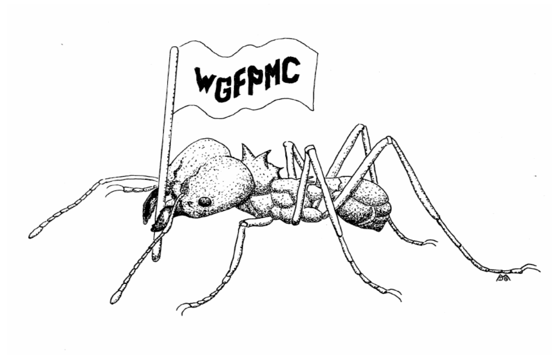
Western Gulf Forest Pest Management Cooperative



Report on

Research Accomplishments in 2007

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2007 WGFPMC Members

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Executive Summary

The Western Gulf Forest Pest Management Cooperative (WGFPMC) made significant strides in 2007. A brief summary of WGFPMC activities is given below. Two primary research projects (systemic injection studies and tip moth impact/hazard/control) were continued from 2006. These projects contained thirteen 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 2008 Project Proposals.

Several changes occurred in the membership of the WGFPMC in 2007. Temple Inland Forest Products announced that they would be selling off nearly their entire land base (1.8 million acres). Without their land base, Temple Inland elected to withdraw from the WGFPMC. The Campbell Group, who purchased Temple's land in November, has elected to join our Cooperative in 2008. Bill Stansfield will represent The Campbell Group on the Executive Committee while Greg Garcia will serve as a Contact for seed orchard interests. In addition, ArborGen acquired International Paper's SuperTree Nurseries and Orchards in November. ArborGen has also decided to join in 2008. Beverly Peoples will represent ArborGen on the Executive Committee while Shannon Stewart will serve as a Contact for seed orchard interests. **Thank you all for your continued support!**

Jason Helvey continued to provide assistance in the management of the tip moth projects. William Upton, our staff forester, continued to manage the systemic insecticide injection and leaf-cutting ant trials. Seasonal technicians Billi Kavanagh and Jeff Childers were hired to provide assistance with field and lab studies. Southern Pine Beetle Prevention Specialists Allen Smith and Mike Murphrey, provided assistance 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 continues to be an important part of the WGFPMC. To this end, four issues of the *PEST* newsletter were prepared and distributed. Also, 6 presentations, 8 meeting requests, and 84 phone/e-mail requests were addressed relating to the following topics: leaf-cutting ants, pine tip moths, reproduction weevils, bark beetles (southern pine beetle, *Ips* engravers, black turpentine beetle and mountain pine beetle), fall webworm, pine webworm, redheaded pine sawfly, scales, and aphids.

In 2007, rainfall generally returned to normal in most of East Texas. Lufkin, which normally receives 46+ inches per year in rainfall, finished the year more than 4 inches above average. However, several areas in the Western Gulf Region were still receiving below average rainfall. Southwest Arkansas (Crossett; -15 in.), central Louisiana (Alexandria; -15 in.), central Mississippi (Jackson, -30 in.) and central Alabama (Birmingham; -36 in.) were some of the hardest hit areas. Several other areas had a relatively short period of drought in August and September.

Since the phase out of Volcano in 2003, efforts have been made to evaluate alternative ant baits (Blitz, Amdro and Advion). Unfortunately, the small leaf-cutting ant market and primary focus on fire ant baits has made it difficult to find and register an effective product. Yet, the significant impact of leaf-cutting ants on forest industry lands in Texas and Louisiana demands that effective control option be found. Considerable effort was made in 2007 to develop a new bait formulation. DuPont provided active ingredient (indoxacarb) and a pellet mill to allow production of several different bait formulations. Preference trials conducted in East Texas found that bait made of grapefruit pulp and of moderate size (3/32" in diameter) was attractive to the ants. However, efficacy trials showed that this bait was ineffective in completely halting ant activity. Adjustments are being made to the bait's composition and size and additional trials are planned for 2008.

Populations and damage caused by several lepidopteran defoliators, including forest tent caterpillar, oak leaf roller and walnut caterpillars, were moderate and localized in several areas of the Western Gulf Region. Pine tip moth damage levels increased markedly from14% shoots infested to 26%; several locations averaged 40 - 50% infested shoots by mid-summer. Due to a relatively small cone crop, coneworm and seed bug pressure increased rather dramatic in 2007 in several Western Gulf seed orchards. On the positive side, no infestations of the southern pine beetle were reported in Texas, Arkansas or Oklahoma in 2007 (Table 1). Southern pine beetle populations continued to decline on state and national forests in Alabama, South Carolina and North Carolina. On the other hand, SPB infestations increased in Louisiana, Mississippi, Florida, and Virginia and dramatically in Georgia. The latest overall trend appears to be generally static SPB activity. With the return of more normal rainfall, *Ips* engraver beetle populations declined in East Texas and Louisiana compared to 2006. In contrast, severe drought conditions in from Mississippi east to North Carolina resulted in a dramatic increase in *Ips* populations during the spring and through late fall and caused considerable tree mortality.

Table 1: Southern Pine Beetle Infestations by State, 2001 - 2007 and Latest Trend.

State	2000	2001	2002	2003	2004	2005	2006	2007	Latest Trend
OK	0	0	0	0	0	0	0	0	Static
AR	0	0	0	0	0	0	0	0	Static
TX	0	0	0	0	0	0	0	0	Static
LA	0	0	0	0	0	0	0	5	UP
MS	809	143	689	65	158	92	50	208	UP
AL	26,407	11,849	4,991	206	1,434	1,791	1,286	765	Down
GA	2,682	4,938	9,070	333	73	0	0	2,077	**UP**
TN	9,883	12,746	6,394	1,294	257	5	14	39	UP
KY	1,664	3,456	NA	NA	0	0	0	0	Static
VA	1,946	763	274	50	10	0	0	64	UP
FL	1,172	2,892	650	2	10	7	3	43	UP
SC	13,124	22,270	67,127	9,514	4,324	2,388	2,267	734	Down
NC	2,199	3,871	4,028	181	10	24	49	15	Down
Total	59,886	62,928	93,223	11,645	6,276	4,307	3,669	3,950	Generally Static

Progress continues on the evaluation and development of systemic insecticides and injection systems. With the discovery that emamectin benzoate and fipronil were effective against bark beetles in 2004 and confirmation in 2005, a trial were established in Texas in 2006 to evaluate the effects of treatment timing and dose rate on chemical efficacy and duration. Other chemicals, including imidacloprid, nemadectin and cyfluthrin, also were tested. The 2005 results again indicate that emamectin benzoate was highly effective against bark beetles and wood borers and fipronil and nemadectin were moderately effective. Emamectin benzoate, fipronil and nemadectin continued to be effective in 2006, particularly at higher rates. An additional trial was established in 2007 to evaluate three new formulations of fipronil. All were found to be equally effective against *Ips*. Also, we are interested in determining if these chemicals are effective against more aggressive *Dendroctonus* species. Trials established in 2005 and 2006 in Mississippi and Alabama for southern pine beetle on loblolly pine, in California for western pine beetle on ponderosa pine, in Utah for spruce beetle on Englemann spruce, and in Idaho, British Columbia and Colorado for mountain pine beetle on lodgepole pine are on going. An additional trial was established in 2007 in Alabama for southern pine beetle on loblolly pine. To date, data from MS, CA and AL trials indicate that emamectin benzoate is highly effective in reducing tree mortality by bark beetles. Fipronil showed some good activity at these sites as well. In contrast, results from ID, UT, and BC 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 AL, CA, ID and UT is being prepared for publication.

Trials were established in two seed orchards in 2007 to evaluate imidacloprid and dinotefuran alone or combined with emamectin benzoate and fipronil and their effects against pine seed bug. The data indicates that both imidacloprid and dinotefuran have activity against seed bug, but the addition of emamectin benzoate or fipronil does not enhance their effects. Neither imidacloprid nor dinotefuran appeared to have any appreciable activity against coneworms. As in the past, emamectin benzoate significantly reduced coneworm damage, but surprisingly only at one orchard. There was no apparent effect at the second orchard. The trial will be extended into 2008 to evaluate treatment duration.

