
Pct. Gain Compared to Check	**10**	**10**	**10**	**6**
	Diameter (cm)			
	at 6"	at 6"	at DBH	at DBH
Mimic®	1.15	3.18	3.32	9.04
Check	1.07	2.93	2.84	8.63
Actual Diff. In Growth (cm)	0.09	0.24	0.48	0.42
Pct. Gain Compared to Check	**8**	**8**	**17**	**5**
	Volume Index (cm^3)			
Mimic®	127	2386	4798	46084
Check	99	1940	3580	38473
Actual Diff. In Growth (cm)	28	446	1217	7611
Pct. Gain Compared to Check	**28**	**23**	**34**	**20**

Volume Index = Height X Diameter^2

PINE TIP MOTH TRIALS

Hazard Rating Study – Western Gulf Region

Highlights:

- Data on site characteristics were collected from 7 plots (4 - first-year and 3 - second-year) in the Western Gulf Region in 2010. In total, 142 hazard-rating plots have been established since 2001.
- Trevor Walker, SFA Graduate Student, is working to develop a model as part of his Master's Thesis. Considerable progress was made in 2010 on the development of the hazard-rating model. Regression analysis indicates important predictors of proportion of infested tips include: age, generation, treatment, site preparation release and additional herbaceous control, fertilization, depth to gleying, boron, sulfur, pH, percent base saturation of magnesium, calcium, and hydrogen.

Objective: Identify abiotic factors that influence the occurrence and severity of pine tip moth infestations in the Western Gulf Region.

Cooperators:

Mr. Conner Fristoe	Plum Creek Timber Co., Crossett, AR
Dr. Nick Chappell	Potlatch Forest Holdings, Warren, AR
Mr. Peter Birks	Weyerhaeuser Co., Columbus, MS
Mr. Bill Stansfield	The Campbell Group, Diboll, TX
Mr. Jeff Hall	Forest Investment Associates, Jackson, MS
Mr. Andrew Burrow	Potlatch Forest Holdings, ID
Mr. Trevor Walker	Stephen F. Austin State University, Nacogdoches, TX
Dr. Dean Coble	Stephen F. Austin State University, Nacogdoches, TX

Study Sites: FPMC members selected from one or five new first-year plantations in 2008 and 2009. These sites were the same as those used in the Impact Study. The untreated Impact plot was also used to collect tip moth and site characteristics data for the Hazard Rating Study. In this situation, a plot area within each plantation was selected, with each plot containing 126 trees (9 rows X 14 trees). The internal 50 trees were evaluated for tip moth damage.

Site Characteristics Data: Site characteristics data collected from 7 Western Gulf plots (4 - first-year and 3 - second-year) in 2010 included:

Soil - Texture and drainage
Soil description/profile: depth of 'A' and to 'B' horizons; color and texture of 'B' horizon
Depth to hard-pan or plow-pan
Depth to gleying
Soil sample (standard analysis plus minor elements and pH)
Tree - Age (1-2)
Percent tip moth infestation of terminal and top whorl shoots – 1st, 2nd, 3rd, and last generation
Height and diameter at 15 cm (6 in) above ground

Site - Previous stand history
- Site index (base 25 years)
- Silvicultural prescription (for entire monitoring period)
- Slope, aspect, and position (ridge, side-slope, bottom, flat)
- Competing vegetation: 5 random samples within each plot to determine proportion of bare ground, grasses, forbes and non arborescent woody stems after 2nd and last tip moth generation.
- Rainfall (on sight or from nearest weather station)
- Estimate of the acreage of susceptible loblolly stands in the 2-5 year age class (< 6 m (15 ft) tall) adjacent to or within 1/2 mile of study stand boundary

Tip Moth Damage Survey: Tip moth infestation levels were determined in each plot by surveying the internal 50 trees during the pupal stage of the first, second and last tip moth generation. Each tree was ranked on the extent of tip moth damage including: 1) tree identified as 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. On second-year sites, the 50 sample trees were measured after the last generation for height and diameter at 6 inches and assessed for the occurrence of fusiform rust galls. Incidence of fusiform rust was measured by counting the number of fusiform galls on the main stem and on branches within 30 cm (12 in) of the main stem of each tree.

Data Analysis: Trevor Walker, SFASU, has nearly completed the tip moth hazard rating model. With a Bachelors' in Forestry and minor in statistics, Mr. Walker has the expertise the FPMC needs to get the job done. The data (eight years' worth; 2001- 2008) was consolidated and sent to Mr. Walker by the end of February 2009. Additional data collected from 2009 was sent to Mr. Walker in April 2010.

The following is an outline provided by Mr. Walker for model development:

A) Choosing a response variable:
- Percent infested => may require variance stabilizing transformation
  - By tree or plot/By generation or year => Measuring variability
    - -By plot using the first two generations may be the response that is most explained by the predictor variables

B) Identify predictor variables that explain the variation in the response variable:
- Stepwise Regression: Multiple or Logistic
- Regression and Classification Trees
  - - Test using subset of data and calculate APER
- Single variable analysis (linear association)
  - - simple linear regression, Pearson's correlation, graphs
- Interactions between predictor variables - Multicollinearity
  - - Correlation Coefficient / Scatterplot Matrix
  - - Variable reduction - PCA/Factor Analysis

C) ANOVA – Fabricate a research design using the class variables
- - Unbalanced sample size structure

D) Model infestation levels by generation.
- - Line chart for infestation level by generation by site and both ages (1 and 2).
- - Investigate correlations between infestation levels by generation with predictor variables

E) Develop hazard-rating map.
  - Map rating class based on important predictor variables.
  - Bayou Bleu Farms, LLC case study/poster.

Results: Figure 29 shows the distribution of all 142 hazard-rating sites established in the Western Gulf Region from 2001 to 2010.

Mr. Trevor Walker and Dr. Dean Coble, Stephen F. Austin and State University, have agreed to provide assistance with future analyses and model development. We are in the process of consolidating all available data (2001 – 2008) for these researchers.

Mr. Walker's preliminary regression analysis indicates the following to be important predictors of proportion of infested tips (many of which are confirmed by prior studies):

1) Age - second year sites have higher tip moth populations than first year
2) Generation - there are higher levels seen in later generations
3) Treatment - spraying reduces tip moth population
4) Site Preparation Release and Additional Herbaceous Control- sites with lower levels of competing vegetation tend to show higher tip moth levels.
5) Fertilized sites have significantly lower tip moth top whorl proportion infested (about 8% on average in Ages 1 and 2). Fertilization appears to increase the average number of total shoots while decreasing the average number of infested shoots.

Other variables (depth to gleying, boron, sulfur, pH, percent base saturation of magnesium, calcium, and hydrogen) are regarded as important in the regression model, but have no clear direct effect on proportion of tips infested individually. This suggests that there is an interaction effect between two or more variables in their contribution to the relationship with proportion infested (A good example of this is the soil calcium/site index interaction with the response percent infestation - a graph of which is found in Figure 8, pg 155 of Berisford 1988 in Berryman's Dynamics of Forest Insect Populations). Interactions like this are often tough to find without prior knowledge.

Acknowledgments: We greatly appreciate the efforts of Peter Burk (Weyerhaeuser), Al Cook (independent contractor for International Paper and Plum Creek), Jeff Earl (independent contractor for Plum Creek), Conner Fristoe (Plum Creek), Nick Chappell (Potlatch), Emily Goodwin (Temple-Inland), Bill Stansfield (Campbell Group), Ragan Bounds (Hancock Forest Management), Doug Long (Rayonier), and Jimmy Murphy and Rodney Schroeder (American Forest Management, contractor for Forest Investment Associates), for establishing and monitoring the hazard-rating plots. Many thanks go to Andy Burrow, Potlatch, for his time and efforts in the initial model development phase.

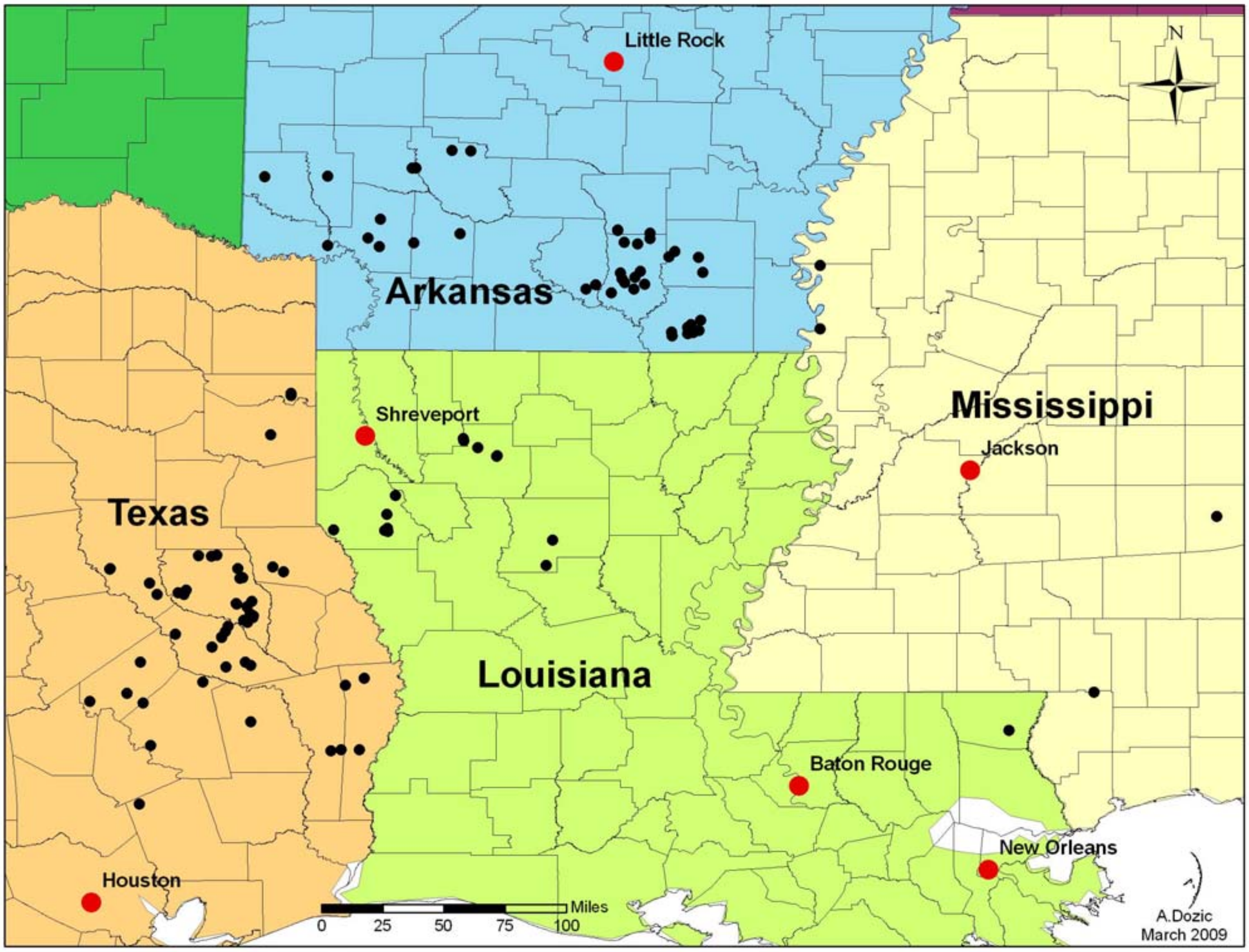


Figure 29. Distribution of 142 hazard-rating plots (●) established from 2001 - 2010 in the Western Gulf Region.

PINE TIP MOTH TRIALS

Evaluation of Fipronil Treatments for Containerized Pine Seedlings

Highlights:

- Fipronil treatments (1X and 5X) applied to containerized pine seedlings provided good protection against tip moth through three full growing seasons: 57% and 72% reduction in damage compared to check. Fipronil soil injection to bare-root seedlings was less effective, but still significantly reduced damage for 3 years by 39%. All fipronil treatments significantly improved height, diameter and volume growth
- In 2010, tip population pressures were severe (100% shoot infestation during generations 4 and 5). The efficacy of both containerized treatments (1X and 5X) disappeared completely after the second generation. Volume growth improvements due to fipronil treatments ranged from 36 – 69%.

Objectives: 1) Evaluate the efficacy of fipronil applied at different rates to containerized seedlings for reducing pine tip moth infestation levels, 2) evaluate the efficacy of fipronil on containerized versus bare-root seedlings; and 4) determine the duration of chemical activity.

Cooperators:

Mr. Bill Stansfield	The Campbell Group, Diboll, TX
Dr. Jim Bean	BASF Corp., Research Triangle Park, NC

Study Sites: Two first-year Campbell Group (formerly Temple Inland) plantations were selected in Polk County and Angelina County, Texas in February 2007.

Insecticides:

Fipronil SC (fipronil) – a phenyl pyrazole with some systemic activity against Lepidoptera.

Research Approach:

A randomized complete block design was used at each site with sites serving as blocks, i.e., each treatment was randomly selected for placement in an area. For each treatment, one hundred seedlings were monitored in each of two subplots. The treatments included:

1) Containerized Fipronil (1X - 3 ml/seedling) -	Injection into cell in July
2) Containerized Fipronil (5X - 15 ml/seedling) -	Injection into cell in July
3) Containerized Check (untreated)	
4) Bare-root Fipronil (12 ml/seedling) -	Soil injection next to transplant in March
5) Bare-root Single Mimic® Foliar -	Mimic® applied 5X /year
6) Bare-root Check (untreated)	

Two families of loblolly pine containerized and bare-root seedlings were selected at the Temple Inland Nursery (now owned by The Campbell Group), Jasper, TX.

Containerized seedlings were individually treated using a small syringe in July 2006. The seedlings were treated at 1X and 5X the rate designated for transplanted bare-root seedlings (1X = 0.13 lbs AI/acre/year = 0.118 g AI/seedling at 500 seedlings/acre). All bare-root seedlings were operationally lifted by machine in March 2007, culled of small and large caliper seedlings, treated with Terrasorb™ root coating, bagged and stored briefly in cold storage. Each family was planted on each of two plantation sites. At each site, treatments were randomly assigned to 1 of 6 plot areas. One hundred seedlings were planted per plot at 8' X 11' spacing (500 TPA).

Data Evaluation: Tip moth damage was evaluated on 50 seedlings located on the interior of each plot 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. Observations also were made as to the occurrence and extent of damage caused by other insects, i.e., aphids, weevils, coneworms, etc. The trees were measured for height and diameter (at 15 cm or 6 in) in December following planting. Data were analyzed by GLM and the Fisher's Protected LSD test using Statview or SAS statistical programs.

Results: In 2007, tip moth populations were quite low on both sites during the first generation; $\leq$ 2% of the shoots were infested on check trees. As a result of the low tip moth pressure, none of the treatments significantly reduced tip moth infestation of top whorl shoots compared to the check during the first generation (Table 37). The fipronil treatments on the containerized seedlings had a significant effect on tip moth damage from the second through the fifth tip moth generation, reducing overall damage by 97 – 100%. The soil injection treatment of the bare-root stock also was quite effective against tip moth but not to the extent observed on the containerized seedlings. All fipronil treatments significantly improved height, diameter and volume index compared to check trees (Tables 41). However, the Mimic® spray treatment had no apparent effect on any of the growth parameters compared to check trees.

In 2008, tip moth population pressure was much greater than in 2007, with an average of >90% of the top-whorl shoots infested on check trees during the 4th and 5th generations and a mean of >57% shoots infested over the entire growing season (5 generations) (Table 38). Efficacies of the two fipronil containerized treatments declined through the second year, but the treatments still reduced overall damage by 52 – 65%. The soil injection treatment only slightly reduced tip moth damage after the second generation. All treatments significantly improved height, diameter, and volume index compared to check trees (Tables 41). Volume growth improvements attributed to fipronil treatments ranged from 64 – 94%. Protection with use of Mimic® actually improved with the application of new product and crop oil surfactant, thus the effect of spray treatment on all growth parameters became significant compared to check trees.

In 2009, tip moth population pressure was moderately high, with an average of >67% of the top-whorl shoots infested on check trees during the 5th generation and a mean of >34% shoots infested over the entire growing season (5 tip moth generations) (Table 39). Efficacies of the two fipronil treatments on containerized trees continued to decline through the third year, but the treatments still reduced overall damage by 16-51%. The efficacy of the soil injection treatment actually improved, reducing tip moth damage by 31% (compared to 11% in the second year). All treatments significantly improved height, diameter and volume index compared to check trees (Tables 41). Volume growth improvements attributed to fipronil treatments ranged from 22 – 70%. Seedlings treated previously with Mimic® (2008) continued to exhibit significantly reduced pine tip moth damage and thus the effect of spray treatment on all growth parameters became even greater compared to check trees.

In 2010, tip moth population pressure was extremely high, with an average of 100% of the top-whorl shoots infested on check trees during the 5th generation and a mean of 71% shoots infested over the entire growing season (5 tip moth generations) (Table 40). Efficacies of the two fipronil treatments on containerized trees continued to decline and faded by the end of the third generation. Overall, treatments still reduced overall damage by 5 - 7%. The soil injection treatment reduced tip moth damage by 10%. All treatments significantly improved height, diameter and volume index compared to check trees (Tables 41). Volume growth improvements attributed to fipronil treatments ranged from 36 – 69%.

Acknowledgments: Thanks go to Jim Tule, formerly with Temple Island, for providing seedlings and research sites in TX and to Bill Stansfield and The Campbell Group for continued access to study sites. We also thank Dr. Harry Quicke, BASF, for providing the fipronil formulation for the project.

Table 37. Effect of fipronil application technique and rate on pine tip moth infestation of loblolly pine shoots after each of 5 generations on two sites in East Texas - 2007.