The tip moth project, established in 2001, to evaluate the true impact of pine tip moth on the growth of loblolly pine and identify site characteristics that influence the occurrence and severity of pine tip moth infestations, was further expanded in 2007. Eighty-eight impact plots on 57 sites are now established in the Western Gulf Region. An additional 11 hazard-rating plots were established in 2007, bringing the total to 120. The analysis of impact data indicates that protected trees continue to grow at an accelerated rated 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. The hazard-rating model developed by Mr. Andy Burrow, Potlatch Forest Holdings, includes data collected through 2006 and indicates that seven site characteristics (in order of increasing importance)- site index, percent sand, clay and silt in the soil, drainage class, texture of soil in B horizon, and depth to B horizon- have the greatest influence on the occurrence and severity of tip moth damage. The additional data collected in 2007 will be used to validate/improve the model.

Systemic insecticide trials revealed that single applications of fipronil continued to be effective against pine tip moth using different application techniques and for extended periods of time. A trial was established in 2006 to evaluate effects of volume of fipronil solution applied. Generally, fipronil efficacy improved with increasing volume. One and three trials were established to begin assessment of operationally applying fipronil by hand or machine planter, respectively. Hand application after planting is marginally effective, whereas applications of fipronil while machine planting was shown to be quite effective in reducing tip moth damage and improving tree growth. In light of the above results, BASF submitted a request to EPA in June 2006 for a full registration of fipronil for protection of pine seedlings against pine tip moth. EPA approved the use of fipronil by soil injection in May 2007 and the new product, "PTM SC Insecticide", now has state approval in TX, OK, AR, LA, MS, AL, GA, FL, SC, NC, VA, TN and WV. Finally, a trial was established on two sites to test the efficacy of fipronil applied to containerized seedlings prior to planting. The results were outstanding; essentially no tip moth damage was found on treated seedlings throughout the first growing season. BASF is considering the possibility of modifying the PTM label to include use on containerized seedlings.

A pilot test was established on one site in 2005 to evaluate the potential efficacy of tablets containing different rates of imidacloprid plus or minus fertilizer. Although most insecticide treatments did reduce tip moth damage levels, the effects on growth were marginal. One trial was established in 2006 on two sites to evaluate effects of different imidacloprid formulations on tip moth damage levels. Most imidacloprid formulations provided good to excellent protection against pine tip moth. Based on these results, Bayer Crop Science submitted a request and received approval from EPA for a full registration for their imidacloprid + fertilizer tablet in December 2006. The new tablet, called "SilvaShield™ Forestry tablets", currently has state approval in all states, except CA. SilvaShield™ tablet trials were established on six sites in 2007 to further evaluate application techniques. Tablets applied in plant holes worked very well against tip moth and improved tree growth. Those tablets applied next to seedlings after planting were less effective. New trials are planned in 2008 to refine application techniques and rates and test operational use.

LEAF-CUTTING ANT

Bait Development and Evaluation - East Texas

Highlights:

- Preference tests showed ants were most attracted to corn, followed by grapefruit and then orange. Indoxacarb did not affect bait retrieval rates. The attractiveness of grapefruit or corn could not be enhanced with the addition of sugar, corn syrup, honey or molasses.
- Two efficacy trials were conducted in 2007 to evaluate the efficacy of grapefruit bait containing different concentrations of indoxacarb against the Texas leaf-cutting ant. None of the rates were consistently attractive or effective in halting ant activity. The bait needs to be modified to improve attraction.

Justification: Amdro® Ant Block bait is the only product whose label currently includes the Texas leaf-cutting ant bait. The results of trials testing this bait in spring 2005 and 2006 were less than satisfactory (see 2005 and 2006 Annual Report). Similarly two indoxacarb baits (Advion® fire ant bait and experimental mole cricket bait) tested in the summer of 2006 were found to be ineffective. With no other alternatives available it is necessary to develop a new bait formulation specifically designed for leaf-cutting ants (LCA). DuPont had acquired LCA bait recipes and a pellet mill from Griffin LLC and was willing to allow us to use it. Citrus flakes, know to be attractive to LCA, are available from the Rio Grande Valley via Texas Citrus Mutual.

Objective: Develop and evaluate the efficacy of new bait using indoxacarb and citrus pulp or corn for reducing activity in Texas leaf-cutting ant colonies.

Cooperators:

Mr. David Stevens	formerly with DuPont, Natchitoches, LA
Dr. Phil Brown	DuPont, Wilmington, DE
Mr. Jay Madden	Texas Citrus Mutual, Mission, TX
Ms. Emily Goodwin	formerly with Temple-Inland Forest Products, Diboll, TX
Mr. Bob Cassell	Hancock Forest Management, Silsbee, TX

Study Sites: Active colonies (60) were located in East Texas on lands owned by Temple-Inland Forest Products, Hancock Forest Management and private landowners.

Insecticide:

Indoxacarb – undetectable, slow-acting poison.

Experimental bait - citrus pulp pellets; packing (tight); color (light yellow); size (3 - 5 mm).

Research Approach:

A recipe to make leaf-cutting ant bait was acquired by DuPont with the acquisition of Griffin LLC. This recipe served as a basic guide to develop several new bait formulations. Citrus pulp (orange and grapefruit) was obtained from Texas Citrus Mutual. DuPont provided a laboratory pellet mill and soybean oil containing different concentrations of indoxacarb. Bait formulations were produced that varied in pellet size, carrier type, additives to enhance attraction, and presence or absence of indoxacarb. These formulations were tested in six different preference tests. The tests and treatments include:

<u>Test 1</u> (5 replicates per treatment):
- A: Orange pulp + Soybean oil (SBO) @ 1/8" diameter
- B: Grapefruit pulp + SBO @ 1/8"
- C: Corn + SBO @ 1/8"
- D: Orange pulp + SBO @ 3/32" diameter
- E: Grapefruit pulp + SBO @ 3/32"
- F: Corn + SBO @ 3/32"

<u>Test 2</u> (12 replicates per treatment):
- A: Orange pulp + SBO
- B: Grapefruit pulp + SBO
- C: Corn + SBO
- D: Orange pulp + SBO + Orange juice (6%)
- E: Grapefruit pulp + SBO + Orange juice (6%)

<u>Test 3</u> (10 replicates per treatment):
- A: Grapefruit pulp + SBO
- B: Grapefruit pulp + SBO + Indoxacarb (0.05%)
- C: Corn + SBO
- D: Corn + SBO + Indoxacarb (0.05%)

<u>Test 4</u> (10 replicates per treatment):
- A: Grapefruit pulp + SBO
- B: Grapefruit pulp + SBO + Indoxacarb (0.05%)

<u>Test 5</u> (10 replicates per treatment):
- A: Corn + SBO
- B: Corn + SBO + Sugar (0.4%)
- C: Corn + SBO + Sugar (5.0%)
- D: Corn + SBO + Indoxacarb (0.15%) + Sugar (0.4%)
- E: Citrus pulp blank

<u>Test 6</u> (10 replicates per treatment):
- A: Corn + SBO
- B: Corn + SBO + Corn Syrup (5.0%)
- D: Corn + SBO + Indoxacarb (0.15%) + Sugar (5.0%)
- D: Corn + SBO + Indoxacarb (0.15%) + Honey (5.0%)
- D: Corn + SBO + Indoxacarb (0.15%) + Corn Syrup (5.0%)
- D: Corn + SBO + Indoxacarb (0.15%) + Molasses (5.0%)

Trials 1-4 were conducted in June 2007, while Trials 5 and 6 were conducted later in December. Five gram portions of different pellet types (see treatments above) were placed into petri dishes. The dishes were sealed with paraffin strips. Each treatment was replicated 5-12 times. For each trial replicate, one dish of each treatment were distributed at random within the central nest area (but near areas of high activity) or along foraging trails. All dishes within each replicate were retrieved when the dish, containing the most attractive bait, was nearly empty or at the end of the test period (approximately 3 hours). The amount (weight) of bait removed by ants from each petri dish was noted and means calculated for each treatment.

Based on the results of the first four preference trials, two efficacy trials were established in July and November 2007 to test grapefruit bait with different concentrations of indoxacarb. Application rates of all baits were 10 g/m^2 per colony. A cyclone spreader was used to evenly spread measured amounts of an assigned bait over the central nest area (CNA). The tests and treatments included:

Test 1 (begun in July 2007):

A. Grapefruit pulp carrier with 0.05% indoxacarb
B. Grapefruit pulp carrier with 0.025% indoxacarb
C. Grapefruit carrier blank (no indoxacarb)
D. Check (no treatment)

Test 2 (begun in November 2007):

A. Grapefruit pulp carrier with 0.15% indoxacarb
B. Grapefruit pulp carrier with 0.1% indoxacarb
C. Grapefruit pulp carrier with 0.05% indoxacarb
D. Grapefruit pulp carrier with 0.025% indoxacarb
E. Check (no treatment)

Treatments were applied to 7 colonies each in July 2007 and 4 – 9 colonies in November 2007.

The number of active entrance/exit mounds was counted prior to treatment and periodically following treatment at 1, 2, 4, and 8 weeks. Seven 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:

Preference Trials: Rather unexpectedly, the first test showed that the ants prefer smaller (3/32” diameter) pellets made of corn to either type of citrus pulp (Fig. 1). Grapefruit was preferred over orange. Although corn was best, there was concern that the high level of fat in corn would reduce the potential storage life of the bait. Thus the intent of the second test was to try to enhance the attraction of the citrus baits. Citrus bait, with and with out orange juice, were compared to corn bait. The addition of orange juice did not improve the attractiveness to either citrus bait (Fig. 2). Corn was significantly more attractive than orange but not to grapefruit. The third trial showed that the addition of indoxacarb did not deter ants from retrieving the bait. In this trial grapefruit with active was essentially equal in attractiveness to corn with active (Fig. 3). The fourth trial confirmed that the presence of indoxacarb in the bait did not effect bait retrieval (Fig. 4). Based on the above results, two efficacy trials were conducted on the grapefruit plus indoxacarb formulation (see below). However, the unsatisfactory results prompted two additional preference tests. The focus was shifted to corn as the carrier. As before, indoxacarb did not influence the attractiveness of bait to the ants (Fig. 5). Although the addition of sugar did not significantly enhance attraction, there appeared to be some increase in attraction with an increase in sugar concentration. Thus another trial was conducted to evaluate effects of adding one of several sugary ingredients. Again the addition of sugary additives or indoxacarb did not influence the attractiveness of the bait to leaf-cutting ants (Fig. 6).

Efficacy Trials: In trial 1, the grapefruit bait treatment with the higher indoxacarb concentration (0.05%) quickly reduced ant activity (91% and 96%) on treated colonies compared to initial activity within 1 and 2 weeks after treatment, respectively (Table 2). The lower rate of indoxacarb (0.025%) also significantly reduced ant activity at 2 weeks post-treatment but not to the extent of the higher rate. At this time (2 weeks), 57% (4 of 7) and 14% (1 of 7) of the high and low treatment colonies, respectively, were completely inactive. Unfortunately, all colonies were active and the level of ant activity increased by 4 and 8 weeks post treatment, although at a reduced level (40% and 30%) compared to initial levels. The reduced ant activity 8 weeks post treatment suggests that the bait was effective in killing a few, but not all, of the queens in each colony. Based on the rate effect observed in this trial, it was surmised that the efficacy of the bait may be improved if the concentration of indoxacarb was doubled (0.1%) or tripled (0.15%).

In trial 2, all four indoxacarb baits significantly reduced ant activity after 1 and 2 weeks after treatment compared to initial activity (Table 3). However, the effect of a given treatment was quite variable - the activity of some colonies was dramatically reduced, whereas, some appeared to be unaffected after 2 weeks. At two weeks, the highest rate (0.15%) had the greatest impact on ant activity, reducing overall activity by 76%. In contrast, the greatest impact caused by the three lower three rates (0.1%, 0.05% and 0.025%) was delayed until 4 - 8 weeks post treatment with reductions of 55%, 64% and 68%, respectively. The 0.15% (highest) rate completely halted all activity on 2 of 9 (22%) after 4 weeks but one resumed activity after 8 weeks. One each of the 0.1% and 0.025% treatments ultimately halted ant activity after 8 weeks.

Conclusions:

The preference trials showed that corn was the most attractive matrix tested. This was surprising given that several effective leaf-cutting ant products (Blitz and Volcano) use citrus pulp. It is possible that corn has not been used in the past because of its relatively high fat content (7+%) and tendency to go rancid when stored at high temperatures. With this in mind, it was decided to go with the next most attractive matrix, grapefruit. Several preference trials also showed that the presence of indoxacarb had no affect on the retrieval rate of bait by the ants. Grapefruit bait containing indoxacarb appeared to be attractive to ants in preference trials. Based on the results of the first efficacy trial we thought we just needed to raise the concentration of indoxacarb in the bait. However, increasing the rate did not improve efficacy in the second test. The results indicate that the ants were not always attracted to the bait; it depended on the colony treated. We attempted to enhance attraction to the grapefruit pulp by the addition of sugar. Unfortunately, no enhancement was observed. Thus, we have decided to switch to corn as the carrier. Phil Brown, DuPont (personal communication), indicates that the inclusion of antioxidants in the formulation may extend the storage life of corn bait. We could not improve attraction to corn with additions of sugar, corn syrup, molasses or honey, so we stuck with corn, soybean oil and water as the primary ingredients.

Future work in 2008 will focus on:

1) The efficacy of corn bait containing the highest rate (0.15%) of indoxacarb. If the results are good to excellent, we could evaluate the potential for reducing indoxacarb rate while maintaining good efficacy.

2) Improve the integrity/strength of bait pellets by adding a “binder”. The pellets are currently too fragile.

3) Evaluate the storage life of the corn bait.

Acknowledgements: Thanks go to Temple-Inland, Hancock Forest Management, and several private landowners who provided access to ant colonies. We appreciate the donation of citrus pulp from Texas Citrus Mutual and indoxacarb formulation made by DuPont, Wilmington, DE for the trial.

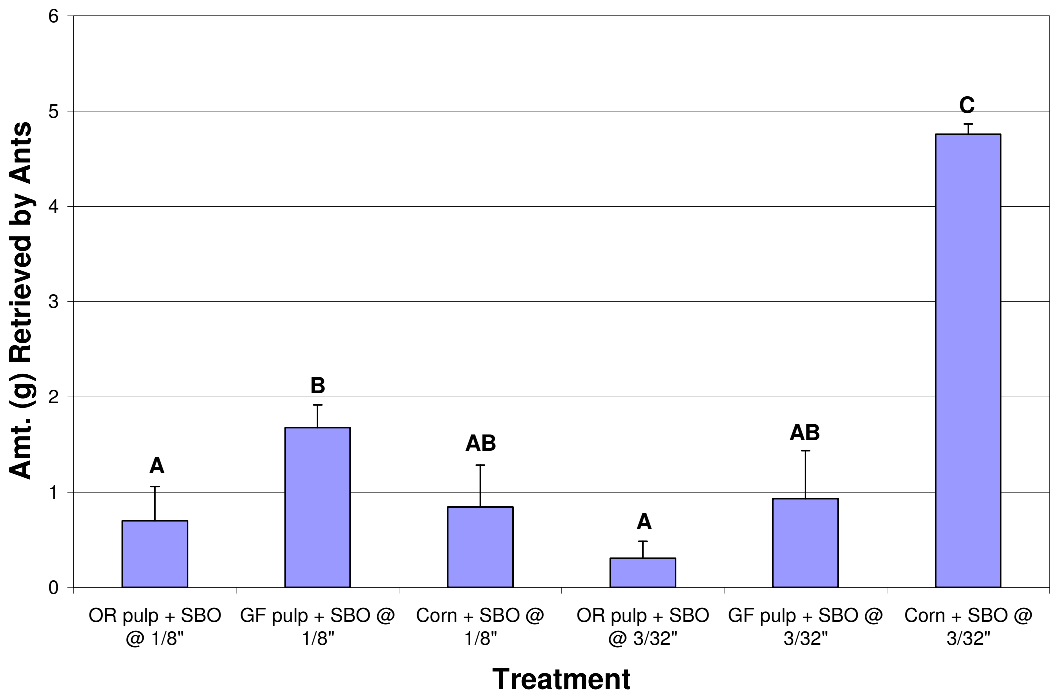


Figure 1. The attractiveness of the Texas leaf-cutting ant to bait of different sizes and made with different carriers, East Texas, Summer 2007. Bars having the same letter are not significantly different at the 5% level based on Fisher's Protected LSD.