		Mean Percent of Loblolly Pine Shoots Infested (**Pct. Reduction Compared to Check**)											
Treatment §	N	Ang.	Polk	Mean		Ang.	Polk	Mean		Ang.	Polk	Mean	
		Generation 1				Generation 2				Generation 3			
Containerized FIP 3 ml	200	0.0	0.0	0.0	**100**	0.0	0.3 *	0.1 *	**97**	0.0 *	0.0 *	0.0 *	**100**
Containerized FIP 15 ml	200	0.0	0.0	0.0	**100**	0.0	0.0 *	0.0 *	**100**	0.0 *	0.0 *	0.0 *	**100**
Containerized Check	200	0.5	0.0	0.2		2.0	7.8	4.9		5.2	4.7	4.9	
BR FIP SI 12 ml	100	1.0	0.0 *	0.5	**62**	4.0 *	0.5	2.3 *	**72**	3.2	2.0 *	2.6	**54**
BR Mimic	100	1.2	0.0 *	0.6	**55**	0.7 *	4.1	2.4 *	**70**	0.0	0.5 *	0.3 *	**96**
BR Check	100	2.0	0.7	1.3		11.8	4.0	7.9		3.0	8.3	5.6	
		Generation 4				Generation 5				Mean			
Containerized FIP 3 ml	200	0.0 *	0.3 *	0.2 *	**100**	1.3 *	0.3 *	0.8 *	**97**	0.3 *	0.2 *	0.2 *	**99**
Containerized FIP 15 ml	200	0.0 *	0.0 *	0.0 *	**100**	0.0 *	0.0 *	0.0 *	**100**	0.0 *	0.0 *	0.0 *	**100**
Containerized Check	200	46.8	39.2	43.0		18.9	38.2	28.5		14.7	18.0	16.3	
BR FIP SI 12 ml	100	3.3 *	6.7	5.0 *	**76**	8.5 *	4.5 *	6.5 *	**79**	4.0 *	2.7 *	3.4 *	**75**
BR Mimic	100	4.2 *	10.2	7.2 *	**65**	4.9 *	21.1 *	13.0 *	**59**	2.2 *	7.2 *	4.7 *	**65**
BR Check	100	26.7	14.7	20.7		25.5	37.7	31.6		13.8	13.1	13.4	

§ SI- Fipronil soil injection

▨ = treatment reduced damage by >75% compared to check.

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

Table 38. Effect of fipronil application technique and rate on pine tip moth infestation of loblolly pine shoots after each of 5 generations on two sites in East Texas - 2008.

		Mean Percent of Loblolly Pine Shoots Infested (**Pct. Reduction Compared to Check**)											
Treatment §	N	Ang.	Polk	Mean		Ang.	Polk	Mean		Ang.	Polk	Mean	
		Generation 1				Generation 2				Generation 3			
Containerized FIP 3 ml	200	4.7 *	12.0 *	8.3 *	**65**	13.0 *	10.1 *	11.6 *	**73**	16.3 *	32.4 *	24.3 *	**61**
Containerized FIP 15 ml	200	3.8 *	11.1 *	7.4 *	**69**	4.5 *	8.9 *	6.7 *	**84**	10.9 *	31.2 *	21.0 *	**66**
Containerized Check	200	23.5	24.1	23.8		46.6	39.9	43.2		50.0	73.2	61.6	
BR FIP SI 12 ml	100	11.2	15.1	13.1	**29**	33.0	15.2 *	24.1 *	**34**	43.5	46.9 *	45.2	**6**
BR Mimic	100	8.0 *	8.8 *	8.4 *	**54**	11.0 *	3.6 *	7.3 *	**80**	17.9 *	7.1 *	12.5 *	**74**
BR Check	100	15.9	20.9	18.4		37.4	35.8	36.6		36.5	59.8	48.2	
		Generation 4				Generation 5				Mean			
Containerized FIP 3 ml	200	23.8 *	70.4 *	47.1 *	**48**	39.8 *	70.1 *	57.3 *	**37**	20.5 *	39.1 *	29.8 *	**52**
Containerized FIP 15 ml	200	15.0 *	51.6 *	33.2 *	**63**	23.2 *	61.0 *	44.1 *	**52**	11.9 *	32.4 *	22.1 *	**65**
Containerized Check	200	82.0	98.4	90.2		77.9	97.2	91.3		57.8	66.9	62.4	
BR FIP SI 12 ml	100	86.3	95.0	90.7	**0**	65.7 *	93.0	82.7 *	**12**	49.4	53.0 *	51.2 *	**11**
BR Mimic	100	34.3 *	15.3 *	24.8 *	**73**	30.9 *	30.6 *	33.0 *	**65**	20.9 *	12.7 *	16.8 *	**71**
BR Check	100	81.4	100.0	90.7		83.0	96.0	94.1		52.7	62.8	57.6	

§ SI- Fipronil soil injection ▨ = treatment reduced damage by >75% compared to check.

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

Table 39. Effect of fipronil application technique and rate on pine tip moth infestation of loblolly pine shoots after each of 5 generations on two sites in East Texas - 2009.

		Mean Percent of Loblolly Pine Shoots Infested (**Pct. Reduction Compared to Check**)											
Treatment §	N	Ang.	Polk	Mean		Ang.	Polk	Mean		Ang.	Polk	Mean	
		Generation 1				Generation 2				Generation 3			
Containerized FIP 3 ml	200	6.9 *	12.3	9.6 *	**39**	3.6	2.4 *	3.0 *	**59**	7.5 *	27.0	17.2 *	**32**
Containerized FIP 15 ml	200	3.2 *	7.4 *	5.3 *	**66**	1.6 *	1.6 *	1.6 *	**79**	7.8 *	16.0 *	11.9 *	**53**
Containerized Check	200	13.9	17.7	15.8		7.2	7.6	7.4		21.6	28.9	25.2	
BR FIP SI 12 ml	100	6.0	5.6 *	5.8 *	**54**	10.5	7.0	8.8	**0**	20.5	6.5 *	13.5 *	**48**
BR Mimic	100	5.1	2.3 *	3.7 *	**71**	4.3	3.5	3.9 *	**55**	12.8 *	14.9	13.8 *	**47**
BR Check	100	7.1	18.3	12.7		9.0	8.4	8.7		26.4	25.4	25.9	
		Generation 4				Generation 5				Mean			
Containerized FIP 3 ml	200	42.5	44.6 *	43.6 *	**13**	73.5	61.4	67.5	**3**	26.8 *	29.5	28.2 *	**16**
Containerized FIP 15 ml	200	19.0 *	31.2 *	25.1 *	**50**	37.9 *	38.8 *	38.3 *	**45**	13.9 *	19.0 *	16.4 *	**51**
Containerized Check	200	44.9	55.4	50.1		76.6	62.8	69.7		32.8	34.5	33.7	
BR FIP SI 12 ml	100	50.3 *	23.3 *	36.8	**8**	67.9 *	34.7 *	51.3 *	**36**	31.1	15.4 *	23.2 *	**31**
BR Mimic	100	24.8	16.7 *	20.8 *	**48**	43.2 *	31.3 *	37.3 *	**54**	18.0 *	13.7 *	15.9 *	**53**
BR Check	100	33.3	46.9	40.1		92.7	68.2	80.5		33.7	33.4	33.6	

§ SI- Fipronil soil injection ▨ = treatment reduced damage by >75% compared to check.

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

Table 40. Effect of fipronil application technique and rate on pine tip moth infestation of loblolly pine shoots after each of 5 generations on two sites in East Texas - 2010.

		Mean Percent of Loblolly Pine Shoots Infested (**Pct. Reduction Compared to Check**)											
Treatment §	N	Ang.	Polk	Mean		Ang.	Polk	Mean		Ang.	Polk	Mean	
		Generation 1				Generation 2				Generation 3			
Containerized FIP 3 ml	200	33.7	20.2	26.9	**-1**	11.3 *	6.7	9.0 *	**38**	79.3	36.9	58.1	**8**
Containerized FIP 15 ml	200	21.9 *	19.0	20.4 *	**23**	15.4	3.7	9.5 *	**34**	75.6	41.4	58.5	**7**
Containerized Check	200	34.2	19.1	26.7		20.8	8.1	14.4		82.1	44.1	63.1	
BR FIP SI 12 ml	100	25.2 *	17.6	21.4 *	**44**	13.0	7.7	10.3	**22**	80.1	18.9 *	49.5 *	**20**
BR Mimic	100												
BR Check	100	51.4	25.0	38.2		19.8	6.7	13.3		81.7	41.8	61.8	
		Generation 4				Generation 5				Mean			
Containerized FIP 3 ml	200	100.0	Trees to Tall to evaluate	100.0	**0**	100.0	Trees to Tall to evaluate	100.0	**0**	63.8		63.8	**5**
Containerized FIP 15 ml	200	100.0		100.0	**0**	100.0		100.0	**0**	62.6 *		62.6 *	**7**
Containerized Check	200	100.0		100.0		100.0		100.0		67.4		67.4	
BR FIP SI 12 ml	100	100.0		100.0	**0**	100.0		100.0	**0**	63.7 *		63.7 *	**10**
BR Mimic	100												
BR Check	100	100.0		100.0		100.0		100.0		70.6		70.6	

§ SI- Fipronil soil injection ▨ = treatment reduced damage by >75% compared to check.

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

Table 41. Effect of fipronil application technique and rate on loblolly pine growth after attack by pine tip moth on two sites in East Texas: 2007 - 2010.

			Mean End of Season Tree Measurements (**Growth Difference (cm or cm^3) Compared to Check**)											
Year	Treatment	N	Height (cm)				Ground Line Diameter (cm)				Volume (cm^3)			
			Ang.	Polk	Mean		Ang.	Polk	Mean		Ang.	Polk	Mean	
2007	Containerized FIP 3 ml	100	78.2	93.0	85.6 *	**16.6**	1.31	1.53	1.42 *	**0.27**	165.3	248.7	207.0 *	**86.9**
	Containerized FIP 15 ml	100	77.9	97.0	87.4 *	**18.4**	1.21	1.76	1.49 *	**0.33**	146.7	353.8	250.2 *	**130.1**
	Containerized Check	100	57.6	80.4	69.0		0.96	1.35	1.16		75.8	165.6	120.2	
	BR FIP SI 12 ml	50	64.9	95.2	80.1 *	**12.4**	1.35	1.88	1.62 *	**0.39**	193.4	409.9	301.6 *	**160.4**
	BR Mimic	50	69.3	86.7	78.0	**10.4**	1.35	1.65	1.50	**0.28**	179.5	294.1	236.8	**95.6**
	BR Check	50	51.0	84.3	67.6		0.94	1.50	1.22		62.4	220.1	141.2	
2008	Containerized FIP 3 ml	100	137.6	163.1	150.3 *	**29.4**	2.59	3.36	2.97 *	**0.48**	1127	2131	1629 *	**634**
	Containerized FIP 15 ml	100	132.0	178.1	155.0 *	**34.1**	2.51	3.66	3.09 *	**0.60**	1091	2795	1943 *	**948**
	Containerized Check	100	104.6	137.4	121.0		1.99	2.99	2.49		608	1381	995	
	BR FIP SI 12 ml	50	130.1	176.2	153.1 *	**33.2**	2.50	3.84	3.17 *	**0.55**	1265	3028	2146 *	**916**
	BR Mimic	50	149.4	181.2	165.3 *	**45.4**	2.85	3.68	3.27 *	**0.65**	1658	2854	2256 *	**1026**
	BR Check	50	92.0	149.0	119.9		1.83	3.43	2.62		423	2071	1230	
							Diameter at Breast Height (cm)							
2009	Containerized FIP 3 ml	100	219.7	275.3	247.5 *	**25.9**	2.23	3.37	2.80 *	**0.44**	1597	3736	2666 *	**806**
	Containerized FIP 15 ml	100	243.9	293.1	268.5 *	**46.9**	2.77	3.95	3.36 *	**1.00**	2643	5439	4041 *	**2180**
	Containerized Check	100	191.9	251.3	221.6		1.66	3.07	2.36		998	2723	1861	
	BR FIP SI 12 ml	50	219.3	293.7	256.9 *	**50.6**	2.30	4.01	3.17 *	**1.06**	1908	5766	3857 *	**1956**
	BR Mimic	50	280.9	314.2	297.5 *	**91.2**	3.52	4.26	3.89 *	**1.79**	5128	6630	5879 *	**3978**
	BR Check	50	157.5	255.1	206.3		0.94	3.26	2.10		411	3390	1900	
2010	Containerized FIP 3 ml	100	325.3	422.4	373.9 *	**25.6**	3.81	5.94	4.88 *	**0.38**	5934	16146	11040 *	**1668**
	Containerized FIP 15 ml	100	371.1	440.1	405.6 *	**57.3**	4.72	6.30	5.51 *	**1.01**	10183	19456	14819 *	**5447**
	Containerized Check	100	296.5	400.1	348.3		3.36	5.63	4.49		5143	13602	9372	
	BR FIP SI 12 ml	50	323.5	441.0	382.2 *	**61.6**	3.93	6.26	5.09 *	**1.27**	6897	20527	13712 *	**5616**
	BR Mimic	50	422.9	469.3	446.1 *	**125.5**	5.35	6.58	5.97 *	**2.14**	15648	22860	19254 *	**11158**
	BR Check	50	240.7	400.6	320.7		2.12	5.54	3.83		1791	14401	8096	

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

PINE TIP MOTH TRIALS

Evaluation of Fipronil Treatments for Second-year Pine Seedlings – East Texas

Highlights:

- In 2008, all fipronil treatments, regardless of placement and depth, significantly reduced tip moth damage during most tip moth generations in the second year after planting. Overall damage was reduced by 45 - 51% compared to check trees. In 2009, fipronil protection declined mardedly or disappeared after the first generation. Overall damage was not significantly reduced compared to check trees. Only the shallow (4") soil injection and Mimic® spray treatments had significantly improved tree growth by the end of 2010.
- In 2009, most fipronil treatments significantly reduced tip moth damage during several generations in the second year after planting. Overall damage was reduced by 30 - 75% compared to check trees. Generally, increasing treatment volume improved protection against tip moth. In 2010, only higher treatment rates reduced average damage compared to checks. However, none of the treatments significantly improved tree growth.
- In 2010, most fipronil treatments provided moderate to good reduction in tip moth damage over the course of the first year after application. Treatments applied in the fall at higher volumes tended to perform better. Silvashield™ (2 tablets) reduced damage more than fipronil. However, trees treated with fipronil were generally larger than those treated with imidacloprid.

Objectives: 1) Evaluate the efficacy of PTM™ Insecticide (fipronil) applied to second-year pine seedlings for reducing pine tip moth infestation levels, 2) evaluate PTM™ efficacy using different soil injection techniques; and 4) determine the duration of PTM™ activity.

Cooperators

Ms. Francis Peavy	Private landowner, Hudson, TX
Mr. Ragan Bounds	Hancock Forest Management, Woodville, TX
Mr. Jim Bean	BASF Corp., Research Triangle Park, NC

Study Sites: Two one-year-old plantations (one planted in 2007 and one planted in 2008) near Hudson and Colmesneil, Texas, were selected. The plots contained 6 treatments and 300 trees (5 rows X 50 trees).

Insecticides:

Fipronil – PTM™ Insecticide (0.9 lbs ai/gal), BASF Corp.
Imidacloprid – SilvaShield™ Forestry Tablet (20% ai), Bayer Crop Science

Research Approach:

A randomized complete block design was used at each site 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. 1 site X 6 treatments X 50 trees = 300 monitored trees. The treatments include:

Trial 1:
Spring 2008
1 = PTM™ (1X - 12 ml/tree) - single injection into soil 4” deep
2 = PTM™ (1X - 12 ml/tree) - double injection (6 ml ea.) into soil 4” deep
3 = PTM™ (1X - 12 ml/tree) - single injection into soil 8” deep
4 = PTM™ (1X - 12 ml/tree) - double injection (6 ml ea.) into soil 8” deep
5 =. Foliar spray - Mimic® applied 5X/ seedling
6 = Check (untreated) - Resident seedling

Trial 2:
Spring 2009
1 = PTM™ (1.4 ml/tree LO Vol) - double injection (7.5 ml ea.) into soil 4” deep
2 = PTM™ (1.4 ml/tree HI Vol) - double injection (15 ml ea.) into soil 4” deep
3 = PTM™ (2.8 ml/tree LO Vol) - double injection (7.5 ml ea.) into soil 4” deep
4 = PTM™ (2.8 ml/tree HI Vol) - double injection (15 ml ea.) into soil 4” deep
5 = SilvaShield™ tablet - 2 tablets (1 on ea. side) into soil 4” deep
6 = Check (untreated) - Resident seedling

Trial 3:
1= Check (untreated) - Resident seedling
Fall 2009
2 = PTM™ (1.4 ml/tree LO Vol) - double injection (7.5 ml ea.) into soil 4” deep
3 = PTM™ (1.4 ml/tree HI Vol) - double injection (15 ml ea.) into soil 4” deep
4 = PTM™ (2.8 ml/tree LO Vol) - double injection (7.5 ml ea.) into soil 4” deep
5 = PTM™ (2.8 ml/tree HI Vol) - double injection (15 ml ea.) into soil 4” deep
6 = SilvaShield™ tablet - 2 tablets (1 on ea. side) into soil 4” deep
Spring 2010
7 = PTM™ (1.4 ml/tree LO Vol) - double injection (7.5 ml ea.) into soil 4” deep
8 = PTM™ (1.4 ml/tree HI Vol) - double injection (15 ml ea.) into soil 4” deep
9 = PTM™ (2.8 ml/tree LO Vol) - double injection (7.5 ml ea.) into soil 4” deep
10 = PTM™ (2.8 ml/tree HI Vol) - double injection (15 ml ea.) into soil 4” deep
11 = SilvaShield™ tablet - 2 tablets (1 on ea. side) into soil 4” deep

A 1-acre (approximate) area within each site was selected. A randomized complete block design was established with beds (or rows of trees) serving as blocks, i.e., each treatment was randomly selected for placement along a bed. Fifty trees for each treatment were selected on each site. Ten trees were assigned a given treatment on each of five beds. The fipronil soil injection treatments were applied 13 February 2008 (Trial 1), 4 February 2009 (Trial 2), and 8 October 2009 and 5 March 2010 (Trial 3).

All soil injection treatments were applied using the PTM™ injection probe (Figure 30). The injector point was positioned about 4 inches from each seedling and forced into the soil at an angle to a depth of 5 inches. Once the fipronil solution was applied the injector was removed and the hole was covered with soil to prevent root desiccation.

Figure 30. PTM™ Injection Probe, Aqumix, Inc. (formerly Enviroquip Inc.)

Tip moth damage was evaluated after each tip moth generation (3-4 weeks after peak moth flight; 5 generations in TX) by 1) identifying if the tree was infested or not, 2) if infested, the proportion of tips infested on the top whorl and terminal were calculated; and 3) separately, the terminal was identified as infested or not. Each tree was measured for diameter (at 15 cm or 6 in) and height in winter 2008 and 2009.