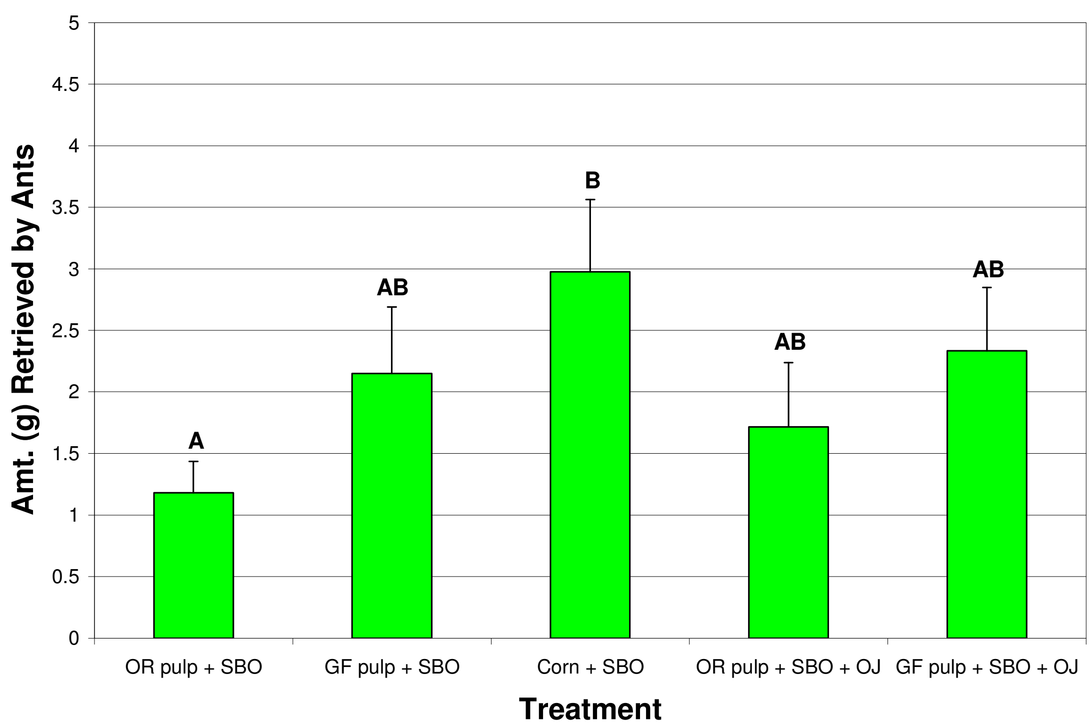


Figure 2. The attractiveness of the Texas leaf-cutting ant to bait made with different carriers, East Texas, Summer 2007. Bars having the same letter are not significantly different at the 5% level based on Fisher's Protected LSD.

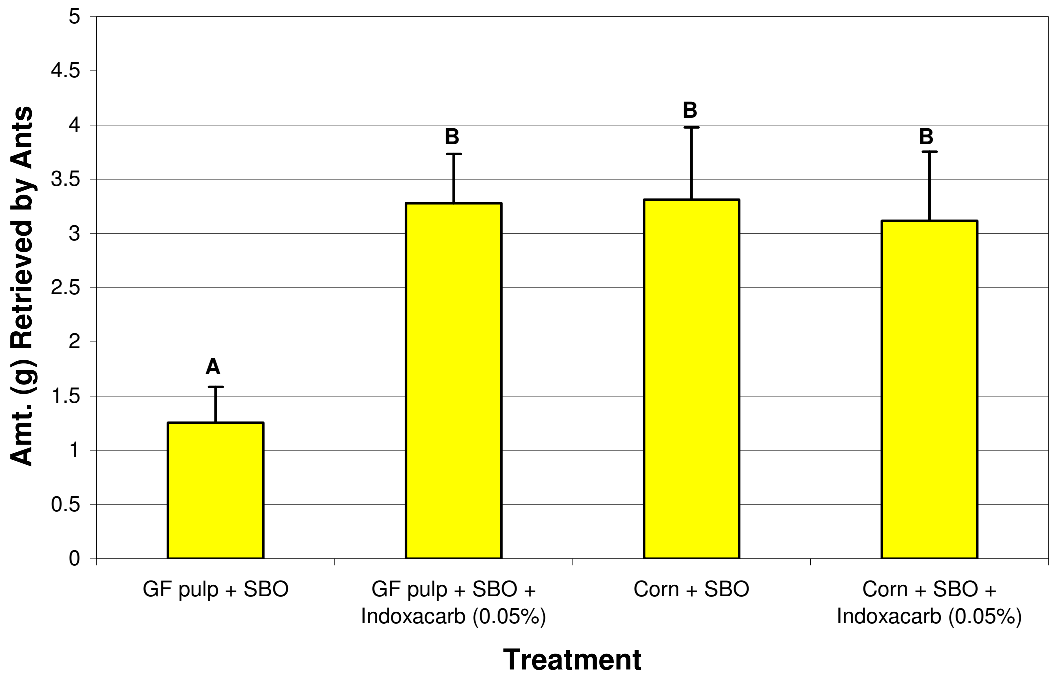


Figure 3. The attractiveness of the Texas leaf-cutting ant to bait made with different carriers with and without indoxacarb, East Texas, Summer 2007. Bars having the same letter are not significantly different at the 5% level based on Fisher's Protected LSD.

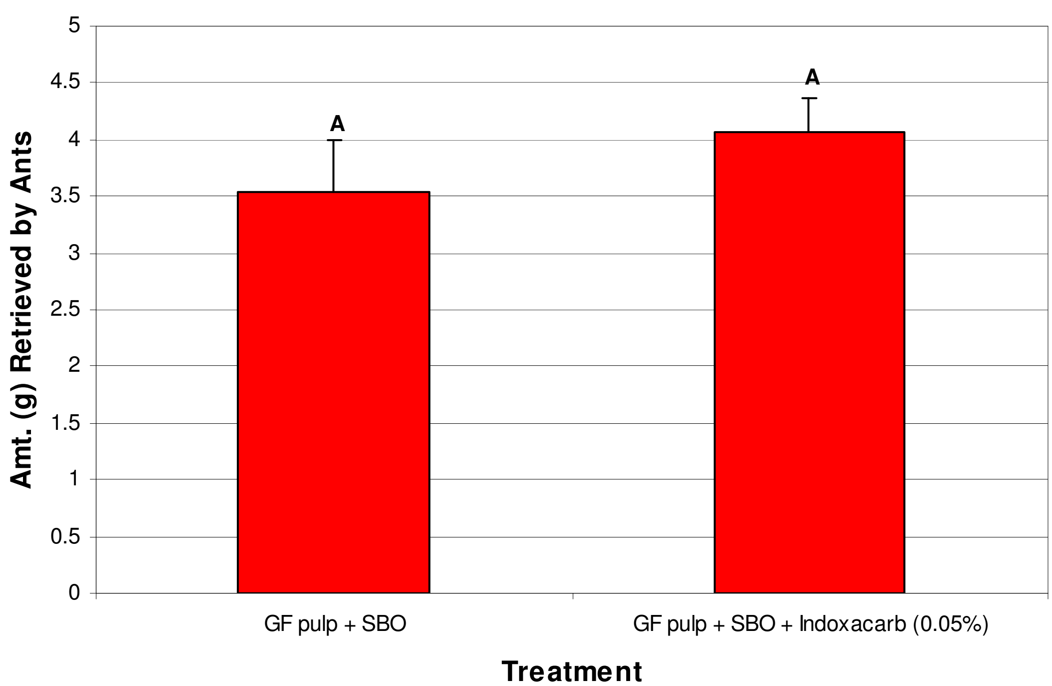


Figure 4. The attractiveness of the Texas leaf-cutting ant to bait made with grapefruit carrier with and without indoxacarb, East Texas, Summer 2007. Bars having the same letter are not significantly different at the 5% level based on Fisher's Protected LSD.

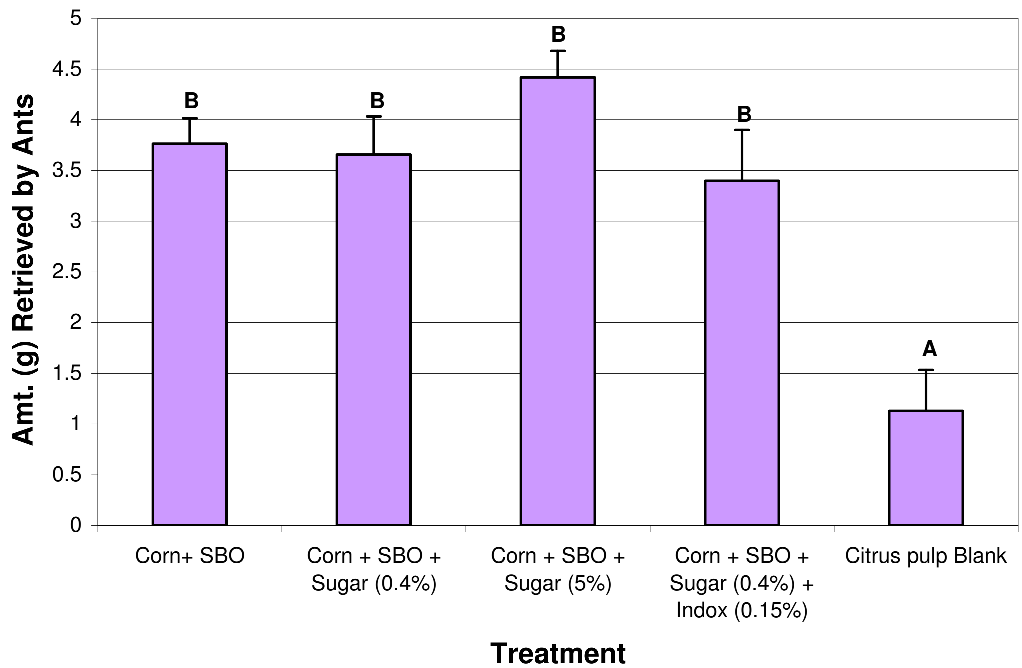


Figure 5. The attractiveness of the Texas leaf-cutting ant to bait made with corn carrier with and without indoxacarb and/or additives, East Texas, Fall 2007. Bars having the same letter are not significantly different at the 5% level based on Fisher's Protected LSD.

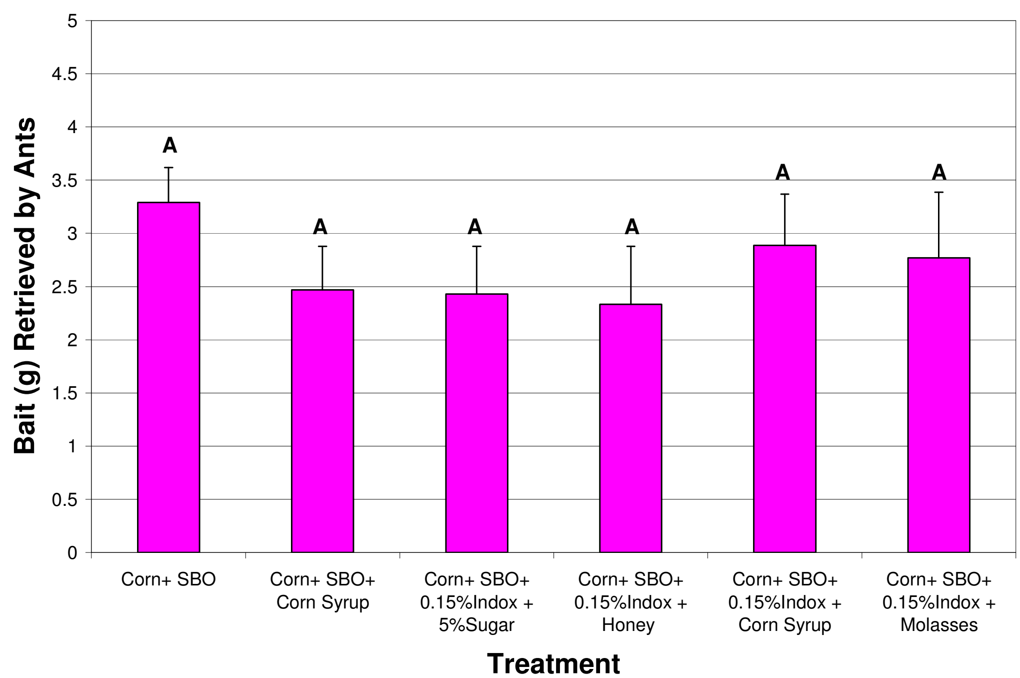


Figure 6. The attractiveness of the Texas leaf-cutting ant to bait made with corn carrier with and without indoxacarb and/or additives, East Texas, Fall 2007. Bars having the same letter are not significantly different at the 5% level based on Fisher's Protected LSD.

Table 2. Efficacy of indoxacarb baits applied to control the Texas leaf-cutting ant, *Atta texana* , in East Texas (summer 2007).

Treatment	No. of colonies treated	Mean central nest area (ft^2)	Mean % of initial activity[a] (% of colonies inactive after): 1 weeks		2 weeks		4 weeks		8 weeks	
Citrus Pulp + Indoxacarb										
0.05% AI	7	547	9.0 **a**	(43)	4.2 **a**	(57)	21.0 **a**	(0)	59.4 **a**	(0)
0.025% AI	7	563	25.8 **a**	(14)	32.6 **b**	(14)	71.7 **b**	(0)	70.5 **ab**	(0)
Citrus Pulp blank	3	505	80.2 **b**	(0)	77.6 **c**	(0)	71.8 **b**	(0)	83.4 **b**	(0)
Check (no treatment)	7	472	106.8 **b**	(0)	110.3 **c**	(0)	113.5 **b**	(0)	132.4 **b**	(0)

CNA = Central Nest Area; FM = Foraging Mounds

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

Table 3. Efficacy of indoxacarb baits applied to control the Texas leaf-cutting ant, *Atta texana* , in East Texas (Fall 2007).