Results:

Trial 1: In 2008, tip moth populations were quite high throughout the year with damage levels ranging from 14% of the shoots infested on check trees after generation 1 to >80% after the 5th generation (Table 42). As a result of the late treatment application date, none of the soil injection treatments significantly reduced tip moth infestation of top whorl shoots compared to the check during the first generation. However, all fipronil treatments, regardless of depth or placement, provided moderate to good protection against tip moth during 2nd, 3rd, 4th and 5th generations. Overall reduction in damage compared to checks ranged from 45% to 51%. None of the fipronil treatments negatively affected seedling survival after 5 generations. On Peavy 1, none the treatments significantly improved tree growth parameters (height, diameter, or volume index) compared to check trees (Table 44). In contrast, seedling growth (height, diameter and volume) was significantly greater for shallow (4”) soil injection treatments and Mimic®.

In 2009, tip moth populations were generally low during the first three generations with damage levels ranging from 1-14% of the shoots infested on check trees (Table 43). Damage levels increased in later generations (4 and 5) to 19-48%. Most fipronil treatments provided some protection against tip moth during the 1st generation. However, protection did not occur thereafter. On the Peavy 1 site, none the treatments significantly improved tree growth parameters (height, diameter or volume index) compared to check trees (Table 44). In contrast, seedling growth (height, diameter and volume) was significantly greater for shallow (4”) soil injection treatments and Mimic® on Peavy 2.

In 2010, on the Peavy 1 site, none the treatments significantly improved tree growth parameters (height, diameter or volume index) compared to check trees (Table 44). In contrast, growth (height, diameter and volume) was significantly greater for shallow (4”) soil injection treatments and Mimic® on Peavy 2.

Trial 2: In 2009, tip moth populations were fairly low through most of the year with damage levels ranging from 2% of the shoots infested on check trees after generation 1 to 19% after the 5th generation (Table 45). As a result of the late treatment application date, none of the treatments significantly reduced tip moth infestation of top whorl shoots compared to the check during the first generation. However, most fipronil treatments provided moderate protection against tip moth during 2nd and 5th generations. Overall reduction in damage compared to checks ranged from 30% to 75%. The higher volume treatments generally provided better protection. None of the fipronil treatments negatively affected seedling survival after 5 generations. None the treatments significantly improved tree growth parameters (height, diameter, or volume index) compared to check trees (Table 46).

In 2010, tip moth populations were again low through the first three generations with damage levels ranging from 2% of the shoots infested on check trees after generation 1 to 5% after the 3rd generation (Table 45). As a result of the low damage levels and low treatment performance, none of the treatments significantly reduced tip moth infestation of top whorl shoots compared to the check during any of the five generation. However, most the SilvaShield™ treatment provided moderate protection against tip moth during the 4th and 5th generations. Overall reduction in damage compared to checks ranged from 17% to 60%. The higher-volume treatments generally provided better protection. None of the fipronil treatments negatively affected seedling survival after 5 tip moth generations. None the treatments significantly improved tree growth parameters (height, diameter or volume index) compared to check trees (Table 46).

Trial 3: In 2010, tip moth populations were quite high through most of the year with damage levels ranging from 11% of the shoots infested on check trees after generation 2 to 97% after the 4th generation (Table 47). As a result of the late treatment application date, none of the soil injection treatments applied in March 2010 significantly reduced tip moth infestation of top whorl shoots compared to the check during the first generation. However, all fipronil treatments, regardless of application date, rate or volume, provided moderate to good protection against tip moth during the 2nd, 3rd, 4th and 5th generations. Overall reduction in damage compared to checks ranged from 28% to 57%. The SilvaShield™ treatments performed better, reducing overall damage by 72 – 86%. All treatments (fipronil and imidacloprid) significantly improved tree height growth compared to check trees (Table 48), but only fipronil treatments significantly improved volume index. Growth (height, diameter, and volume) tended to be greater for high volume fipronil treatments and/or those applied in the fall.

Acknowledgments: Thanks go to Ms. Francis Peavy and Mr. Ragan Bounds for providing research sites. We also thank Dr. Harry Quicke, BASF, and Mr. Bruce Monke, Bayer, for providing chemical product for the project.

Table 43. Effect of fipronil application depth and placement on pine tip moth infestation of loblolly pine shoots after each of 5 generations on two sites in East Texas - Trial 1 - 2009.

		Mean Percent of Loblolly Pine Shoots Infested (**Pct. Reduction Compared to Check**)											
Treatment §	N	P 1	P 2	Mean		P 1	P 2	Mean		P 1	P 2	Mean	
		Generation 1				Generation 2				Generation 3			
Single 12 ml SI @ 4" depth	100	3.0 *	4.0	3.5 *	**55**	2.7	2.0	2.4	**39**	0.4	5.4 *	2.8 *	**61**
Single 12 ml SI @ 8" depth	100	9.3	2.0	5.5	**29**	3.8	1.6	2.7	**31**	0.7	5.7 *	3.2	**56**
Double 6 ml SI @ 4" depth	100	2.2 *	3.9	3.1 *	**60**	2.9	2.4	2.7	**31**	2.8	13.0	7.9	**-7**
Double 6 ml SI @ 8" depth	100	2.6 *	3.1	2.8 *	**64**	4.1	2.1	3.1	**21**	1.3	7.7	4.5	**39**
Mimic	100	0.9 *	2.5	1.7 *	**78**	1.0	3.5	2.3	**42**	0.8	8.5	4.7	**37**
Check	100	9.0	6.4	7.8		2.7	5.1	3.9		1.1	14.0	7.3	
		Generation 4				Generation 5				Mean			
Single 12 ml SI @ 4" depth	100	18.5	28.1	23.2	**4**	26.2	41.7	33.8	**5**	10.1	16.3	13.2	**17**
Single 12 ml SI @ 8" depth	100	15.6	28.3	22.0	**9**	30.1	45.2	37.7	**-6**	11.9	16.6	14.3	**10**
Double 6 ml SI @ 4" depth	100	20.0	30.9	25.4	**-5**	26.2	43.8	34.9	**2**	10.8	18.9	14.8	**6**
Double 6 ml SI @ 8" depth	100	24.0	23.3	23.6	**2**	25.9	47.8	37.0	**-4**	11.6	16.8	14.2	**10**
Mimic	100	18.4	24.5	21.4	**11**	27.1	31.7 *	29.4	**18**	9.7	14.2 *	11.9 *	**25**
Check	100	19.3	29.4	24.2		23.9	48.3	35.7		11.2	20.7	15.8	

§ SI- Fipronil soil injection ▨ = treatment reduced damage by >75% compared to check.

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

Table 44. Effect of fipronil application depth and placement on loblolly pine growth 8, 20 and 32 months after treatment on two sites in East Texas - Trial 1 - 2008 - 2010.

			Mean End of Season Tree Measurements (**Growth Difference (cm or cm3) Compared to Check**)											
Year	Treatment	N	Height (cm)				Groundline Diameter (cm)				Volume (cm^3)			
			P 1	P 2	Mean		P 1	P 2	Mean		P 1	P 2	Mean	
2008	Single 12 ml SI @ 4" depth	100	157.1	115.6 *	136.6 *	**8.2**	3.43	2.50	2.97	**0.14**	2066.5	833.3 *	1456.1 *	**15**
	Single 12 ml SI @ 8" depth	100	140.2	106.7	123.3	**-5.1**	3.14	2.27	2.70	**-0.13**	1675.8	666.0	1165.8	**-275**
	Double 6 ml SI @ 4" depth	100	156.9	118.7 *	137.8 *	**9.4**	3.52	2.56 *	3.04 *	**0.21**	2136.1	887.3 *	1511.7 *	**71**
	Double 6 ml SI @ 8" depth	100	158.8	108.8	133.6	**5.2**	3.60	2.33	2.96	**0.12**	2438.3	654.5	1537.2	**96**
	Mimic	100	148.7	115.6 *	142.1 *	**13.7**	3.28	3.00 *	3.14 *	**0.31**	1890.3	1349.2 *	1619.8 *	**179**
	Check	100	153.2	103.1	128.4		3.38	2.28	2.83		2242.2	623.4	1441.0	
2009	Single 12 ml SI @ 4" depth	100	295.3	232.8 *	264.7 *	**20.4**	6.16	5.08 *	5.63 *	**0.35**	11880	6412 *	9202 *	**1189**
	Single 12 ml SI @ 8" depth	100	266.7	221.4	243.8	**-0.5**	5.60	4.89 *	5.24	**-0.05**	9529	5691 *	7590	**-423**
	Double 6 ml SI @ 4" depth	100	287.6	231.1 *	259.6 *	**15.3**	6.27	5.00 *	5.64 *	**0.36**	11988	6234 *	9141 *	**1128**
	Double 6 ml SI @ 8" depth	100	296.0	219.8	257.5	**13.2**	6.32	4.80	5.55	**0.27**	13088	5321	9164	**1151**
	Mimic	100	282.2	251.5 *	266.8 *	**22.5**	6.04	5.60 *	5.82 *	**0.54**	11390	8284 *	9837 *	**1824**
	Check	100	279.7	206.7	244.3		5.99	4.53	5.28		11217	4604	8013	
							Diameter @ Breast Height (cm)							
2010	Single 12 ml SI @ 4" depth	100	440.8	367.4	404.9 *	**18.7**	6.03	4.68 *	5.37 *	**0.38**	17569	8723 *	13236 *	**1532**
	Single 12 ml SI @ 8" depth	100	397.9	359.3	378.4	**-7.8**	5.32	4.54	4.93	**-0.06**	13320	8289	10779	**-926**
	Double 6 ml SI @ 4" depth	100	420.0	372.8	396.6	**10.5**	5.78	4.58	5.18	**0.19**	15533	8883	12242	**538**
	Double 6 ml SI @ 8" depth	100	439.0	349.5	393.8	**7.6**	6.00	4.28	5.13	**0.14**	18157	6911	12476	**772**
	Mimic	100	413.3	401.8 *	407.6 *	**21.4**	5.68	4.97 *	5.32	**0.33**	15321	10531 *	12926 *	**1222**
	Check	100	419.8	351.8	386.2		5.86	4.10	4.99		16766	6536	11704	

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

Table 45. Effect of fipronil application rate and volume on pine tip moth infestation of loblolly pine shoots after each of 5 generations on one site in East Texas - Trial 2 - 2009 & 2010.

			Mean Percent of Loblolly Pine Shoots Infested (**Pct. Reduction Compared to Check**)											
Year	Treatment §	N	Gen 1		Gen 2		Gen 3		Gen 4		Gen 5		Mean	
2009	PTM (1.4 ml) - 15 ml dilution	50	4.0	**-65**	0.3 *	**91**	0.4	**89**	4.3	**-26**	12.9	**31**	4.4 *	**30**
	PTM (1.4 ml) - 30 ml dilution	50	1.5	**38**	1.6	**55**	1.0	**71**	3.9	**-14**	9.3 *	**50**	3.5 *	**45**
	PTM (2.8 ml) - 15 ml dilution	50	5.2	**-115**	0.3 *	**91**	1.1	**70**	3.7	**-10**	9.2 *	**51**	3.9 *	**38**
	PTM (2.8 ml) - 30 ml dilution	50	1.0	**59**	1.2 *	**67**	0.0 *	**100**	0.0 *	**100**	5.8 *	**69**	1.6 *	**75**
	SilvaShield (2 tablets)	50	2.1	**12**	0.0 *	**100**	1.8	**48**	1.5	**57**	7.1 *	**62**	2.5 *	**60**
	Check	50	2.4		3.6		3.5		3.4		18.6		6.3	
2010	PTM (1.4 ml) - 15 ml dilution	50	1.3	**40**	2.4	**-11**	8.3	**-51**	25.8	**23**	26.3	**23**	12.8	**17**
	PTM (1.4 ml) - 30 ml dilution	50	2.6	**-19**	1.3	**39**	5.7	**-4**	24.8	**26**	28.0	**18**	12.5	**19**
	PTM (2.8 ml) - 15 ml dilution	50	0.9	**61**	1.2	**44**	2.8	**50**	25.2	**25**	29.1	**15**	11.8 *	**24**
	PTM (2.8 ml) - 30 ml dilution	50	1.2	**47**	1.0	**54**	4.2	**23**	21.6	**36**	22.4	**35**	10.1 *	**35**
	SilvaShield (2 tablets)	50	2.1	**5**	0.7	**67**	1.5	**73**	9.5 *	**72**	17.5 *	**49**	6.3 *	**60**
	Check	50	2.2		2.2		5.5		33.5		34.3		15.5	

§ SI- Fipronil soil injection ▨ = treatment reduced damage by >75% compared to check.
***** Means followed by an asterik are significantly different from checks at the 5% level based on Fisher's Protected LSD.

Table 46. Effect of fipronil application rate and volume on loblolly pine growth 8 and 20 months after treatment on one site in East Texas - Trial 2 - 2009 & 2010.

			Mean Second Year Growth (**Growth Difference (cm or cm^3) Compared to Check**)					
					Groundline			
Year	Treatment	N	Height (cm)		Diameter (cm)		Volume (cm^3)	
2009	PTM (1.4 ml) - 15 ml dilution	50	119.1	**-7.8**	2.70	**0.11**	1005.1	**-31**
	PTM (1.4 ml) - 30 ml dilution	50	104.7 *	**-22.2**	2.35	**-0.24**	748.0 *	**-288**
	PTM (2.8 ml) - 15 ml dilution	50	112.6 *	**-14.2**	2.66	**0.07**	1116.7	**81**
	PTM (2.8 ml) - 30 ml dilution	50	115.8	**-11.1**	2.50	**-0.08**	851.8	**-184**
	SilvaShield (2 tablets)	50	126.1	**-0.7**	2.78	**0.19**	1239.7	**204**
	Check	50	126.8		2.59		1035.8	
2010	PTM (1.4 ml) - 15 ml dilution	50	334.8	**2.1**	6.70	**-0.25**	16319	**-2550**
	PTM (1.4 ml) - 30 ml dilution	50	293.8 *	**-38.9**	6.04	**-0.91**	12666 *	**-6203**
	PTM (2.8 ml) - 15 ml dilution	50	317.1 *	**-15.6**	6.40	**-0.55**	16122	**-2747**
	PTM (2.8 ml) - 30 ml dilution	50	333.2	**0.5**	6.63	**-0.32**	16094	**-2775**
	SilvaShield (2 tablets)	50	339.4	**6.7**	7.10	**0.15**	19391	**522**
	Check	50	332.7		6.95		18869	

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

Table 47. Effect of fipronil application timing, rate and volume on pine tip moth infestation of loblolly pine shoots after each of 5 generations on one site in East Texas - Trial 3 - 2010.

				Mean Percent of Loblolly Pine Shoots Infested (**Pct. Reduction Compared to Check**)											
Year	Treatment §	Timing	N	Gen 1		Gen 2		Gen 3		Gen 4		Gen 5		Mean	
2010	PTM (1.4 ml) - 15 ml dilution	Oct. '09	50	25.2	**17**	5.7	**50**	24.8 *	**52**	75.7 *	**22**	70.2 *	**26**	40.3 *	**29**
	PTM (1.4 ml) - 30 ml dilution	Oct. '09	50	23.1	**24**	11.3	**1**	22.1 *	**57**	53.0 *	**45**	55.4 *	**42**	33.0 *	**42**
	PTM (2.8 ml) - 15 ml dilution	Oct. '09	50	17.2 *	**43**	2.7 *	**76**	17.9 *	**65**	59.5 *	**39**	48.3 *	**49**	29.1 *	**49**
	PTM (2.8 ml) - 30 ml dilution	Oct. '09	50	20.1	**34**	4.2 *	**63**	7.9 *	**85**	43.8 *	**55**	46.1 *	**52**	24.4 *	**57**
	SilvaShield (2 tablets)	Oct. '09	50	13.5 *	**55**	3.5 *	**69**	11.2 *	**78**	24.7 *	**74**	28.4 *	**70**	16.1 *	**72**
	PTM (1.4 ml) - 15 ml dilution	Mar. '10	50	28.9	**5**	5.9	**48**	21.5 *	**58**	61.0 *	**37**	53.7 *	**44**	34.2 *	**40**
	PTM (1.4 ml) - 30 ml dilution	Mar. '10	50	22.4	**26**	11.8	**-4**	23.5 *	**54**	78.9 *	**19**	68.1 *	**29**	41.0 *	**28**
	PTM (2.8 ml) - 15 ml dilution	Mar. '10	50	20.3	**33**	3.0 *	**74**	13.6 *	**74**	47.6 *	**51**	47.9 *	**50**	26.5 *	**54**
	PTM (2.8 ml) - 30 ml dilution	Mar. '10	50	29.2	**4**	5.8	**49**	27.9 *	**46**	73.2 *	**24**	76.2 *	**20**	42.5 *	**26**
	SilvaShield (2 tablets)	Mar. '10	50	27.0	**11**	3.0 *	**74**	4.1 *	**92**	2.5 *	**97**	4.3 *	**95**	8.2 *	**86**
	Check		50	30.4		11.4		51.3		96.8		95.5		57.1	

§ SI- Fipronil soil injection ▨ = treatment reduced damage by >75% compared to check.

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

Table 48. Effect of fipronil application timing, rate and volume on loblolly pine growth 9 and 14 months after treatment on one site in East Texas - Trial 3 - 2010.

				Mean Second Year Growth (**Growth Difference (cm or cm^3) Compared to Check**)					
Year	Treatment	Timing	N	Height (cm)		Groundline Diameter (cm)		Volume (cm^3)	
2010	PTM (1.4 ml) - 15 ml dilution	Oct. '09	50	182.3 *	**26.4**	4.63 *	**0.67**	4376 *	**1519**
	PTM (1.4 ml) - 30 ml dilution	Oct. '09	50	174.0 *	**18.1**	4.36	**0.40**	3770 *	**913**
	PTM (2.8 ml) - 15 ml dilution	Oct. '09	50	173.4 *	**17.5**	4.27	**0.31**	3529 *	**672**
	PTM (2.8 ml) - 30 ml dilution	Oct. '09	50	179.3 *	**23.4**	4.56 *	**0.60**	4092 *	**1236**
	SilvaShield (2 tablets)	Oct. '09	50	181.0 *	**25.1**	4.12	**0.16**	3350	**493**
	PTM (1.4 ml) - 15 ml dilution	Mar. '10	50	170.8 *	**14.9**	4.27	**0.31**	3444	**588**
	PTM (1.4 ml) - 30 ml dilution	Mar. '10	50	170.5 *	**14.6**	4.29	**0.33**	3447 *	**590**
	PTM (2.8 ml) - 15 ml dilution	Mar. '10	50	168.3 *	**12.4**	4.06	**0.10**	3178	**322**
	PTM (2.8 ml) - 30 ml dilution	Mar. '10	50	174.2 *	**18.4**	4.31	**0.35**	3663 *	**807**
	SilvaShield (2 tablets)	Mar. '10	50	180.7 *	**24.8**	3.97	**0.01**	3366	**509**
	Check		50	155.9		3.96		2857	

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

PINE TIP MOTH TRIALS

Comparison of PTM™ and SilvaShield™ for Control of Pine Tip Moth

Highlights:

- All PTM™ soil injection and SilvaShield™ tablet treatments with initial applications in December 2009, significantly reduced tip moth damage levels through the first year. Only tablets significantly improved height growth parameters.