Treatment	No. of colonies treated	Mean central nest area (ft^2)	Mean % of initial activity[a] (% of colonies inactive after): 1 weeks		2 weeks		4 weeks		8 weeks	
Citrus Pulp + Indoxacarb										
0.15% AI	9	706	35.2 **a**	(0)	24.5 **a**	(0)	31.4 **a**	(22)	32.9 **a**	(11)
0.1% AI	9	648	58.9 **a**	(0)	58.4 **b**	(0)	48.0 **a**	(0)	44.8 **a**	(11)
0.05% AI	8	655	62.9 **a**	(0)	61.8 **b**	(0)	35.8 **a**	(0)	36.2 **a**	(0)
0.025% AI	4	786	51.5 **a**	(0)	77.8 **b**	(0)	31.6 **a**	(0)	58.3 **a**	(25)
Check (no treatment)	8	957	114.6 **b**	(0)	97.2 **c**	(0)	123.6 **b**	(0)	98.8 **b**	(0)

CNA = Central Nest Area; FM = Foraging Mounds

[a] 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 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 onto all the queens, the surviving queens will ultimately repopulate the colony. The data collected during the 2005 and 2006 Amdro trial indicate 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, communication with several forest industries, TIMOs and private landowners continues to indicate that this bait is rarely effective in completely halting ant activity with a single application, let alone several applications.

The future availability of Volcano is very limited due to the persistence of sulfluramid in the environment (e.g., chemicals related to sulfluramid have been found in the blood of factory workers). Communications with DuPont personnel indicated that they have no plans to resume production or sale of the Volcano bait.

Although DuPont has decided not to resume production of Volcano, they recognize a need for a safe and effective control option for Texas leaf-cutting ants. In light of this, they provided the WGFPMC with a laboratory pellet mill (acquired from Griffin LLC) and active ingredient (indoxacarb) to develop a new bait formulation specifically designed for leaf-cutting ants. Initial plans called for the use of citrus pulp (donated by Texas Citrus Mutual) as the carrier. However, subsequent tests indicate the ants prefer corn. Although we persisted with the use of grapefruit pulp in the bait (for different reasons), efficacy trials showed that the grapefruit bait was ineffective in halting ant activity. The reason appears to be inadequate attraction and retrieval of the bait by the ants. Modifications to the bait and testing for efficacy are planned for 2008.

In the mean time, landowners have no safe and effective means of controlling leaf-cutting ants. The use of methyl bromide for control of leaf-cutting ants was phased out at the end of 2005. The Grants' Total Ant Killer bait and new Amdro® Ant Block bait are safe but, frequently, are ineffective with a single application. If a landowner elects to use one of these products, we advise that they follow two primary rules to insure the best possible results: 1) apply the bait in the winter after the first major frost to reduce competition with preferred plant sources; 2) apply the bait when the ants first become active (foraging and/or building mounds) during the day. In the winter, this usually occurs in the late morning when temperature rises above 50^{o}F. In the summer, this is in the late evening when temperatures cool below 85^{o}F. 3) Apply the bait when the ground is dry and rain or heavy dew is not expected for 24 hrs. If the ground is wet, the bait will absorb the moisture and become unattractive to the ants.

SYSTEMIC INSECTICIDE INJECTION TRIALS

Potential Insecticides for Seed Bug Control in Pine Seed Orchards - AR & TX

Highlights:

- Tree IV injections of imidacloprid alone or combined with emamectin benzoate (EB) or fipronil did significantly reduce seed bug damage on first and second-year cones. Dinotefuran combined with EB also reduce seed bug damage.
- Tree IV injections of EB reduced coneworm damage by 73 - 85% at the slash orchard but surprisingly had no apparent effect in the loblolly orchard. Fipronil also had no apparent effect on the amount of coneworm damage in the loblolly orchard.
- None of the systemic insecticide treatments affected seed germination percent compared to checks.

Justification: Trials conducted from 1998 – 2006 at TX, LA, AL and FL seed orchards showed that both emamectin benzoate and fipronil were very effective in reducing damage caused by coneworms, but to a lesser extent damage caused by seed bugs. New formulations of imidacloprid and dinotefuran 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 a new formulation of imidacloprid and dinotefuran against seed bugs in pine seed orchards and 2) determine the duration of treatment efficacy.

:

Cooperators:

Dr. Tom Byram	Western Gulf Tree Improvement Program
I.N. Brown	Texas Forest Service, Magnolia Springs, TX
Mr. Steve Smith	Weyerhaeuser Company, Magnolia, AR
Mr. Joseph Doccola	Arborjet, Inc., Worchester, MA

Study Sites

Loblolly pine:

Weyerhaeuser's Magnolia orchard near Magnolia, AR (Columbia Co.)

Slash pine:

Texas Forest Service's Magnolia Springs orchard near Jasper, TX (Jasper Co.)

Insecticides:

Emamectin benzoate (Ava-jet, Arborjet, Inc.) -- avermectin derivative

Fipronil (experimental BAS 350 UB I) -- a phenyl pyrazole insecticide that has shown systemic activity against other Lepidoptera (tip moth)

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

Dinotefuran (experimental, Valent) – neonicotinoid insecticide with reported activity against sucking insects.

Design: Randomized complete block with clones as blocks. 7 - 11 treatments X 6 -7 clones = 49 - 66 ramets used per study site.

Treatments:

TX Orchard (Slash pine)

1) Imidacloprid (Ima-jet®) (0.4 g AI per inch DBH of tree)
2) Dinotefuran (0.4 g AI per inch DBH of tree)
3) Imidacloprid + Emamectin benzoate (each at 0.4 g AI per inch DBH of tree)
4) Dinotefuran + Emamectin benzoate (each at 0.4 g AI per inch DBH of tree)
5) Emamectin benzoate (0.4 g AI per inch DBH of tree)
6) Asana®XL (standard) applied by hydraulic sprayer to foliage at labeled rate 2 times per year (May and July).
7) Check - untreated

AR Orchard (Loblolly pine)

1) Imidacloprid (Ima-jet®) (0.2 g AI per inch DBH of tree)
2) Imidacloprid (Ima-jet®) (0.4 g AI per inch DBH of tree)
3) Imidacloprid + emamectin benzoate (each at 0.2 g AI per inch DBH of tree)
4) Imidacloprid + emamectin benzoate (each at 0.4 g AI per inch DBH of tree)
5) Imidacloprid + fipronil (each at 0.2 g AI per inch DBH of tree)
6) Imidacloprid + fipronil (each at 0.4 g AI per inch DBH of tree)
7) Emamectin benzoate (0.2 g AI per inch DBH of tree)
8) Emamectin benzoate (0.4 g AI per inch DBH of tree)
9) Fipronil (0.2 g AI per inch DBH of tree)
10) Fipronil (0.4 g AI per inch DBH of tree)
11) Check - untreated

Application Methods:

In April 2007, at least four holes, 3/8 in diameter and 5-8 cm (2-3 in) deep, were drilled about 30 cm high at cardinal points on 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 varied from 5-30 min and was dependent on tree, species, location and weather.

The foliar spray treatment (Asana®XL standard) was applied at one orchard (Magnolia Springs) to foliage in May and July using a hydraulic sprayer at 10 gal/tree. The distance between test trees was ≥20 m to minimize the effects of drift.

Data Collection:

Conelet and Cone Survival – Six to ten branches were tagged per sample tree (minimum of 50 conelets and 50 cones) in April 2007; conelets and cones were reevaluated for damage and survival in late September.

Seed Bug Damage to Conelets - 10 healthy first-year cones were picked "at random" from each tree in July and September; 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.

Seed Germination – 5 – 10 healthy cones were picked "at random" from all healthy cones collected from each ramet; seeds were extracted and cleaned; 200 seeds from each tree were soaked overnight, placed in stratification for 14 days at 35-40^{o}F; seed were then placed on Kimpak germ paper in germination dishes; placed in a germinator at 72^{o}F on a 16h photoperiod; the number of seedlings with all essential structures were counted at 7, 14, 21 and 28 days.

Results:

This trial resulted in only the second incidence of phytotoxic effects produced by a systemic insecticide. In this case, four trees at the Magnolia orchard began exhibiting yellow needles on some (not all) branches in June, about two months after treatment. It turns out that all trees were from the same clone and all had received the full rate of imidacloprid (0.4 g AI per inch DBH)

The study orchard blocks at both orchards have not been sprayed for several years suggesting that pressure from coneworms and seed bugs would likely be high. This was confirmed for coneworms by 16% and 49% damage on check cones in at the Magnolia Springs and Magnolia orchards, respectively (Table 5). Relatively high numbers of both leaffooted and shieldbacked pine seed bugs were observed in the trees at both orchards (Steve Smith, personal communication). This was confirmed for seed bugs by 45% and 63% damage on check cones in at the Magnolia Springs and Magnolia orchards, respectively (Table 6).

Treatment Effect on Conelet and Cone Survival: Cones and conelets on tagged branches were examined in April and September. At both Magnolia Springs and Magnolia, all (or nearly all) treatments containing emamectin benzoate significantly improved survival of conelets compared to check trees (Table 4, Figures 7 & 8). In contrast, none of the treatments improved survival of cones.

Treatment Effect on Coneworm Damage: At Magnolia Springs, all injection treatments containing emamectin benzoate significantly reduced late, but not early, coneworm damage compared to the checks (Table 5, Figure 9). Overall, the emamectin benzoate treatments provided the greatest reductions in total coneworm damage (73 - 85%) compared to the check (Figure 3). They also improved the percentage of healthy cones. Dinotefuran also reduced late coneworm damage but not overall damage. Imidacloprid had no apparent effect on coneworm damage. At Magnolia, in stark contrast, none of the treatments significantly reduced coneworm damage compared to the check. This is the first time in 9 years of testing emamectin benzoate that this chemical has not reduced coneworm damage.

Treatment Effect on Seed Bug Damage to First-Year Conelets: Evaluation of conelet ovules from Magnolia Springs showed all treatments (injection and spray) improved the percentage of good ovules in conelets early in the year compare to checks (Table 6). All, except imidacloprid alone, continued to protect conelets to early fall. At Magnolia, treatments with full rates of imidacloprid and/or emamectin benzoate improved proportion of good ovules. All treatments with emamectin benzoate were still effective into early fall.

Treatment Effect on Seed Bug Damage to Second-Year Cones: Analysis of seed lots from Magnolia Springs showed that treatments containing imidacloprid or dinotefuran significantly reduced seed bug damage compared to checks and were comparable to the spray treatment in efficacy (Table 6, Figure 10). Only dinotefuran + emamectin benzoate improved the number of filled (healthy) seed. Overall, reductions in seed bug damage ranged from 27 – 38% for the best injection treatments to 23% for foliar spray. Analysis of seed lots from Magnolia also showed that treatments containing full and half rates of imidacloprid significantly reduced seed damage compared to checks and improved the number of filled (healthy) seed (Table 6). Overall, reductions in seed bug damage for imidacloprid treatments ranged from 43 – 59%

Treatment Effect on Overall Insect Damage: An estimate of the combined losses due to the two primary insect pest groups, coneworms and seed bugs, was calculated by adding the proportion of coneworm-damaged cones to the proportion of all seed in healthy cones damaged by seed-bug. In this study, it is conservatively estimated that in 2007 coneworms and seed bugs in combination reduced the potential seed crops of check trees by 50% and 81% at Magnolia Springs and Magnolia, respectively (Table 7, Figure 11). All treatments reduced overall insect damage at Magnolia Springs,; but dinotefuran + emamectin benzoate was best – reducing damage by 42%. At Magnolia, only treatments containing the full rate of imidacloprid were able to reduce overall insect damage (20 – 28%).

Treatment Effect on Seed Germination: None of treatments significantly reduced or enhanced germination of either loblolly or slash pine seed (Table 8).

Conclusions: As expected, imidacloprid and dinotefuran were very effective and emamectin benzoate and fipronil were only marginally effective against pine seed bug. Both imidacloprid and dinotefuran, particularly when combined with emamectin benzoate, improved survival of first year conelets and number of filled seed per cone.

As in past trials, the results obtained in 2007 at the Magnolia Springs seed orchard confirm that emamectin benzoate can protect cones against coneworm and will often improve survival of second-year cones. Surprisingly, neither emamectin benzoate nor fipronil had any effect against coneworms at the Magnolia orchard. This is the first time, in 10 years for EB and 5 years for fipronil, that they have not significantly reduced damage during the first year after injection.

The duration of imidacloprid, dinotefuran, emamectin benzoate and fipronil treatment efficacy continues to be of considerable interest. Cone crops at each orchard will be monitored in 2008.

Acknowledgements: We appreciate the assistance provide by Steve Smith, Weyerhaeuser Co., and I.N. Brown, Texas Forest Service. Thanks go to Weyerhaeuser and ArborGen for there assistance with the seed germination evaluation. We appreciate the financial support, chemical donations, and/or injection equipment loans made by Arborjet, Inc, BASF, and Syngenta.