Objectives:

The objectives of this research proposal were to 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; and 3) determine the duration of protection provided by these insecticide applications.

Cooperators:

Mr. Bill Stansfield	The Campbell Group, Diboll, TX
Mr. Greg Garcia	The Campbell Group, Jasper, TX
Mr. Jim Bean	BASF Corp., Research Triangle Park, NC
Mr. Bruce Monke	Bayer Environmental Science, Research Triangle Park, NC

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 neonictinoid 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 has 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.

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)*	*white*
F	*PTM at planting + PTM post plant (2 pts, Feb. '11)*	*red/white*
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/white*
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/white*

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 description:

1) PTM™ solution (1.4ml product in 13.6 ml water) applied into plant hole at planting (Dec. '09).
2) PTM™ solution (1.4ml product in 13.6 ml water) applied post plant at 1 point next to seedling (Dec. '09).
3) PTM™ solution (0.7ml product in 14.3 ml water) applied post plant at 2 points next to seedling (Sept. '10).
4) 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).
5) PTM™ solution (0.7ml product in 14.3 ml water) applied post plant at 2 points next to seedling (Feb. '11).
6) 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).
7) 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).
8) SilvaShield™ (SS) (1 tablet) applied into plant hole at planting (Dec. '09).
9) SS (1 tablet) applied post plant next to seedling (Dec. '09).
10) SS (1 tablet) applied post plant next to seedling (Sept. '10).
11) SS (1 tablet) applied into plant hole at planting (Dec. '09) and SS (1 tablet) applied post plant next to seedling (Sept. '10).

12) SS (1 tablet) applied post plant next to seedling (Feb. ’11).
13) SS (1 tablet) applied to plant hole at planting (Dec. ’09) and SS (1 tablet) applied post plant next to seedling (Feb. ’11).
14) SS (1 tablet) applied post plant next to seedling (Dec. ’09) and SS (1 tablet) applied post plant next to seedling (Feb. ’11).
15) Check –seedlings planted by hand without additional treatment.

Treatment Evaluation: Tip moth damage was/will be 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 will be calculated; and 3) separately, the terminal will be identified as infested or not. Observations also were/will be 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 diameter and height (at 6”) in the fall (November) following planting. If warranted, three-year old trees will be measured for height and diameter (at DBH) and ranked for form. 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).

<u>Tip Moth Damage Assessment or Tree Measurement Times for Jasper Co., TX site:</u>

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

Efficacy was/will be evaluated by comparing treatment differences for direct and indirect measures of insect-caused losses. Direct treatment effects include reduction in pine tip moth damage. Indirect treatment effects include increases in tree growth parameters (height, diameter and volume index). Data will be subjected to analyses of variance using Statview software (SAS Institute, Inc. 1999). Percentage and measurement data will be transformed by the arcsine % and log transformations, respectively, prior to analysis.

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 49). All PTM™ 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™ treatments and 94-100 % for SS treatments. There was no difference between PTM™ and SS treatments applied at planting. However, SS treatments applied post plant generally provided better protection compared to post plant PTM™ treatments. Only SS treatments (3 of 5) significantly improved tree height growth compared to check trees (Table 50). There were no differences in tree survival among the treatments.

Acknowledgments: Thanks go to The Campbell Group for providing research site and seedlings. We also thank Jim Bean, Bayer Environmental Science, and Bruce Monke, BASF, for providing Silvashield™ tablets and PTM™, respectively, for the project.

Reference:

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.

Fettig, C.J., J.T. Nowak, D.M. Grosman and C.W. Berisford. 2003. Nantucket pine tip moth phenology and timing of insecticide spray applications in the Western Gulf Region. USDA Forest Service So. Res. Stat. Res. Pap. SRS-32. 13pp.

Table 49. 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	7.3	**41**		34.6	**-8**		26.0	**-31**		39.8	**16**		47.0	**13**		30.9	**5**	
	SS	F '11	PP	50	7.6	**38**		33.7	**-5**		13.8	**30**		33.0	**30**	*	22.6	**58**	*	22.6	**31**	*
	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 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 50. 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)**						
Year	Product	Season	Tech.	N	Height (cm)		Diameter (cm) [a]		Volume (cm^3)		Mean Percent Tree 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**	86
	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	57.3	**-1.4**	0.88	**-0.04**	58.5	**-0.4**	86
	PTM	F '11	PP	50	58.7	**-0.1**	0.95	**0.04**	67.7	**8.8**	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	61.4	**2.7**	0.95	**0.03**	65.5	**6.6**	88
	SS	F '11	PP	50	53.4	**-5.4**	0.83	**-0.08**	46.4	**-12.5**	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] Groun Line Diameter.

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

PINE TIP MOTH TRIALS

Imidacloprid Tablet Trials – Western Gulf Region

Highlights:

- All imidacloprid tablet treatments, applied in 2007, significantly reduced tip moth damage levels on nearly all sites through the third year. The tablets significantly improved growth parameters on all four sites measured after the fourth year.
- All imidacloprid tablet treatments, applied in 2008 at different rates and depths, significantly reduced tip moth damage levels on all sites for two full years. The tablets only improved growth parameters on sites treated after planting and tree growth improved with higher rates.
- All treatments containing imidacloprid tablets, applied in 2009, significantly reduced tip moth damage levels through most of the first year. The additive treatments (fertilizer and/or herbicide) did not improve protection but may have helped to improve height and diameter growth.

Objectives: 1) Determine the efficacy of imidacloprid tablets in reducing pine tip moth infestation levels on loblolly pine seedlings; 2) evaluate this product applied at different rates to transplanted or resident seedlings; 3) determine the effect of imidacloprid alone or combined with fertilizer on seedling growth; 4) determine the efficacy of SilvaShield™ tablets in reducing pine tip moth infestation levels on loblolly pine seedlings when applied at planting to bedded areas with and without fertilizer and/or herbaceous weed control; and 6) determine the duration of chemical activity.

Cooperators:

Mr. Bill Stansfield	The Campbell Group, Diboll, TX
Mr. Conner Fristoe	Plum Creek Timber Co., Crossett, AR
Dr. Nick Chappell	Potlatch Forest Holdings, Warren, AR
Mr. Peter Birks	Weyerhaeuser Co., Columbus, MS
Mr. Doug Long	Rayonier, Lufkin, TX
Mr. Bruce Monke	Bayer Environmental Science, Research Triangle Park, NC

Study Sites: In 2007, 6 second-year sites were selected in TX (2 near Colmesneil), Mississippi (near Millard) and Arkansas (1 each near Crossroads, Warren and Crossett). Second-year pine plantations were used in the study because tip moth populations are usually well established at this age, increasing the likelihood that significant tip moth pressure would be placed on treated seedlings. The plots contained 4 - 11 treatments with 50 trees per treatment. In 2008, two separate trials were established on three sites in Texas. In 2009, a trial was established on a newly planted site at Cottingham Bridge in east Texas. In 2010, a fourth replicate of the rate/depth trial was established in east Texas.

Insecticides:

Imidacloprid (SilvaShield™ Forestry Tablet, Bayer) – highly systemic neonictinoid with activity against Lepidoptera.

Fipronil (PTM™ Insecticide, BASF) – a phenyl pyrazole with some systemic activity against Lepidoptera.

Research Approach:

A randomized complete block design was used at each site 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. The treatments by year and trial included:

2007:
1) 20% Merit® FXT Std. tablet - 1 tablet in plant hole
2) 20% Merit® FXT Std. tablet - 1 tablet in soil next to transplant
3) Mimic® or Pounce® Foliar - Apply Mimic® (0.6 ml/L water) 5X / season
4) Bare-root Check - Treat w/ Terrasorb™ and plant bare-root

2008 Trial 1:
1) SilvaShield™ (20% Imid.) tablet - 1 tablet in plant hole
2) SilvaShield™ (20% Imid.) tablet - 1 tablet in soil (4”) next to transplant
3) SilvaShield™ (20% Imid.) tablet - 2 tablets in plant hole
4) SilvaShield™ (20% Imid.) tablet - 3 tablets in plant hole
5) PTM™ SC Insecticide (fipronil) - Soil injection at planting
6) Bare-root Check - Treat w/ Terrasorb™ and plant bare-root

Trial 2:
1) SilvaShield™ (20% Imid.) tablet - 1 tablet in soil (4”) next to transplant
2) SilvaShield™ (20% Imid.) tablet - 2 tablets in soil (4”) next to transplant
3) SilvaShield™ (20% Imid.) tablet - 3 tablets in soil (4”) next to transplant
4) SilvaShield™ (20% Imid.) tablet - 1 tablet in soil (8”) next to transplant
5) SilvaShield™ (20% Imid.) tablet - 2 tablets in soil (8”) next to transplant
6) SilvaShield™ (20% Imid.) tablet - 3 tablets in soil (8”) next to transplant
7) SilvaShield™ (20% Imid.) tablet - 1 tablet in plant hole
8) Bare-root Check - Treat w/ Terrasorb™ and plant bare-root

2009 :
1) Check (untreated) - seedling planted by hand
2) SilvaShield™ (SS, 1 tablet) - in plant hole (PH) under seedling
3) Diamm. phosphate (DAP 1X) - applied (125 lb/A) after planting around seedling
4) SS (1 tablets) + DAP 1/2X - tablet in PH and fert. after plant
5) Herb. weed control (HWC) only- banded application of Oustar (12)
6) SS (1 tab) + HWC - tablet in PH + Oustar
7) SS (1 tab) + DAP 1/2X + HWC - tablet in PH + fert after plant + Oustar
8) SS (1 tab) + DAP 1X + HWC - tablets in PH + fert after plant + Oustar
9) DAP 1X + HWC - fert after plant + Oustar

2010 :
1) SilvaShield™ (20% Imid.) tablet - 1 tablet in soil (4”) next to transplant
2) SilvaShield™ (20% Imid.) tablet - 2 tablets in soil (4”) next to transplant
3) SilvaShield™ (20% Imid.) tablet - 3 tablets in soil (4”) next to transplant
4) SilvaShield™ (20% Imid.) tablet - 1 tablet in soil (8”) next to transplant
5) SilvaShield™ (20% Imid.) tablet - 2 tablets in soil (8”) next to transplant
6) SilvaShield™ (20% Imid.) tablet - 3 tablets in soil (8”) next to transplant
7) Bare-root Check - Treat w/ Terrasorb™ and plant bare-root

In all research years (2007 – 2010), a single family of loblolly pine bare-root seedlings was selected at the Texas Forest Service Indian Mounds Nursery, Alto, TX, or ArborGen SuperTree Nursery, Livingston, TX. All seedlings were operationally lifted by machine in January or February, culled of small and large caliper seedlings, treated with Terrasorb™ or clay slurry root coating, bagged and stored briefly in cold storage.

Fifty seedlings for each treatment were planted (variable spacing) on new or one-year-old (entering 2nd growing season) plantation sites – to ensure a high level of tip moth pressure on the treatment trees. At the one-year-old site, individual resident trees were removed and each was replaced with a single treatment tree. A randomized complete block design was used at each site 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. Just after seedling transplant, one treatment tablet (2007) was pushed into the soil 6 cm deep and 4 cm from each assigned seedling. In 2008 and 2010, a lance was used to make a 4" or 8" deep hole. The tablet(s) was then dropped in the hole. In 2008 and 2009, one to three tablets were dropped into the plant hole just prior to placement of the seedling in the same hole.

In 2009, DAP (diammonia phosphate) was applied by hand around the seedling after planting. Banded applications of herbicide by backpack sprayer were made in May.

Tip moth damage was evaluated after each tip moth generation (3-4 weeks after peak moth flight) for each tablet trial by 1) identifying if the tree was infested or not, 2) if infested, the proportion of tips infested on the top whorl and terminal were calculated; and 3) separately, the terminal was identified as infested or not. Observations also were made as to the occurrence and extent of damage caused by other insects, i.e., aphids, weevils, coneworm, etc. Each tree was measured for diameter (at 6" for one and two-year old trees or at DBH for 3-, 4-, or 5-year old trees) and height in the fall (December). Data were analyzed by GLM and the Tukey's Compromise test using Statview or SAS statistical programs.

Results:

Imidacloprid Tablets (2007)

In 2007, tip moth populations were quite variable across the six sites with mean percent shoots infested on checks ranging from 0% after the first generation on one Texas site to 55% at the end of the year at one Arkansas site (Table 51). All tablet treatments placed in the plant hole were highly effective in reducing tip moth damage throughout the year. Overall, damage was reduced by 81%. Tablets pushed into the soil after the seedlings were planted and foliar sprays were less effective; reducing damage by 50-55%. Tablet treatments significantly improved growth parameters compared to checks on four of six sites (Table 52).

In 2008, tip moth populations were considerably higher compared to 2007 across the six sites with mean percent shoots infested on checks ranging from 14% after the first tip moth generation on one TX site to 79% at the end of the year on one Texas site (Table 53). All treatments in which tablets were placed in the plant hole continued to significantly reduce tip moth damage throughout the year. Overall, damage was reduced by 50%. Treatments consisting of tablets pushed into the soil after the seedlings were planted and foliar sprays were variable in their efficacy; they reduced damage by 37 - 63%. Tablet treatments significantly improved growth parameters compared to checks on four of six sites (Table 54).

In 2009, tip moth damage evaluations were continued on two Texas sites. Tip moth levels were considerably lower compared to 2008 with mean percent shoots infested on checks ranging from 2% after the first generation to 33% at the end of the year (Table 55). All treatments in which tablets were placed in the plant hole continued to significantly reduce tip moth damage throughout the year. Overall, damage was reduced by 68%. Tablets pushed into the soil after the seedlings were planted and foliar sprays were less effective, reducing damage by 38 - 51%. Tablet treatments again significantly improved growth parameters compared to checks on four of six sites (Table 56).

In 2010, measurements were continued on 4 sites (2 TX and 2 AR). Tablet treatments significantly improved growth parameters compared to checks on all four sites measured (Table 57).

<u>Imidacloprid Tablets</u>

<u>Rate at Planting (Moffet)</u>: In 2008, tip moth populations were low on the single site during the first and second generations with averages of 0.5% and 2.7% of the shoots infested on check trees, respectively (Table 58). As a result of the low tip moth pressure, none of treatments significantly reduced tip moth infestation levels compared to the check during the first generation. In contrast, all tablet treatments provided very good protection during the third through fifth generations, reducing damage by 78 – 100% (78 – 96% overall). The post-plant tablet and fipronil soil injection (at planting) treatments both had similar effects on tip moth damage levels. Surprisingly, none of the study treatments significantly improved any of the tree growth parameters compared to check trees (Table 59).

In 2009, tip moth populations were initially higher during the first through third generations with averages of 17%, 8% and 16% of the shoots infested on check trees, respectively (Table 58). Most treatments significantly reduced tip moth infestation levels compared to the check during the first three generations. In contrast, most tablet treatments appeared to fade during the fourth generation, reducing damaged by -6 – 70% (47 – 73% overall). The post-plant tablet and fipronil soil injection (at planting) treatments both had similar effects on tip moth damage levels. Again, none of the study treatments significantly improved any of the tree growth parameters compared to check trees (Table 59).

In 2010, tip moth populations were much higher with mean percent shoots infested on checks ranging from 8% after the second tip moth generation to 96% at the end of the year (Table 58). Only higher rate treatments (2 and 3 tablets) significantly reduced tip moth infestation levels compared to the check during the last three generations. The efficacy of the other treatments appeared to declined markedly in the third year. The post plant tablet and fipronil soil injection (at planting) treatments both had similar effects on tip moth damage levels. Only the fipronil adjacent treatment significantly improved any of the tree height and volume growth parameters compared to check trees (Table 59).

<u>Rate and Depth Just After Plant (Loving Ferry and Moffett)</u>: In 2008, tip moth populations were low on both sites during the first generation with averages of 0.8% (Loving Ferry) and 0%

(Moffet) of the shoots infested on check trees (Table 60 and 62). As a result of the low tip moth pressure, none of the treatments significantly reduced tip moth infestation levels compared to the check during the first generation. In contrast, nearly all treatments provided very good protection during the second through fifth generations, reducing damaged by 48 – 100% (62 – 99% overall). Treatment efficacy against tip moth did not appear to be influenced by dose rate or treatment depth. However, tree height and diameter growth tended to improve with dose rate compared to check trees (Tables 61 and 63). Growth parameters did not appear to be affected by treatment depth.

In 2009, tip moth populations were low on the both sites during the first generation with averages of 22% (Loving Ferry) and 7% (Moffet) of the shoots infested on check trees (Table 60 and 62). All treatments provided good protection during the first through fifth generations, reducing damaged by 22 – 100% (44 – 76% overall). Treatment efficacy against tip moth did not appear to be influenced by dose rate or treatment depth. However, height and diameter growth tended to improve with dose rate compared to that of check trees (Tables 61 and 63). Growth parameters did not appear to be affected by treatment depth.

In 2010, tip moth populations were much higher on the both sites during the first generation with averages of 46% (Loving Ferry) and 55% (Moffet) of the shoots infested on check trees (Table 60 and 62). Most treatments had faded during the first through fifth generations, reducing damaged by -40 – 58% (-2 – 41% overall). Treatment efficacy against tip moth did not appear to be influenced by dose rate or treatment depth. However, tree height and diameter growth tended to improve with dose rate compared to check trees (Tables 61 and 63). Growth parameters did not appear to be affected by treatment depth.

Rate and Depth 1 year after Plant (Peavy and CR 3260): Understandably, tip moth populations were higher during the first generation on this second-year site with an average of 15% of the shoots infested on check trees (Table 64). Because of the late treatment date, none of treatments significantly reduced tip moth infestation levels compared to the check during the first generation. In contrast, all treatments provided very good protection during the second through fifth generations, reducing damaged by 35 – 99% (49 – 83% overall). Treatment efficacy against tip moth did not appear to be influenced by dose rate or treatment depth (Table 65).

Tip moth populations were considerably lower during the third growing season with an average of 15% of the shoots infested on check trees (Table 64). Because of low levels, most treatments did not significantly reduced tip moth infestation levels compared to the check during the first two generation. In contrast, all treatments provided very good protection during the third through fifth generations, reducing damaged by 48 – 100% (54 – 90% overall). Treatment efficacy against tip moth did not appear to be influenced by dose rate or treatment depth (Table 65).

In 2010, measurements were continued on the Peavy site. Three treatments significantly improved growth parameters compared to checks, but dose rate or treatment depth were not contributing factors (Table 65).

On the CR3260 site, tip moth population levels were moderate initially (17 – 19%) but increased dramatically later in the year (90 – 91%) (Table 66). All treatments provided very good to excellent protection during the third through fifth generations, reducing damaged by 45 – 98% (46– 92% overall). None of the study treatments significantly improved any of the tree growth parameters compared to those of check trees (Table 67).

Input Comparison (Cottingham Bridge)

In 2009, tip moth populations were low during the first and second generations with averages of 5% and 4% of the shoots infested on check trees, respectively (Table 81). Populations rose to moderate levels (62%) by the fifth generation. As a result of the low tip moth pressure, none of treatments significantly reduced tip moth infestation levels compared to the check during the first generation. In contrast, treatments containing tablets provided good protection during the third and four generations, reducing damaged by 43 – 100% (35 – 52% overall). The effects of the tablets appeared to disappear by the fifth generation. Most treatments with tablets significantly improved tree growth parameters compared to check trees (Table 82).

In 2010, tip moth populations were much higher with mean percent shoots infested on checks ranging from 55% after the first generation to 96% at the end of the fourth generation (Table 68). Treatments containing tablets provided limited protection through the year, reducing damaged by 7 – 43% (15 – 29% overall). The addition of fertilizer or herbicide did not appear to have influence tip moth damage. All treatments with tablets significantly improved growth parameters compared to those of check trees (Table 69).

Acknowledgments: Thanks go to The Campbell Group, Weyerhaeuser Co., Potlatch Forest Holding, Plum Creek Timber Co., and Rayonier for providing research sites. We thank Harry Vanderveer and Ted Moore for providing assistance at the nursery and the Texas Forest Service and ArborGen for donating the seedlings. We also thank Nate Royalty and Bruce Monke, Bayer Environmental Science, for providing support funds and imidacloprid tablets and other formulations for the project.

Table 51. Effect of Bayer tablets on percent shoots infested by pine tip moth after each of five generations during the first growing season on six sites - 2007.

Mean Percent Shoots Infested (Pct. Reduction Compared to Check)

Treatment §	N	Generation 1								Generation 2							
		TX1	AR1	TX2	AR2	AR3	MS1	Mean		TX1	AR1	TX2	AR2	AR3	MS1	Mean	
20% FXT Ball PH	50	0.0	0.9	1.7	4.0 *	1.7 *	1.9 *	1.7	**85**	0.0 *	3.1	2.0	2.8 *	3.1 *	1.3 *	2.1	**84**
20% FXT Ball Adjacent	50	0.0	0.4	1.0	12.7 *	0.0 *	11.3	4.2	**63**	2.5 *	10.8	0.0	9.2 *	3.4 *	9.1 *	5.8	**56**
Mimic foliar spray	50	2.1	0.5	1.2	10.0 *	10.7	8.8	5.5	**51**	3.2 *	2.8	2.0	19.1	10.2 *	6.1 *	7.2	**46**
Check	50	0.0	0.9	5.8	25.4	16.6	19.2	11.3		13.3	9.4	4.9	21.5	25.9	19.6	15.8	

Treatment §	N	Generation 3								Generation 4							
		TX1	AR1	TX2	AR2	AR3	MS1	Mean		TX1	AR1	TX2	AR2	AR3	MS1	Mean	
20% FXT Ball PH	50	0.0 *	6.5 *	0.0 *	4.7 *	1.6	0.4 *	2.2	**83**	1.8 *		0.0 *			NA	0.9	**96**
20% FXT Ball Adjacent	50	0.0 *	6.8 *	0.0 *	39.3	2.9	1.5	8.4	**34**	0.0 *		0.0 *			NA	0.0	**100**
Mimic foliar spray	50	2.2	8.2	0.0 *	49.7	0.9	4.5	10.9	**15**	2.4 *		0.4 *			NA	1.4	**93**
Check	50	5.4	16.4	4.3	40.3	4.0	6.5	12.8		24.6		17.8			NA	21.2	

Treatment §	N	Generation 5 (Last)								Mean							
		TX1	AR1	TX2	AR2	AR3	MS1	Mean		TX1	AR1	TX2	AR2	AR3	MS1	Mean	
20% FXT Ball PH	50	2.1 *	8.3 *	0.0 *	20.9 *	0.0	11.4 *	8.5	**74**	0.6 *	4.8 *	0.7 *	7.7 *	1.5 *	3.7 *	3.8	**81**
20% FXT Ball Adjacent	50	0.0 *	12.1	2.5 *	48.5	3.8	9.4 *	15.3	**53**	0.4 *	7.2 *	0.6 *	27.4	2.5 *	7.7 *	9.1	**55**
Mimic foliar spray	50	2.4 *	8.9 *	0.0 *	27.6 *	2.6	35.9	15.5	**52**	2.1 *	5.5 *	0.7 *	22.8 *	6.1 *	13.4 *	10.1	**50**
Check	50	24.5	21.5	14.8	54.7	1.7	45.0	32.4		11.0	12.7	8.8	34.7	11.5	22.6	20.2	

§ PH- placed in plant hole; Adjacent- tablet placed in soil next to seedling ▨ = treatment reduced damage by >75% compared to check.

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

Table 52. Effect of Bayer tablets on height, diameter and volume index after the first growing season on six sites - 2007.

		Mean Parameter Growth (**Growth Difference (cm or cm^3) Compared to Check**)							
		Height (cm)							
Treatment §	N	TX1	AR1	TX2	AR2	AR3	MS1	Mean	
20% FXT Ball PH	50	53.5 *	57.7	46.9 *	56.4 *	42.2	91.4	58.0 *	**8.6**
20% FXT Ball Adjacent	50	54.6 *	58.0	40.7 *	53.9 *	39.6	97.2	57.3 *	**7.9**
Mimic foliar spray	50	45.8	48.3	42.9 *	56.1 *	37.9	83.6	52.4	**3.0**
Check	50	39.1	50.3	33.5	47.3	35.6	90.7	49.4	

		Diameter (cm)							
Treatment §	N	TX1	AR1	TX2	AR2	AR3	MS1	Mean	
20% FXT Ball PH	50	0.91 *	0.77	0.68 *	1.05	0.53	1.82	0.96	**0.08**
20% FXT Ball Adjacent	50	0.87 *	0.73	0.56	0.99	0.47	2.01	0.94	**0.06**
Mimic foliar spray	50	0.74	0.73	0.66 *	1.06 *	0.47	1.85	0.92	**0.04**
Check	50	0.68	0.70	0.54	0.93	0.47	1.94	0.88	

		Volume Index (cm^3)							
Treatment §	N	TX1	AR1	TX2	AR2	AR3	MS1	Mean	
20% FXT Ball PH	50	59.0 *	48.8	24.6 *	75.1 *	15.3	355.0	96.3 *	**12.5**
20% FXT Ball Adjacent	50	51.3 *	39.1	15.6	65.6	11.7	355.0	89.7 *	**6.0**
Mimic foliar spray	50	32.5	31.7	21.8 *	73.7 *	10.7	346.8	86.2	**2.4**
Check	50	22.9	30.0	11.2	50.7	11.6	376.2	83.8	

§ PH- placed in plant hole; Adjacent- tablet placed in soil next to seedling

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

Table 53. Effect of Bayer tablets on percent shoots infested by pine tip moth after each of five generations during the second growing season on six sites - 2008.

		Mean Percent Shoots Infested (Pct. Reduction Compared to Check)															
		Generation 1								Generation 2							
Treatment §	N	TX1	AR1	TX2	AR2	AR3	MS1	Mean		TX1	AR1	TX2	AR2	AR3	MS1	Mean	
20% FXT Ball PH	50	9.9	12.0	3.1 *	12.9 *	6.3 *	NA	8.8 *	**64**	5.9 *	12.8 *	5.4 *	4.3 *	NA	NA	6.9 *	**78**
20% FXT Ball Adjacent	50	4.5 *	10.8	6.3 *	26.0 *	8.5 *	NA	11.2 *	**55**	4.0 *	12.5 *	12.0 *	33.4	NA	NA	16.4 *	**47**
Mimic foliar spray	50	3.0 *	12.4	6.0 *	35.4	6.1 *	NA	12.6 *	**49**	3.7 *	32.8	5.1 *	7.6 *	NA	NA	11.5 *	**63**
Check	50	13.5	20.2	26.3	46.0	17.6	NA	24.7		17.8	32.7	31.1	41.9	NA	NA	31.2	

		Generation 3								Generation 4							
Treatment §	N	TX1	AR1	TX2	AR2	AR3	MS1	Mean		TX1	AR1	TX2	AR2	AR3	MS1	Mean	
20% FXT Ball PH	50	1.9 *	12.0 *	0.6 *	11.3 *	NA	38.2	13.9 *	**55**	8.9 *		7.5 *			NA	8.1 *	**83**
20% FXT Ball Adjacent	50	4.9 *	16.3 *	10.8 *	38.0	NA	30.7	21.3 *	**31**	11.9 *		21.4 *			NA	16.6 *	**65**
Mimic foliar spray	50	0.5 *	36.7	4.7 *	24.3 *	NA	29.8	15.4 *	**50**	3.5 *		2.7 *			NA	3.1 *	**93**
Check	50	14.4	33.9	27.9	45.4	NA	32.7	31.0		49.3		45.6			NA	47.4	

		Generation 5 (Last)								Mean							
Treatment §	N	TX1	AR1	TX2	AR2	AR3	MS1	Mean		TX1	AR1	TX2	AR2	AR3	MS1	Mean	
20% FXT Ball PH	50	16.6 *	53.9	13.4 *	15.9 *	28.9	69.0	33.5 *	**46**	8.6 *	22.7 *	5.9 *	11.1 *	17.6 *	43.9	19.0 *	**50**
20% FXT Ball Adjacent	50	16.8 *	39.9 *	20.8 *	60.1 *	35.6	49.3	38.3 *	**38**	8.4 *	19.9 *	14.4 *	39.4 *	22.1	34.8	24.1 *	**37**
Mimic foliar spray	50	0.6 *	NA	2.3 *	30.5 *	22.5 *	13.9 *	14.4 *	**76**	2.3 *	NA	4.2 *	24.5 *	14.4 *	24.3 *	14.3 *	**63**
Check	50	56.0	72.3	66.8	78.7	35.5	67.6	62.3		30.2	39.4	38.9	53.5	26.6	45.0	38.2	

§ PH- placed in plant hole; Adjacent- tablet placed in soil next to seedling

▨ = treatment reduced damage by >75% compared to check.

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

Table 54. Effect of Bayer tablets on height, diameter and volume index after the second growing seasons on six sites - 2008.

		Mean Parameter Growth (**Growth Difference (cm or cm^3) Compared to Check**)							
		Height (cm)							
Treatment §	N	TX1	AR1	TX2	AR2	AR3	MS1	Mean	
20% FXT Ball PH	50	130.4 *	120.7	95.3 *	109.9 *	144.6 *	210.7	120.1 *	**21.8**
20% FXT Ball Adjacent	50	123.4 *	132.6	87.4	96.3 *	133.4 *	220.6	115.2 *	**16.8**
Mimic foliar spray	50	113.3	108.6	102.2 *	93.1 *	143.1 *	213.6	111.9 *	**13.6**
Check	50	100.5	114.6	80.5	81.5	114.7	188.0	98.4	

		Diameter @ 6" (cm)					DBH		
Treatment §	N	TX1	AR1	TX2	AR2	AR3	MS1	Mean	
20% FXT Ball PH	50	2.30 *	2.53	1.47 *	1.70 *	2.77 *	1.91	2.15 *	**0.38**
20% FXT Ball Adjacent	50	2.20 *	2.54	1.34	1.57	2.60 *	2.08	2.07 *	**0.30**
Mimic foliar spray	50	2.00	2.24	1.57 *	1.51	2.72 *	1.90	1.99 *	**0.22**
Check	50	1.80	2.36	1.17	1.39	2.15	2.10	1.77	

		Volume Index (cm^3)							
Treatment §	N	TX1	AR1	TX2	AR2	AR3	MS1	Mean	
20% FXT Ball PH	50	856 *	1115	251 *	380 *	1247 *	987	761 *	**319**
20% FXT Ball Adjacent	50	723 *	1148	189 *	300 *	1040 *	1253	689 *	**248**
Mimic foliar spray	50	564	750	321 *	277	1167 *	973	607 *	**165**
Check	50	396	820	156	217	636	1117	441	

§ PH- placed in plant hole; Adjacent- tablet placed in soil next to seedling

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

Table 55. Effect of Bayer tablets on percent shoots infested by pine tip moth after each of five generations during the third growing season on two of six sites - 2009.

		Mean Percent Shoots Infested (Pct. Reduction Compared to Check)													
		Generation 1							Generation 2						
Treatment §	N	TX1	AR1	TX2	AR2	AR3	MS1	Mean	TX1	AR1	TX2	AR2	AR3	MS1	Mean
20% FXT Ball PH	50	0.9		0.0 *				0.4 * ▨ **89**	0.0		0.0 *				0.0 * ▨ **100**
20% FXT Ball Adjacent	50	1.2		0.7 *				1.1 * **73**	0.9		0.0 *				0.5 * ▨ **84**
Mimic foliar spray	50	3.1		0.7 *				2.2 **46**	0.0		0.5 *				0.3 * ▨ **89**
Check	50	1.5		6.0				4.1	0.8		4.5				2.9
		Generation 3							Generation 4						
Treatment §	N	TX1	AR1	TX2	AR2	AR3	MS1	Mean	TX1	AR1	TX2	AR2	AR3	MS1	Mean
20% FXT Ball PH	50	0.0		1.2 *				0.8 * ▨ **81**	2.9 *		4.8				4.2 * **61**
20% FXT Ball Adjacent	50	0.0		0.7 *				0.4 * ▨ **90**	2.7 *		7.6				5.2 * **53**
Mimic foliar spray	50	4.0		1.0 *				2.6 **36**	7.8		6.2				7.5 **32**
Check	50	1.9		5.4				4.1	12.1		10.5				11.0
		Generation 5 (Last)							Mean						
Treatment §	N	TX1	AR1	TX2	AR2	AR3	MS1	Mean	TX1	AR1	TX2	AR2	AR3	MS1	Mean
20% FXT Ball PH	50	8.8 *		9.1 *				9.0 * **66**	2.5 *		3.0 *				4.7 * **68**
20% FXT Ball Adjacent	50	14.9 *		14.3				14.2 * **47**	3.9 *		4.6 *				7.2 * **51**
Mimic foliar spray	50	22.0		9.5 *				15.0 * **44**	7.4		3.6 *				8.9 * **38**
Check	50	32.9		23.6				26.8	9.8		9.8				14.5

§ PH- placed in plant hole; Adjacent- tablet placed in soil next to seedling ▨ = treatment reduced damage by >75% compared to check.

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

Table 56. Effect of Bayer tablets on height, diameter and volume index after the second growing seasons on three of six Western Gulf sites - 2009.

		Mean Parameter Growth (**Growth Difference (cm or cm^3) Compared to Check**)							
		Height (cm)							
Treatment §	N	TX1	AR1	TX2	AR2	AR3	MS1	Mean	
20% FXT Ball PH	50	235.8 *	253.7	209.7 *	211.6 *	225.2 *	362.7	252.3	**26.2**
20% FXT Ball Adjacent	50	219.7 *	271.7	205.1 *	192.5	212.9 *	371.9	245.6	**19.6**
Mimic foliar spray	50	207.1	215.7	217.7 *	184.8	224.3 *	360.2	246.8	**20.7**
Check	50	192.9	234.7	184.2	169.4	180.4	370.2	226.0	

		Diameter (cm)							
Treatment §	N	TX1	AR1	TX2	AR2	AR3	MS1	Mean	
20% FXT Ball PH	50	2.57 *	4.86	2.06 *	1.95 *	2.38 *	5.28	2.92 *	**0.57**
20% FXT Ball Adjacent	50	2.18 *	4.71	1.94 *	2.01 *	2.00 *	5.38	2.83 *	**0.49**
Mimic foliar spray	50	1.86	3.93	2.22 *	1.42	2.34 *	5.22	2.80	**0.46**
Check	50	1.64	4.31	1.48	1.14	1.28	5.47	2.34	

		Volume Index (cm^3)							
Treatment §	N	TX1	AR1	TX2	AR2	AR3	MS1	Mean	
20% FXT Ball PH	50	2188 *	7542	1194	1098 *	1743 *	11146	3795 *	**430**
20% FXT Ball Adjacent	50	1416 *	7492	949	697 *	1193 *	11997	3709 *	**344**
Mimic foliar spray	50	1037	4573	1451 *	598	1644 *	10794	3622	**257**
Check	50	782	5295	741	487	409	11822	3365	

§ PH- placed in plant hole; Adjacent- tablet placed in soil next to seedling

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

Table 57. Effect of Bayer tablets on height, diameter and volume index after the four growing seasons on four of the original six Western Gulf sites - 2010.

		arameter Growth (**Growth Difference (cm or cm^3) Compared to**					
		Height (cm)					
Treatment §	N	TX1	TX2	AR2	AR3	Mean	
20% FXT Ball PH	50	387.4 *	347.9 *	277.1 *	332.2 *	332.1 *	**55.0**
20% FXT Ball Adjacent	50	352.1	330.3 *	260.1 *	304.9 *	308.3 *	**31.2**
Mimic foliar spray	50	342.1	342.0 *	275.3 *	315.4 *	318.0 *	**40.9**
Check	50	324.2	288.8	226.3	279.0	277.1	
		Diameter (cm)					
Treatment §	N	TX1	TX2	AR2	AR3	Mean	
20% FXT Ball PH	50	4.95 *	4.26 *	4.18 *	3.84 *	4.19 *	**1.15**
20% FXT Ball Adjacent	50	4.21	4.14 *	3.68 *	3.14	3.75 *	**0.71**
Mimic foliar spray	50	3.94	4.47 *	4.10 *	3.44 *	4.00 *	**0.95**
Check	50	3.67	3.28	2.59	2.76	3.04	
		Volume Index (cm^3)					
Treatment §	N	TX1	TX2	AR2	AR3	Mean	
20% FXT Ball PH	50	10031 *	7225 *	6167 *	5710 *	7119 *	**3564**
20% FXT Ball Adjacent	50	7324	6591 *	4484 *	3636 *	5349 *	**1795**
Mimic foliar spray	50	6385	7927 *	6051 *	4476 *	6231 *	**2677**
Check	50	5380	4513	1905	2823	3554	

§ PH- placed in plant hole; Adjacent- tablet placed in soil next to seedling
***** Means followed by an asterik are significantly different from checks at the 5% level based on Fisher's Protected LSD.

Table 58. Effect of SilvaShield™ tablet dose on pine tip moth infestation of loblolly pine shoots (top whorl) on one site (Moffett) in east Texas, 2008 - 2010.

			Mean Percent Top Whorl Shoots Infested by Tip Moth (**Pct. Reduction Compared to Check**)																	
Year	Treatment §	N	Gen 1			Gen 2			Gen 3			Gen 4			Gen 5			Overall Mean		
2008	1 Tablet at Planting	50	0.7	**-40**		0.0	**100**	*	0.0	**100**	*	2.2	**96**	*	5.9	**91**	*	0.7	**96**	*
	2 Tablets at Planting	50	0.0	**100**		2.0	**26**		2.1	**83**	*	11.7	**78**	*	10.5	**83**	*	3.9	**78**	*
	3 Tablets at Planting	50	0.0	**100**		0.0	**100**	*	0.0	**100**	*	6.0	**89**	*	9.0	**86**	*	1.5	**91**	*
	1 Tablet Adjacent	50	0.4	**20**		0.3	**89**		1.1	**91**	*	2.7	**95**	*	4.8	**92**	*	1.1	**94**	*
	Fipronil at Planting	50	1.7	**-240**		0.4	**85**		0.0	**100**	*	1.3	**98**	*	2.0	**97**	*	0.9	**95**	*
	Check	100	0.5			2.7			12.6			52.6			63.3			17.5		
2009	1 Tablet at Planting	50	2.7	**84**	*	4.2	**50**		1.2	**92**	*	7.5	**55**	*	0.0	####		3.0	**72**	*
	2 Tablets at Planting	50	4.1	**76**	*	0.9	**89**	*	6.8	**58**	*	17.7	**-6**		0.0	####		5.8	**47**	*
	3 Tablets at Planting	50	0.4	**98**	*	2.1	**75**	*	3.4	**79**	*	4.9	**70**	*	4.1	####		2.9	**73**	*
	1 Tablet Adjacent	50	3.6	**79**	*	3.7	**55**		2.7	**83**	*	1.7	**90**	*	0.0	####		2.3	**79**	*
	Fipronil at Planting	50	1.0	**94**	*	0.5	**94**	*	5.4	**67**	*	9.0	**46**		0.0	####		3.2	**71**	*
	Check	100	17.1			8.4			16.1			16.6			0.0			10.8		
2010	1 Tablet at Planting	50	55.3	**-18**		12.0	**-43**		51.9	**18**		85.1	**6**		87.2	**9**		58.3	**5**	
	2 Tablets at Planting	50	60.5	**-30**		7.0	**16**		35.5	**44**	*	67.3	**26**	*	73.9	**23**	*	49.1	**20**	*
	3 Tablets at Planting	50	42.0	**10**		7.1	**15**		17	**73**	*	45.3	**50**	*	48.5	**50**	*	31.7	**48**	*
	1 Tablet Adjacent	50	58.6	**-26**		7.5	**11**		50.3	**21**		79	**13**		81.7	**15**	*	55.4	**9**	
	Fipronil at Planting	50	50.1	**-7**		10.4	**-23**		54.9	**14**		82.2	**10**		81.2	**15**	*	55.8	**9**	
	Check	100	46.7			8.4			63.6			90.9			96			61.1		

***** 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 59. Effect of SilvaShield™ tablet dose on loblolly pine growth on one site (Moffet) in east Texas, 2008 - 2010.

			Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm3) Compared to Check)**						Mean Percent Tree Survival
Year	Treatment	N	Height (cm)		Diameter (cm) [a]		Volume (cm^3)		
2008	1 Tablet at Planting	50	42.8	**-4.2**	0.77	**-0.10**	28.6	**-16.7**	96
	2 Tablets at Planting	50	44.1	**-2.9**	0.81	**-0.06**	35.1	**-10.2**	100
	3 Tablets at Planting	50	46.8	**-0.2**	0.88	**0.01**	40.1	**-5.2**	100
	1 Tablet Adjacent	50	43.4	**-3.6**	0.81	**-0.06**	35.3	**-10.0**	98
	Fipronil Adjacent	50	48.9	**1.9**	0.88	**0.01**	43.5	**-1.8**	100
	Check	50	47.0		0.87		45.3		94
2009	1 Tablet at Planting	50	95.8	**-11.3**	2.20	**-0.41**	512.0	**-306.2**	96
	2 Tablets at Planting	50	102.1	**-5.0**	2.41	**-0.19**	693.8	**-124.4**	98
	3 Tablets at Planting	50	104.1	**-3.0**	2.39	**-0.21**	671.8	**-146.4**	98
	1 Tablet Adjacent	50	99.4	**-7.6**	2.38	**-0.22**	666.6	**-151.6**	98
	Fipronil Adjacent	50	114.9	**7.9**	2.69	**0.08**	925.9	**107.7**	100
	Check	50	107.0		2.60		818.2		92
2010	1 Tablet at Planting	50	179.9	**-4.0**	4.01	**-0.37** *	3076.1	**-743.0**	96
	2 Tablets at Planting	50	193.0	**9.1**	4.31	**-0.07**	3895.4	**76.2**	98
	3 Tablets at Planting	50	193.8	**9.9**	4.17	**-0.21**	3632.8	**-186.4**	96
	1 Tablet Adjacent	50	181.0	**-3.0**	4.15	**-0.23**	3426.6	**-392.6**	98
	Fipronil Adjacent	50	203.1 *	**19.2**	4.67	**0.29**	4668.9 *	**849.7**	100
	Check	50	184.0		4.38		3819.2		92

[a] Diameter taken at 6" above ground.

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

Table 60. Effect of SilvaShield™ tablet dose and depth on pine tip moth infestation of loblolly pine shoots (top whorl) on a first year sites (Loving Ferry) in east Texas, 2008 - 2010.

			Mean Percent Top Whorl Shoots Infested by Tip Moth (**Pct. Reduction Compared to Check**)																	
Year	Treatment §	N	Gen 1			Gen 2			Gen 3			Gen 4			Gen 5			Overall Mean		
2008	1 Tablet at 4"	50	1.7	**-108**		2.6	**66**		3.2	**63**	*	5.5	**87**	*	10.0	**78**	*	4.5	**79**	*
	2 Tablets at 4"	50	1.3	**-68**		3.9	**48**		0.0	**100**	*	5.0	**88**	*	10.3	**77**	*	4.1	**81**	*
	3 Tablets at 4"	50	2.3	**-193**		1.6	**78**	*	3.0	**66**	*	9.8	**77**	*	10.0	**78**	*	5.4	**75**	*
	1 Tablet at 8"	50	0.0	**100**		0.4	**95**	*	1.2	**86**	*	13.9	**67**	*	11.7	**74**	*	5.5	**75**	*
	2 Tablets at 8"	50	1.5	**-88**		3.1	**58**		0.0	**100**	*	0.7	**98**	*	7.1	**85**	*	2.0	**91**	*
	3 Tablets at 8"	50	0.5	**36**		0.0	**100**	*	0.5	**94**	*	4.6	**89**	*	7.6	**83**	*	2.7	**88**	*
	Check	50	0.8			7.5			8.7			42.7			45.7			21.6		
2009	1 Tablet at 4"	50	2.0	**91**	*	4.5	**46**		7.1	**49**	*	34.7	**38**	*	60.7	**29**	*	22.3	**40**	*
	2 Tablets at 4"	50	3.8	**83**	*	3.1	**62**	*	5.7	**59**	*	20.7	**63**	*	41.7	**51**	*	15.0	**59**	*
	3 Tablets at 4"	50	2.1	**90**	*	1.6	**81**	*	4.8	**66**	*	35.6	**36**	*	53.8	**37**	*	19.6	**47**	*
	1 Tablet at 8"	50	2.9	**87**	*	4.2	**50**		8.3	**40**		36.0	**35**	*	66.1	**22**	*	23.6	**36**	*
	2 Tablets at 8"	50	3.3	**85**	*	1.4	**83**	*	3.3	**77**	*	17.0	**69**	*	32.9	**61**	*	11.9	**68**	*
	3 Tablets at 8"	50	2.5	**88**	*	4.7	**43**		5.7	**59**	*	33.3	**40**	*	58.1	**32**	*	20.8	**44**	*
	Check	50	21.9			8.3			13.9			55.7			85.2			37.0		
2010	1 Tablet at 4"	50	45.8	**1**		14.2	**28**		35.9	**2**		88.7	**4**		89.8	**-3**		54.4	**3**	
	2 Tablets at 4"	50	40.4	**13**		11.8	**40**		20.4	**44**	*	74.2	**20**	*	79.7	**9**		45.2	**20**	*
	3 Tablets at 4"	50	42.6	**8**		10.7	**46**	*	30.2	**18**		67.4	**27**	*	64.1	**27**	*	43.2	**23**	*
	1 Tablet at 8"	50	29.6	**36**	*	15.9	**19**		33.9	**8**		78.3	**15**		82.7	**6**		47.9	**15**	*
	2 Tablets at 8"	50	19.9	**57**	*	8.2	**58**	*	23.4	**36**	*	66.7	**28**	*	58.4	**33**	*	33.4	**41**	*
	3 Tablets at 8"	50	33.1	**28**		16.7	**15**		25.5	**30**		74.1	**20**	*	76.5	**13**		45.4	**19**	*
	Check	50	46.2			19.6			36.7			92.4			87.6			56.2		

***** 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 61. Effect of SilvaShield™ tablet dose and depth on loblolly pine growth during first year and second year (Loving Ferry) in east Texas, 2008 - 2010.

			Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm^3) Compared to Check)**						
Year	Treatment	N	Height (cm)		Diameter (cm) [a]		Volume (cm^3)		Mean Percent Tree Survival
2008	1 Tablet at 4"	50	40.2	**8.3**	0.74	**0.13**	44.6	**27.7**	92
	2 Tablets at 4"	50	43.8 *	**11.9**	0.74 *	**0.13**	33.6 *	**16.7**	88
	3 Tablets at 4"	50	44.2 *	**12.4**	0.77 *	**0.16**	36.4 *	**19.4**	88
	1 Tablet at 8"	50	39.6 *	**7.7**	0.72	**0.11**	31.2 *	**14.2**	98
	2 Tablets at 8"	50	43.8 *	**11.9**	0.81 *	**0.20**	40.4 *	**23.5**	92
	3 Tablets at 8"	50	44.6 *	**12.7**	0.82 *	**0.21**	39.1 *	**22.2**	86
	Check	50	31.9		0.61		16.9		96
2009	1 Tablet at 4"	50	126.5 *	**24.2**	2.46	**0.45**	1439.2	**763.6**	84
	2 Tablets at 4"	50	129.5 *	**27.1**	2.39 *	**0.38**	974.6 *	**298.9**	82
	3 Tablets at 4"	50	130.2 *	**27.8**	2.61 *	**0.60**	1248.8 *	**573.2**	88
	1 Tablet at 8"	50	115.3	**12.9**	2.34	**0.34**	987.5	**311.8**	94
	2 Tablets at 8"	50	128.6 *	**26.2**	2.53 *	**0.52**	1199.4 *	**523.7**	88
	3 Tablets at 8"	50	129.2 *	**26.8**	2.46 *	**0.45**	1052.2 *	**376.5**	86
	Check	50	102.3		2.01		675.7		96
2010	1 Tablet at 4"	50	227.3	**23.9**	4.12	**0.39**	6037.7	**2051.2**	84
	2 Tablets at 4"	50	230.7 *	**27.3**	4.16	**0.43**	4742.8	**756.3**	80
	3 Tablets at 4"	50	249.2 *	**45.8**	4.57 *	**0.84**	6291.5 *	**2305.0**	84
	1 Tablet at 8"	50	222.4	**19.1**	3.90	**0.17**	4730.4	**743.9**	94
	2 Tablets at 8"	50	231.2	**27.9**	4.05	**0.32**	5306.6	**1320.2**	88
	3 Tablets at 8"	50	223.0	**19.7**	4.24	**0.51**	4862.6	**876.1**	86
	Check	50	203.4		3.73		3986.4		92

[a] Diameter taken at 6" above ground.

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

Table 62. Effect of SilvaShield™ tablet dose and depth on pine tip moth infestation of loblolly pine shoots (top whorl) on a first year site (Moffet) in east Texas, 2008 - 2010.

			Mean Percent Top Whorl Shoots Infested by Tip Moth (**Pct. Reduction Compared to Check**)																	
Year	Treatment §	N	Gen 1			Gen 2			Gen 3			Gen 4			Gen 5			Overall Mean		
2008	1 Tablet at 4"	50	0.5	####		0.0	**100**	*	3.2	**76**	*	3.0	**93**	*	1.3	**97**	*	1.6	**93**	*
	2 Tablets at 4"	50	1.0	####		0.0	**100**	*	0.0	**100**	*	0.0	**100**	*	0.0	**100**	*	0.2	**99**	*
	3 Tablets at 4"	50	0.0	####		1.5	**89**	*	1.0	**93**	*	1.0	**98**	*	1.0	**98**	*	0.9	**96**	*
	1 Tablet at 8"	50	0.7	####		0.0	**100**	*	0.0	**100**	*	0.0	**100**	*	0.0	**100**	*	0.1	**99**	*
	2 Tablets at 8"	50	0.8	####		1.8	**86**	*	5.1	**62**	*	15.4	**64**	*	18.4	**57**	*	8.5	**62**	*
	3 Tablets at 8"	50	2.9	####		0.5	**96**	*	0.0	**100**	*	1.4	**97**	*	0.7	**98**	*	1.1	**95**	*
	1 Tablet at 8" PH	50	0.0	####		0.0	**100**	*	2.0	**85**	*	0.7	**98**	*	1.1	**97**	*	0.8	**97**	*
	Check	100	0.0			12.9			13.5			43.0			42.7			22.4		
2009	1 Tablet at 4"	50	3.7	**45**	*	3.4	**52**	*	1.1	**90**	*	12.8	**42**	*	31.0	**47**	*	10.4	**50**	*
	2 Tablets at 4"	50	0.4	**94**	*	0.0	**100**	*	1.0	**90**	*	4.4	**80**	*	28.0	**52**	*	6.9	**67**	*
	3 Tablets at 4"	50	0.0	**100**	*	1.2	**83**	*	1.2	**89**	*	7.5	**66**	*	27.8	**52**	*	7.3	**65**	*
	1 Tablet at 8"	50	1.6	**77**	*	0.4	**94**	*	1.0	**90**	*	6.1	**72**	*	31.2	**46**	*	8.1	**61**	*
	2 Tablets at 8"	50	1.8	**73**	*	0.6	**92**	*	4.1	**61**	*	7.8	**65**	*	29.7	**49**	*	8.8	**58**	*
	3 Tablets at 8"	50	0.0	**100**	*	0.0	**100**	*	1.0	**90**	*	3.3	**85**	*	21.1	**64**	*	5.1	**76**	*
	1 Tablet at 8" PH	50	0.4	**94**	*	0.5	**92**	*	1.7	**84**	*	5.8	**74**	*	29.3	**49**	*	7.6	**64**	*
	Check	100	6.9			7.1			10.4			22.0			58.1			20.9		
2010	1 Tablet at 4"	50	45.8	**16**		22.3	**-40**		35.8	**9**		66.2	**-9**		74.2	**-7**		48.9	**-2**	
	2 Tablets at 4"	50	40.4	**26**		16.7	**-5**		36.3	**8**		70.6	**-16**		73.7	**-6**		47.6	**1**	
	3 Tablets at 4"	50	42.6	**22**		12.0	**25**		21.8	**45**	*	64.0	**-5**		64.0	**8**		40.9	**15**	
	1 Tablet at 8"	50	52.1	**4**		13.6	**15**		27.5	**30**	*	63.5	**-5**		64.6	**7**		44.3	**8**	
	2 Tablets at 8"	50	47.7	**13**		16.3	**-2**		35.1	**11**		70.0	**-15**		69.2	**0**		47.7	**1**	
	3 Tablets at 8"	50	47.8	**12**		12.8	**20**		26.6	**32**	*	65.2	**-7**		70.5	**-2**		44.6	**7**	
	1 Tablet at 8" PH	50	41.4	**24**		20.6	**-29**		37.4	**5**		68.5	**-13**		74.6	**-8**		48.5	**-1**	
	Check	100	54.6			16.0			39.4			60.7			69.2			48.0		

***** 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 63. Effect of SilvaShield™ tablet dose and depth on loblolly pine growth during first and second year (Moffet) in east Texas, 2008 - 2010.

Year	Treatment	N	Mean End of Season Loblolly Pine Seeding Growth Measurements **(Growth Difference (cm or cm^3) Compared to Check)**						Mean Percent Tree Survival
			Height (cm)		Diameter (cm) [a]		Volume (cm^3)		
2008	1 Tablet at 4"	50	40.1	**3.7**	0.69	**0.00**	22.1	**1.6**	100
	2 Tablets at 4"	50	38.2	**1.8**	0.68	**-0.01**	21.6	**1.1**	90
	3 Tablets at 4"	50	41.2	**4.8**	0.74	**0.05**	29.2	**8.7**	98
	1 Tablet at 8"	50	40.1	**3.7**	0.70	**0.01**	23.1	**2.6**	96
	2 Tablets at 8"	50	42.3 *	**5.8**	0.71	**0.0**	26.2	**5.7**	90
	3 Tablets at 8"	50	43.7 *	**7.3**	0.75	**0.06**	31.2 *	**10.7**	96
	1 Tablet at 8" PH	50	39.9	**3.4**	0.69	**0.0**	23.9	**3.4**	90
	Check	50	36.4		0.69		20.5		100
2009	1 Tablet at 4"	50	86.1	**-2.8**	1.91	**-0.07**	368.0	**-55.2**	100
	2 Tablets at 4"	50	87.9	**-1.0**	1.88	**-0.10**	371.0	**-52.2**	88
	3 Tablets at 4"	50	92.4	**3.6**	2.05	**0.07**	511.7	**88.5**	100
	1 Tablet at 8"	50	86.3	**-2.6**	1.85	**-0.13**	333.7	**-89.5**	96
	2 Tablets at 8"	50	95.6	**6.8**	2.07	**0.1**	503.6	**80.4**	92
	3 Tablets at 8"	50	96.4	**7.5**	2.02	**0.04**	472.5	**49.3**	96
	1 Tablet at 8" PH	50	90.7	**1.9**	1.91	**-0.1**	396.9	**-26.3**	92
	Check	50	88.9		1.98		423.2		100
2010	1 Tablet at 4"	50	156.4	**-8.5**	3.19	**-0.18**	1831.3	**-323.3**	100
	2 Tablets at 4"	50	158.3 *	**-6.6**	3.15 *	**-0.22**	1794.6	**-360.0**	88
	3 Tablets at 4"	50	163.7	**-1.2**	3.38	**0.01**	2323.7	**169.1**	100
	1 Tablet at 8"	50	154.9 *	**-10.0**	3.21 *	**-0.17**	1791.4	**-363.2**	96
	2 Tablets at 8"	50	166.8	**2.0**	3.36	**0.0**	2204.7	**50.1**	92
	3 Tablets at 8"	50	166.3	**1.4**	3.29	**-0.09**	2066.9	**-87.7**	96
	1 Tablet at 8" PH	50	162.3	**-2.6**	3.22	**-0.2**	1965.7	**-188.9**	92
	Check	50	164.9		3.37		2154.6		100

[a] Diameter taken at 6" above ground.

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

Table 64. Effect of SilvaShield™ tablet dose and depth on pine tip moth infestation of loblolly pine shoots (top whorl) on one second year site (Peavy) in east Texas, 2008 and 2009.

			Mean Percent Top Whorl Shoots Infested by Tip Moth (**Pct. Reduction Compared to Check**)																	
Year	Treatment §	N	Gen 1			Gen 2			Gen 3			Gen 4			Gen 5			Overall Mean		
2008	1 Tablet at 4"	50	14.4	**1**		20.9	**35**	*	8.7	**64**	*	13.5	**80**	*	20.9	**65**	*	15.4	**61**	*
	2 Tablets at 4"	50	17.1	**-17**		14.1	**56**	*	6.2	**74**	*	5.4	**92**	*	5.7	**90**	*	9.9	**75**	*
	3 Tablets at 4"	50	13.2	**9**		7.4	**77**	*	0.9	**96**	*	0.4	**99**	*	13.2	**78**	*	7.0	**82**	*
	1 Tablet at 8"	50	12.7	**13**		15.2	**53**	*	10.2	**58**	*	30.2	**55**	*	33.3	**44**	*	20.3	**49**	*
	2 Tablets at 8"	50	13.3	**9**		5.8	**82**	*	3.7	**85**	*	7.8	**88**	*	7.3	**88**	*	7.7	**81**	*
	3 Tablets at 8"	50	14.5	**1**		11.5	**65**	*	2.5	**90**	*	3.0	**95**	*	2.5	**96**	*	6.8	**83**	*
	Check	50	14.6			32.4			24.2			66.5			59.6			39.6		
2009	1 Tablet at 4"	50	1.6	**39**		3.5	**-602**	*	1.0	**79**	*	5.4	**83**	*	15.1	**61**	*	5.3	**66**	*
	2 Tablets at 4"	50	1.0	**64**		1.0	**-96**		0.4	**91**	*	2.2	**93**	*	5.8	**85**	*	2.1	**86**	*
	3 Tablets at 4"	50	0.0	**100**	*	1.2	**-138**		0.7	**85**	*	3.1	**90**	*	2.7	**93**	*	1.5	**90**	*
	1 Tablet at 8"	50	2.0	**25**		1.2	**-138**		1.9	**58**	*	10.1	**68**	*	20.1	**48**	*	7.1	**54**	*
	2 Tablets at 8"	50	1.0	**62**		0.4	**20**		0.5	**89**	*	5.6	**82**	*	10.2	**73**	*	3.5	**77**	*
	3 Tablets at 8"	50	1.3	**50**		0.8	**-60**		0.0	**100**	*	0.4	**99**	*	1.7	**95**	*	0.9	**94**	*
	Check	50	2.6			0.5			4.6			31.2			38.4			15.5		

***** 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 65. Effect of SilvaShield™ tablet dose and depth on loblolly pine growth on one second year site (Peavy) in east Texas, 2008 - 2010.

			Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm^3) Compared to Check**)						Mean Percent
Year	Treatment	N	Height (cm)		Diameter (cm) [a]		Volume (cm^3)		Tree Survival
2008	1 Tablet at 4"	50	156.2 *	**21.3**	3.31 *	**0.39**	2076 *	**775**	92
	2 Tablets at 4"	50	135.6	**0.7**	2.80	**-0.12**	1228	**-73**	96
	3 Tablets at 4"	50	141.5	**6.6**	2.90	**-0.02**	1293	**-8**	100
	1 Tablet at 8"	50	141.6	**6.7**	2.91	**-0.01**	1327	**26**	98
	2 Tablets at 8"	50	150.6 *	**15.7**	3.08	**0.16**	1632	**331**	100
	3 Tablets at 8"	50	143.4	**8.5**	2.87	**-0.04**	1401	**100**	98
	Check	50	134.9		2.92		1301		98
2009	1 Tablet at 4"	50	284.1 *	**26.8**	5.69	**0.40**	10232 *	**2443**	92
	2 Tablets at 4"	50	256.4	**-1.0**	5.05	**-0.24**	7135	**-654**	92
	3 Tablets at 4"	50	280.3 *	**23.0**	5.49	**0.20**	9459	**1669**	98
	1 Tablet at 8"	50	265.4	**8.1**	5.26	**-0.03**	7700	**-90**	98
	2 Tablets at 8"	50	273.8	**16.5**	5.47	**0.18**	8936	**1147**	100
	3 Tablets at 8"	50	269.0	**11.6**	5.20	**-0.09**	7935	**146**	98
	Check	50	257.4		5.29		7789		98
2010	1 Tablet at 4"	50	413.1	**18.1**	5.70 *	**0.76**	15203 *	**3682**	92
	2 Tablets at 4"	50	401.0	**6.0**	4.89	**-0.05**	10474	**-1047**	92
	3 Tablets at 4"	50	426.4 *	**31.4**	5.42 *	**0.47**	14176 *	**2655**	98
	1 Tablet at 8"	50	408.1	**13.1**	5.15	**0.20**	11876	**355**	98
	2 Tablets at 8"	50	410.0	**15.1**	5.44 *	**0.50**	13352 *	**1832**	100
	3 Tablets at 8"	50	408.8	**13.9**	5.06	**0.12**	11588	**67**	98
	Check	50	394.9		4.94		11521		98

[a] Diameter taken at 6" above ground.

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

Table 66. Effect of SilvaShield™ tablet dose and depth on pine tip moth infestation of loblolly pine shoots (top whorl) on one second year site (CR 3260) in east Texas, 2010.

			Mean Percent Top Whorl Shoots Infested by Tip Moth (**Pct. Reduction Compared to Check**)																	
Year	Treatment §	N	Gen 1			Gen 2			Gen 3			Gen 4			Gen 5			Overall Mean		
2010	1 Tablet at 4"	50	9.9	**50**	*	10.9	**37**		11.3	**70**	*	40.0	**56**	*	48.8	**45**	*	23.9	**53**	*
	2 Tablets at 4"	50	11.7	**41**	*	13.9	**20**		14.6	**61**	*	43.1	**53**	*	44.2	**51**	*	25.5	**50**	*
	3 Tablets at 4"	50	8.2	**59**	*	3.4	**80**	*	1.0	**97**	*	6.2	**93**	*	9.0	**90**	*	5.6	**89**	*
	1 Tablet at 8"	50	19.4	**3**		10.4	**40**	*	13.9	**63**	*	45.7	**50**	*	47.5	**47**	*	27.4	**46**	*
	2 Tablets at 8"	50	14.9	**25**		3.5	**80**	*	3.6	**91**	*	13.7	**85**	*	16.5	**82**	*	10.4	**79**	*
	3 Tablets at 8"	50	5.8	**71**	*	3.3	**81**	*	0.7	**98**	*	2.9	**97**	*	6.8	**92**	*	3.9	**92**	*
	Check	50	19.9			17.3			38.0			91.2			89.6			50.7		

***** 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 67. Effect of SilvaShield™ tablet dose and depth on loblolly pine growth on one second year site (CR 3260) in east Texas, 2010.

			Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm^3) Compared to Check**)						
Year	Treatment	N	Height (cm)		Diameter (cm) [a]		Volume (cm^3)		Mean Percent Tree Survival
2010	1 Tablet at 4"	50	195.5	**2.4**	4.50 *	**-0.57**	4357	**-1142**	100
	2 Tablets at 4"	50	195.9	**2.9**	4.49 *	**-0.58**	4307	**-1193**	100
	3 Tablets at 4"	50	182.1	**-10.9**	3.85 *	**-1.22**	3124 *	**-2375**	100
	1 Tablet at 8"	50	196.9	**3.9**	4.41 *	**-0.66**	4586 *	**-913**	100
	2 Tablets at 8"	50	197.8	**4.7**	4.46 *	**-0.61**	4489	**-1010**	100
	3 Tablets at 8"	50	196.4	**3.3**	4.11 *	**-0.97**	4066 *	**-1434**	100
	Check	50	193.0		5.07		5499		98

[a] Diameter taken at 6" above ground.

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

Table 68. Effect of SilvaShield™ tablet dose and depth on pine tip moth infestation of loblolly pine shoots (top whorl) on one second year site (Cottingham Bridge) in east Texas, 2009 and 2010.

			Mean Percent Top Whorl Shoots Infested by Tip Moth (**Pct. Reduction Compared to Check**)																	
Year	Treatment §	N	Gen 1			Gen 2			Gen 3			Gen 4			Gen 5			Overall Mean		
2009	1 SS	50	6.6	**-34**		3.0	**26**		0.7	**93**	*	15.9	**62**	*	46.6	**25**	*	14.7	**41**	*
	DAP 1X	50	2.1	**57**		6.2	**-53**		10.4	**2**		42.3	**-2**		55.0	**12**		23.4	**5**	
	1 SS + DAP 1/2X	50	2.5	**49**		2.7	**33**		2.3	**79**	*	21.0	**49**	*	52.0	**17**		16.1	**35**	*
	HWC	50	8.0	**-63**		9.5	**-136**		10.1	**6**		38.8	**6**		58.7	**6**		25.0	**-1**	
	1 SS + HWC	50	3.1	**36**		0.7	**82**		1.4	**86**	*	11.7	**72**	*	48.1	**23**		12.8	**48**	*
	1 SS + DAP 1/2X + HWC	50	1.0	**80**		0.3	**91**		0.0	**100**	*	13.0	**69**	*	45.1	**28**	*	11.9	**52**	*
	1 SS + DAP 1X + HWC	50	3.3	**33**		1.2	**70**		1.7	**84**	*	23.5	**43**	*	45.4	**27**	*	14.6	**41**	*
	DAP 1X + HWC	50	5.7	**-16**		11.7	**-189**		14.7	**-37**		32.1	**22**		55.7	**11**		24.2	**2**	
	Check	50	4.9			4.0			10.7			41.3			62.3			24.7		
2010	1 SS	50	48.6	**12**		49.1	**24**	*	53.2	**24**	*	72.9	**24**	*	71.0	**25**	*	59.0	**23**	*
	DAP 1X	50	61.0	**-10**		62.7	**3**		73.0	**-5**		94.7	**2**		93.1	**2**		77.4	**-1**	
	1 SS + DAP 1/2X	50	48.5	**13**		50.8	**21**		61.7	**11**		81.3	**16**	*	82.3	**13**	*	64.9	**15**	*
	HWC	50	48.3	**13**		68.8	**-7**		69.9	**0**		88.8	**8**		85.7	**10**		72.3	**6**	
	1 SS + HWC	50	38.7	**30**	*	52.1	**19**		58.4	**16**		77.0	**20**	*	86.3	**9**		62.5	**18**	*
	1 SS + DAP 1/2X + HWC	50	37.6	**32**	*	45.3	**30**	*	49.4	**29**	*	83.7	**13**	*	87.9	**7**		60.6	**21**	*
	1 SS + DAP 1X + HWC	50	44.6	**20**		48.8	**24**	*	39.7	**43**	*	65.6	**32**	*	73.9	**22**	*	54.6	**29**	*
	DAP 1X + HWC	50	52.4	**5**		69.1	**-7**		71.3	**-2**		96.9	**-1**		97.9	**-3**		77.6	**-1**	
	Check	50	55.4			64.3			69.6			96.3			95.0			76.6		

***** 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 69. Effect of SilvaShield™ tablet dose and depth on loblolly pine growth on one second year site (Cottingham Bridge) in east Texas, 2009 and 2010.

			Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm^3) Compared to Check)**						Mean Percent Tree Survival
Year	Treatment	N	Height (cm)		Diameter (cm) [a]		Volume (cm^3)		
2009	1 SS	50	68.8	**7.1**	1.63	**0.17**	212.4	**33.0**	90
	DAP 1X	50	71.4 *	**9.7**	1.73 *	**0.26**	255.6 *	**76.2**	80
	1 SS + DAP 1/2X	50	80.4 *	**18.7**	1.91 *	**0.45**	322.2 *	**142.8**	98
	HWC	50	58.9	**-2.8**	1.38	**-0.08**	144.7	**-34.7**	84
	1 SS + HWC	50	73.1 *	**11.4**	1.74 *	**0.28**	257.5 *	**78.1**	92
	1 SS + DAP 1/2X + HWC	50	72.0 *	**10.3**	1.73 *	**0.27**	256.0 *	**76.6**	96
	1 SS + DAP 1X + HWC	50	75.1 *	**13.4**	1.79 *	**0.33**	273.9 *	**94.5**	78
	DAP 1X + HWC	50	59.4	**-2.3**	1.50	**0.03**	169.7	**-9.7**	94
	Check	50	61.7		1.46		179.4		94
2010	1 SS	50	148.5	**18.5**	3.54 *	**0.43**	2094.9 *	**512.5**	90
	DAP 1X	50	142.6	**12.6**	3.67 *	**0.55**	2189.1 *	**606.7**	78
	1 SS + DAP 1/2X	50	162.7 *	**32.7**	3.86 *	**0.74**	2596.0 *	**1013.6**	98
	HWC	50	125.2	**-4.8**	3.27	**0.16**	1637.7	**55.3**	84
	1 SS + HWC	50	159.7 *	**29.7**	3.89 *	**0.78**	2634.8 *	**1052.4**	92
	1 SS + DAP 1/2X + HWC	50	160.6 *	**30.6**	3.80 *	**0.69**	2517.0 *	**934.6**	94
	1 SS + DAP 1X + HWC	50	158.5 *	**28.5**	3.91 *	**0.80**	2674.5 *	**1092.1**	78
	DAP 1X + HWC	50	132.0	**2.0**	3.29	**0.18**	1796.1	**213.7**	94
	Check	50	130.0		3.11		1582.4		94

[a] Diameter taken at 6" above ground.

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

PINE TIP MOTH TRIALS

SilvaShield™ Operational Soil Injection Study - Western Gulf Region

Highlights:

- SilvaShield™ Forestry Tablets operationally applied by hand (2008) significantly reduced tip moth damage in the first year (by 77%) and second year (by 69%) after application. The treatment significantly improved height, diameter, and volume growth by 22%, 15% and 54%, respectively, three years post treatment.
- Operational treatment of second-year trees only reduced overall tip moth damage by 38% (first year after application) and 52% (second year after application) compared to untreated checks, but the treatment has improved height, diameter, and volume growth by 8%, 11% and 26%, respectively, three years post treatment.
- SilvaShield™ operationally applied by hand into plant holes significantly reduced tip moth damage in the first year (by 85%) and second year (by 39%) after application. The treatment significantly improved height, diameter, and volume growth by 14%, 11% and 73%, respectively, two years post treatment.

Objectives: To 1) determine the efficacy of SilvaShield™ tablets in reducing area-wide pine tip moth infestation levels on loblolly pine seedlings; 2) evaluate this product applied after planting to bedded or unbedded areas; and 3) determine the duration of protection provided by this insecticide application.

Cooperators:

Mr. Steve Anderson	Texas Forest Service, Hudson, TX
Ms. Francis Peavy,	Private land owner, Hudson, TX
R. Ragan Bounds	Hancock Forest Management, Woodville, TX
Dr. Bruce Monke	Bayer Environmental Science, Research Triangle Park, NC

Study Sites: One first-year plantation and one second-year plantation were selected east of Lufkin, TX and north of Hudson, TX (Angelina Co.) in February 2008. A second first-year site was selected near Rockland (Tyler Co.) in February 2009.

Insecticides:

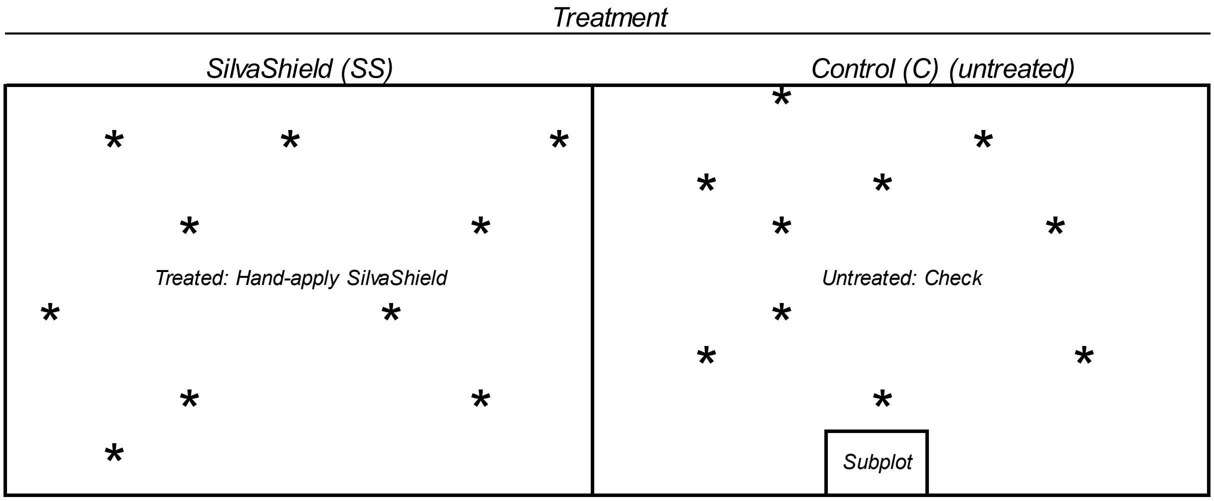
SilvaShield™ Forestry Tablet (imidacloprid + fertilizer) – imidacloprid is highly systemic neonictinoid with activity against Lepidoptera. The fertilizer consisted of a N:P:K ratio of 12:9:4.

Research Approach:

A randomized complete block design was used at each site with site areas serving as blocks, i.e., each treatment was randomly selected for placement in one-half of the area. For each treatment, one hundred seedlings were monitored in each main plot area. The treatments (per 40 acre block) included:

1) SilvaShield™ (one tablet) applied after planting next to each seedling to a depth of 8 inches.
2) Check –seedlings planted by hand

Two tracts about to be planted, and one one-year old tract, each 80 acres in size, were selected in Texas based on uniformity of soil, drainage, topography and susceptibility to tip moth infestation (based on FPMC Tip Moth Hazard-Rating Model, Andy Burrow, and Temple Inland Forest Products).



Main treatment plots = 40 acres each; Internal treatment subplots = 0.5 acres each; ten 10-tree plots (*) evenly spaced within each main plot

Figure 31. Generalized plot design

In 2008, each plantation was hand-planted. On one half of the plantation, the applicator applied one SilvaShield™ tablet to each seedling after planting (Figure 40). A lance was used to create an 8-inch deep hole in the soil, angled toward the seedling. The tablet was then dropped into the hole and covered up. In the other half of the plantation, seedlings were hand or machine planted at the same spacing without SilvaShield™ tablets. In 2009, tablets were placed in the planting hole prior to placement of the containerized seedling.

Ten 10-tree plots were spaced equally within each main plantation half (but outside the internal treatment plots) to evaluate tip moth damage levels in these area. All stands were treated with herbicide after planting to minimize herbaceous and/or woody competition.

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 calculated; and 3) separately, the terminal was identified as infested or not. Observations also were made as to the occurrence and extent of damage caused by other insects, i.e., coneworm, aphids, sawfly, etc. Each tree was measured for diameter (at ground line) and height in the fall (November).

Efficacy was evaluated by comparing treatment differences for direct and indirect measures of insect-caused losses. Direct treatment effects consisted of a reduction in pine tip moth damage. Indirect treatment effects consisted of increases in tree growth parameters (height, diameter and volume index). Data were subjected to analyses of variance using Statview software (SAS

Institute, Inc. 1999). Percentage and measurement data were transformed by the arcsine % and log transformations, respectively, prior to analysis.

Results:

In 2008, tip moth populations were low on the first-year site (Moffet) during the first generation with an average of 3.4% of the shoots infested on check trees. As a result of the low tip moth pressure, the tablet treatment did not significantly reduced tip moth infestation levels compared to the check during this generation (Table 70). In contrast, the treatment provided very good protection during the second through fifth generations, reducing damaged by 74 – 85% (77% overall). During the second year, damage was reduced by 69%. The tablet treatment significantly improved all (height, diameter, and volume) growth parameters by 22%, 15%, and 54%, respectively, compared to check trees (Table 71).

Tip moth populations were higher on the second-year site (Peavy) during the first generation in 2008 with an average of 19.4% of the shoots infested on check trees. The tablet treatment was not applied until the end of March, so it is understandable that the treatment did not significantly reduce tip moth infestation levels compared to the check during this generation (Table 70). In contrast, the treatment provided good protection during the second through fifth generations, reducing damaged by 31 – 52% (38% overall). During the second year, damage was reduced by 52%. The tablet treatment significantly improved all (height, diameter, and volume) growth parameters by 8%, 11%, and 26%, respectively, compared to check trees (Table 71).

In 2009, tip moth populations were generally low on the first-year site (Rockland) during the first two generations with an average of 2.6 – 2.8% of the shoots infested on check trees. As a result of the low tip moth pressure, the tablet treatment did not significantly reduced tip moth infestation levels compared to the check during this generation (Table 72). In contrast, the treatment provided very good protection during the second through fifth generations, reducing damaged by 65 – 90% (85% overall). During the second year, damaged was reduced by 39%. The tablet treatment significantly improved tree height, and volume growth parameters by 14%, 11%, and 73%, respectively, compared to check trees (Table 73).

Conclusions:

Data from new sites (Moffet and Rockland) indicate that SilvaShield™ tablets operationally applied by hand provide good protection against tip moth and improve growth during the second and third year after planting. Additional data indicate that tablets applied to one-year-old trees are not quite as effective against tip moth, but the treatment still can significantly improve tree growth. The trials will be continued in 2011 to evaluate for duration of treatment effects.

Acknowledgments: Thanks go to Mr. Steve Anderson, TFS, Ms. Francis Peavy, private landowner, and Ragan Bounds, Hancock Forest Management, for providing research sites in Texas. We thank Weyerhaeuser Company for donating the seedlings. We also thank Dr. Nate Royalty, Bayer, for providing the SilvaShield™ tablets for the project.

Table 70. Effect of SilvaShield™ tablet on areawide pine tip moth infestation of loblolly pine shoots (top whorl) on two sites (Moffet and Peavy) in east Texas, 2008 and 2009.

Site	Year	Treatment §	N	Mean Percent Top Whorl Shoots Infested by Tip Moth (**Pct. Reduction Compared to Check**)																	
				Gen 1			Gen 2			Gen 3			Gen 4			Gen 5			Overall Mean		
Moffet 1st Yr	2008	1 Tablet at 8"	100	1.7	**50**		2.8	**74**	*	3.0	**76**	*	2.4	**85**	*	5.6	**77**	*	3.1	**77**	*
		Check	100	3.4			10.9			12.6			16.3			24.6			13.6		
	2009	1 Tablet at 8"	100	1.1	**70**		1.9	**72**	*	4.3	**80**	*	9.6	**82**	*	32.0	**55**	*	9.8	**69**	*
		Check	100	3.6			6.9			21.0			54.3			71.4			31.4		
Peavy 2nd Yr	2008	1 Tablet at 8"	100	19.6	**-1**		25.4	**30**	*	20.2	**48**	*	37.3	**52**	*	48.4	**30**	*	30.2	**38**	*
		Check	100	19.4			36.5			38.6			78.0			69.3			48.4		
	2009	1 Tablet at 8"	100	2.3	**71**	*	5.0	**0**		1.5	**71**	*	15.1	**56**	*	28.8	**51**	*	10.5	**52**	*
		Check	100	7.8			5.0			5.2			34.2			58.5			22.1		

* 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 71. Effect of SilvaShield™ tablet on areawide loblolly pine growth on two sites (Moffet and Peavy) in east Texas, 2008 - 2010.

				Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm^3) Compared to Check)**			
Site	Year	Treatment	N	Height (cm)	Diameter (cm) [a]	Volume (cm^3)	Mean Percent Tree Survival
Moffet 1st Yr	2008	1 Tablet at 8"	100	60.9 * **15.9**	0.95 * **0.23**	69.9 * **41.6**	100
		Check	100	45.1	0.72	28.3	100
	2009	1 Tablet at 8"	100	132.2 * **25.4**	2.32 * **0.33**	845.2 * **319.4**	100
		Check	100	106.8	1.99	525.8	100
	2010	1 Tablet at 8"	100	219.1 * **39.0**	4.08 * **0.54**	4080.0 * **1442.4**	100
		Check	100	180.1	3.54	2637.6	100
Peavy 2nd Yr	2008	1 Tablet at 8"	100	156.2 * **14.5**	3.10 * **0.45**	1724.0 * **512.0**	100
		Check	100	141.7	2.65	1212.0	100
	2009	1 Tablet at 8"	100	278.2 * **17.7**	5.25 * **0.50**	8296.2 * **1620.7**	100
		Check	100	260.5	4.75	6675.5	100
	2010	1 Tablet at 8"	100	419.2 * **30.2**	at DBH 5.48 * **0.54**	13656.2 * **2809.1**	100
		Check	100	389.0	4.94	10847.1	100

[a] Diameter taken at 6" above ground.

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

Table 72. Effect of SilvaShield™ tablet on areawide pine tip moth infestation of loblolly pine shoots (top whorl) on one site (Rockland) in east Texas, 2009 and 2010.

				Mean Percent Top Whorl Shoots Infested by Tip Moth (**Pct. Reduction Compared to Check**)																	
Site	Year	Treatment §	N	Gen 1			Gen 2			Gen 3			Gen 4			Gen 5			Overall Mean		
Rockland 1st Yr	2009	1 Tablet in PH	100	0.6	**78**		1.0	**65**	*	2.2	**81**	*	2.5	**85**	*	2.5	**90**	*	1.7	**85**	*
		Check	100	2.6			2.8			11.4			16.9			24.0			11.5		
Rockland 2nd Yr	2010	1 Tablet in PH	100	8.8	**57**	*	9.8	**71**	*	13.5	**55**	*	42.1	**19**		48.4	**25**	*	24.5	**39**	*
		Check	100	20.6			34.0			30.1			51.8			64.7			40.2		

***** 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 73. Effect of SilvaShield™ tablet on areawide loblolly pine growth on one site (Rockland) in east Texas, 2009 and 2010.

				Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm^3) Compared to Check)**						Mean Percent
Site	Year	Treatment	N	Height (cm)		Diameter (cm) [a]		Volume (cm^3)		Tree Survival
Rockland 1st Yr	2009	1 Tablet in PH	100	75.3 *	**7.7**	1.19	**0.10**	146.8 *	**45.9**	100
		Check	100	67.7		1.09		100.9		100
	2010	1 Tablet in PH	100	195.1 *	**23.9**	3.03 *	**0.49**	2361.2 *	**996.5**	100
		Check	100	171.2		2.54		1364.7		100

[a] Diameter taken at 6" above ground.

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

PINE TIP MOTH TRIALS

Summary of Tested Systemic Insecticides

Over the past 13 years (1998 – 2010), the FPMC has been monitoring and assessing the impact of pine tip moth on pine tree growth. It has been well established through our impact, hazard-rating, and control trials that this insect significantly impacts seedling growth and form, at least in the short term. However, several questions remain to be answered in their entirety, particularly 1) What is the long term impact of tip moth on tree growth? and 2) what are the primary factors that influence the occurrence and severity of tip moth infestations? During the past ten years, we have established 110 impact plots and 142 hazard-rating plots in the Western Gulf Region and accumulated a large pool of data from which to address these two questions. Preliminary data analyses suggest that the damage threshold for impact to be about 11% of shoots infested during the first two years after planting. Regression analyses continue to determine the relationship between time and extent of tip moth protection and tree growth. Andy Burrows, Potlatch, developed a preliminary hazard-rating model in 2005 that identified site index and soil texture composition as the two primary factors that influence the occurrence and severity of pine tip moth damage. A revised model developed in 2007 based on data from numerous sites indicated that sites with deep, excessively or poorly drained soils are more prone to tip moth damage. This model needs to be validated with data from additional sites. Mr. Trevor Walker and Dr. Dean Coble, Stephen F. Austin State University worked cooperatively with FPMC to further develop the model in 2010. It is important that evaluations and data collections continue on already established impact and hazard-rating sites in 2011 and beyond and that new impact sites be established that utilize PTM™ as the protective agent.

Fipronil: Over the past nine years (2002 – 2010), fipronil has proven to be highly effective in reducing tip moth damage to first-year seedlings. Further evaluations indicate that residual effects can occur into the second and third year after planting. However, application techniques and rates can influence treatment efficacy and need to be considered in the development of one or more operational treatments.

The treatment of pine seedlings in the nursery, prior to lifting, is likely to be the most cost effective and least hazardous (exposure-wise) application technique. However, EPA has restricted the amount of active ingredient that can be applied per acre per year, to 0.13 lb. – this is a very small amount of active ingredient spread over approximately 600,000 seedlings per acre of nursery. We tried to push the envelope in the 2004 and 2005 trials by applying fipronil in the nursery at 2X, 4X, 8X and 16X the annual rate. Unfortunately, none of the treatments was found to be effective in reducing tip moth damage.

Three methods of treating bare-root seedlings after lifting were evaluated in 2003 and 2004: root soak, root dip or plant hole treatment. All three treatment techniques proved to be effective in reducing tip moth damage at least through the first year. The root dip and plant hole treatments provide extended protection into the second year, but only the high rate plant hole treatment significantly reduced damage through the third year. However, at that time BASF and EPA were concerned about the potential for excessive chemical exposure when treating or handling treated bare-root seedlings. Given these concerns and limitations, it was decided to focus on the development of treatments made at or post plant of seedlings.

Two portable applicators, PTM Spot Gun™ ($140), and PTM Injection Probe™ ($420), have been successfully used to apply fipronil solution by hand. Note: A third applicator, the Kioritz™ soil injector has been discontinued. Soil injection trials established in 2005-2009 showed that soil injection treatments are consistently effective in reducing pine tip moth damage. A trial established in 2008 showed that post-plant applications of fipronil were effective even when applied at the beginning of the 2nd year. However it is important to note that **fipronil solution applied directly into a plant hole at time of planting is consistently more effective in reducing tip moth damage compared to applications made to the soil after the seedlings is planted.**

Planting seedlings by machine has become more popular because: 1) hand-planting crews have become scarce, 2) machine-planted seedlings tend to show better survival and growth compared to hand-planted seedlings. A safe and efficient way of treating machine-planted bare-root or containerized seedlings with fipronil would be to apply the chemical as they are placed by the machine in the furrow. The FPMC was able to developed and successfully tesedt a new soil injection system in late 2006. The treatment applied by machine was consistently effective in protecting first-year seedlings on three sites through 2007. Additional machine planter trials established early in 2008 indicated that fipronil can reduce tip moth damage for two years across large areas. At least one FPMC member has implemented this technique for operational treatments during the winter of 2010/2011. FPMC plans to monitor some of these sites for treatment efficacy in 2011.

Fipronil treatments with containerized seedlings and rooted cuttings also were highly effective in reducing tip moth damage in 2004. A second trial established in 2007 in which fipronil was applied to containerized plugs 7 month in advance of planting showed outstanding first year results ($\geq$99% reduction in damage), good results the second year ($\geq$52% reduction), and moderate results the third year ($\geq$ 16% reduction). As this segment of the seedling market is continuing to build, a safe and efficient method of treating these containerized and rooted-cutting seedlings in trays should be developed. BASF is now (as of 2010) willing to consider a request to modify the PTM™ label to include use on containerized seedlings if FPMC can address concerns related to chemical leaching and worker exposure. A new trial is planned in 2011 to further evaluate the performance of plug injections of PTM™ at different rates on ten sites across the South.

In response to the results described above, BASF submitted a package to EPA to register a formulation of fipronil for use to protect conifers against pine tip moth in May 2006. EPA approved the full registration (Section 3) of PTM™ for use against tip moth and aphids by soil injection in June 2007. The product became available for the winter 2007/2008 planting season. Table 74 provides updated information about the PTM™ product (distributors, cost, etc.).

Trials established in 2009 to refine treatment rates and timing and determine effects on second-year trees will be monitored again in 2011. An additional trial was installed in 2010 to directly compare the efficacy and duration of PTM™ and SilvaShield™. Preliminary first-year results indicated that both products are highly and equally effective when applied at planting. However, SilvaShield™ generally performed better when applied post plant.

Imidacloprid: Imidacloprid has been shown in the past to be highly effective in reducing tip moth damage levels on treated seedlings. However, the cost of treatment per seedling had been a deterrent to its registration for forestry use (Scott Cameron, personal communication). Bayer Environmental

Science has registered imidacloprid/fertilizer spikes (Advance Garden™ 2-in-1 plant spikes) for residential use against tip moth. Although the plant spikes have performed well in single trial replicates (Technique and Rate Trial, 2003-2004), again the cost of treatment per seedling for operational forestry use is prohibitive.

Bayer Environmental Science became interested in the potential for using tablets containing imidacloprid + fertilizer to protect seedlings against tip moth. Trials in 2004 and 2005 indicated that these tablets provided good protection against tip moth in the first year after planting. A new trial in 2006 evaluated several new tablets, granular and gel formulations. All tablet and granular formulations were effective. As a result of the above trials as well as other trials on the East Coast, Bayer requested and EPA approved a full Section 3 registration for SilvaShield™ Forestry Tablets in 2006**.** The tablets can be applied for protection of pine against tip moth, aphids and soft scales and hybrid poplar against leaf beetles. Table 74 provides updated information about the SilvaShield™ product (distributors, cost, etc.).

Trials were established in 2008 to refine treatment rates and timing, application depth and determine effects on second year trees. Application rate or depth had no significant effect on tip moth damage and growth of first year seedling, but high rates did provide greater protection and improved growth of second-year trees. Assessments made in 2009 and 2010 indicate protection is provided through the second year but disappears in the third year. Operational applications at planting and post plant both show that these tablets are effective in reducing tip moth damage and improving tree growth.

Trials established in 2010 to determine the relative effects of input types (SilvaShield™, fertilizer and/or weed control) occurrence and severity of tip moth damage and effects on tree growth will be monitored in 2011.

Table 74. Comparison of SilvaShield™ and PTM™ products for Pine Tip Moth Control.

Characteristic	SilvaShield™ Forestry Tablet	PTM™ Insecticide
Active Ingredient(s)	Imidacloprid (20%) + Fertilizer (12N:9P:4K)	Fipronil (9.1%)
Manufacturer	Bayer Environmental Science	BASF Corporation
Distributors	Helena Red River Specialties (RRS) UAP	C3M Helena ProSource Red River Specialties (RRS) UAP
Cost per container	RRS quote*: $750 per case of 3 bags (contains a total of 3600 tablets); cost depends on quantity purchased.	RRS quote*: $325 per gallon (available in 2.5 gallon and 20 ounce containers); cost depends on quantity purchased.
Restrictions on Amount per Acre	450 tablets per acre per year	21 fluid oz per acre per year
Chemical Cost per Acre	$93.75	$53.32
Treatments at Planting into Plant Holes or Furrows	No equipment required; tablets easily applied by gloved hand into plant holes created by dibble bars.	Not easily applied with hand applicator system, but can be applied effectively with a machine planter system: **System for C&G planter** Available on a per order basis; contact Mr. Lane Day (phone:936-240-8294) for a price quote **System for Whitfield planter** Not currently available;
Duration of At Planting Treatment Efficacy	18 - 24 months	24 - 36 months
Post-plant Treatments into Soil Adjacent to Seedling	No equipment available; tablets can be pushed into soil next to seedling with gloved hand; hand applicator system is being developed.	Easily applied with hand applicator systems: **PTM Spot Gun** (1.2 gallon capacity) $140.00 thru RRS **PTM Injection Probe** (4.0 gallon capacity) ~$255.00 for probe assembly only ~$425.00 for gun + backpack sprayer thru aqumix.com
Recommended Quantity per Seedling	1 tablet	1.4 ml PTM + 13.6 ml water = 15 ml dilution per tree
Duration of Post-Plant Treatment Efficacy	Currently less than plant hole applications; research underway to improve efficacy.	Currently less than plant hole or machine planter applications; research underway to improve efficacy.

* Prices as of March 31, 2011