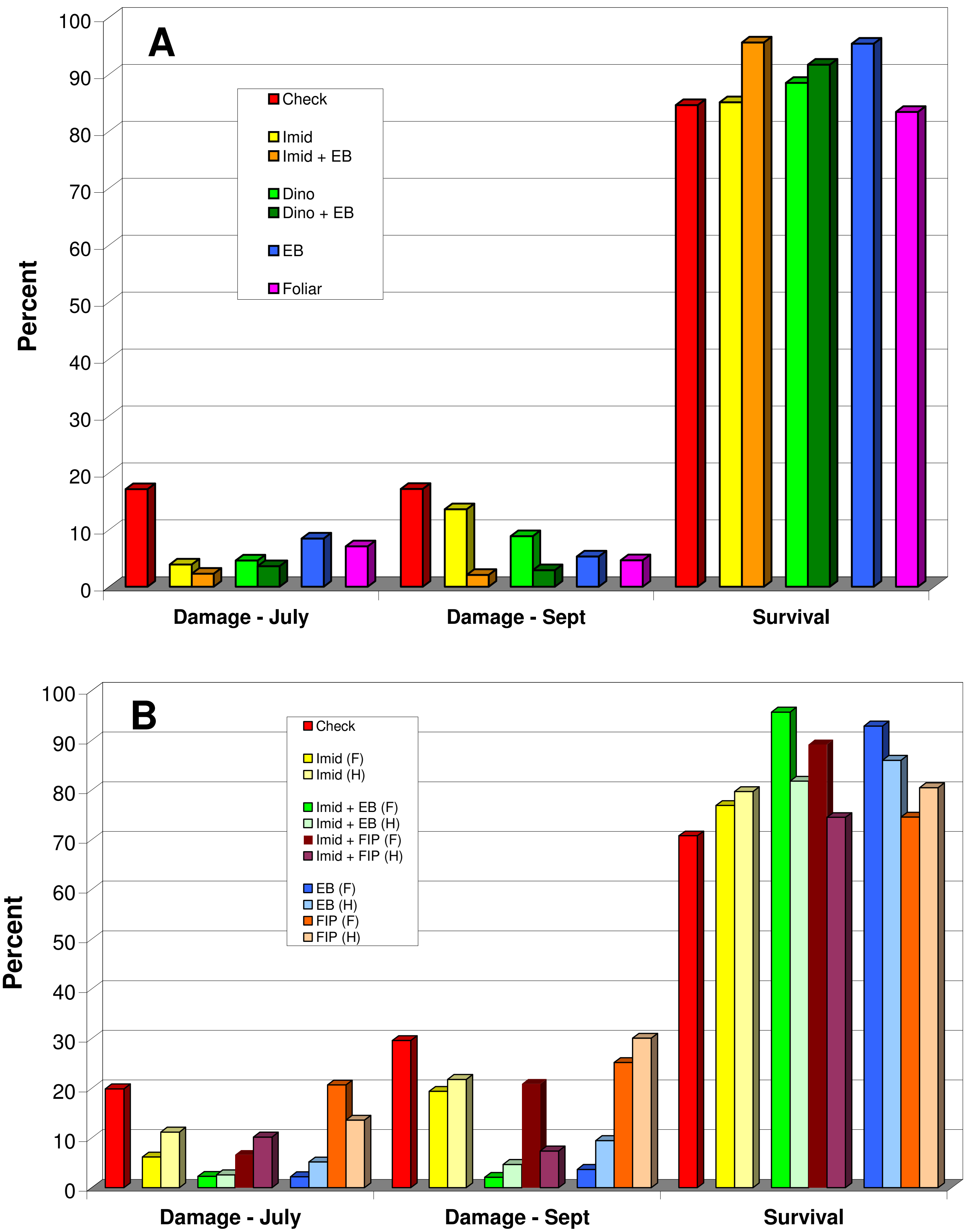
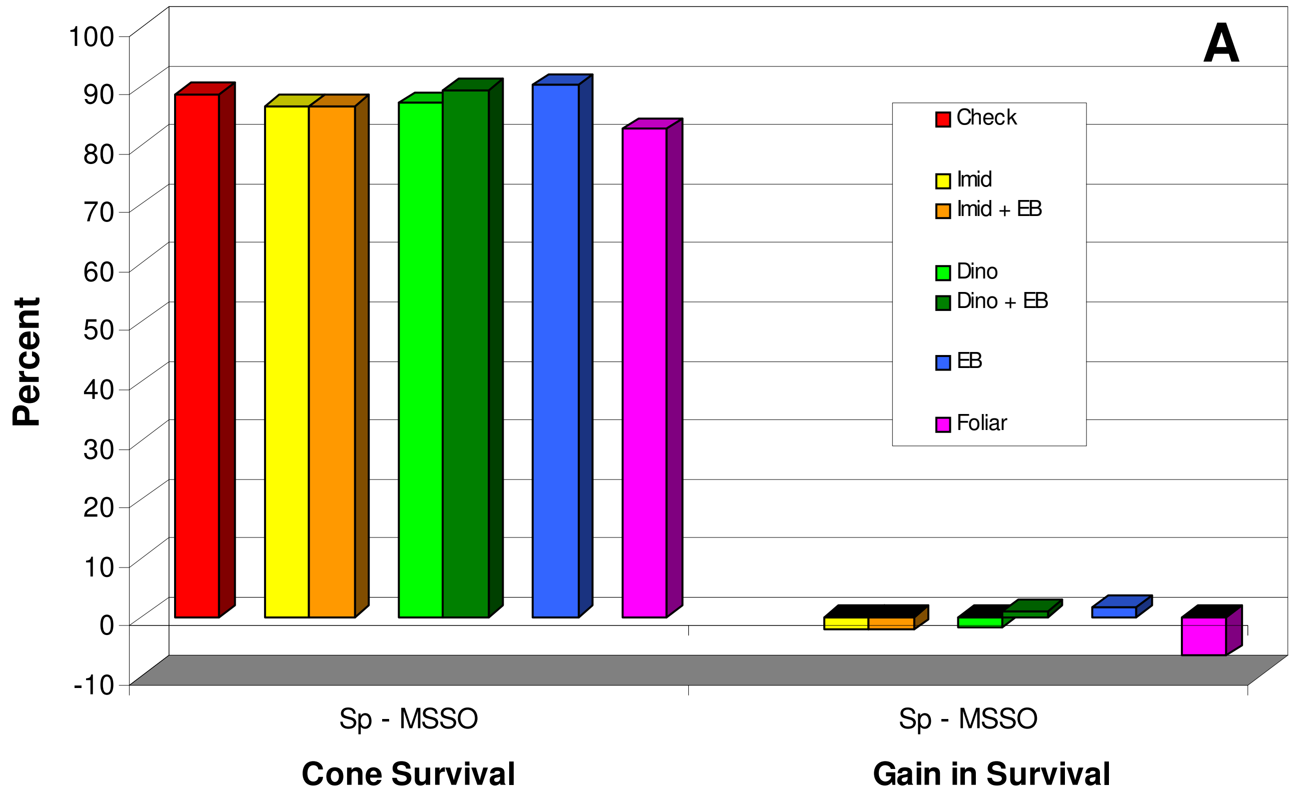


Figure 7. Percent survival and gain in survival of slash pine (A) and loblolly pine (B) conelets protected with injections of systemic insecticides or foliar spray treatments in Texas (A) or Arkansas (B), 2007.



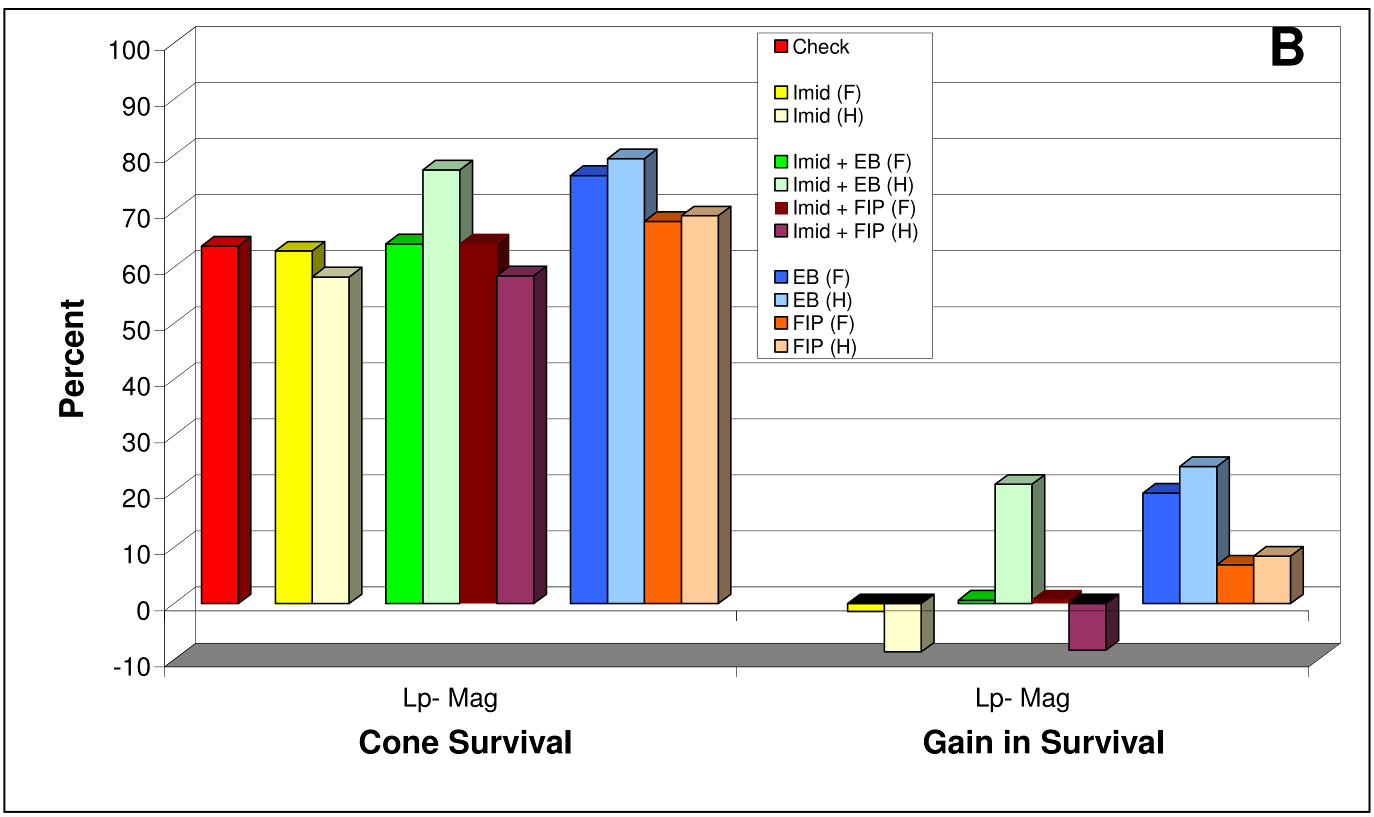


Figure 8. Percent survival and gain in survival of slash pine (A) or loblolly pine (B) cones protected with injections of systemic insecticides or foliar treatments in Texas (A) or Arkansas (B), 2007.

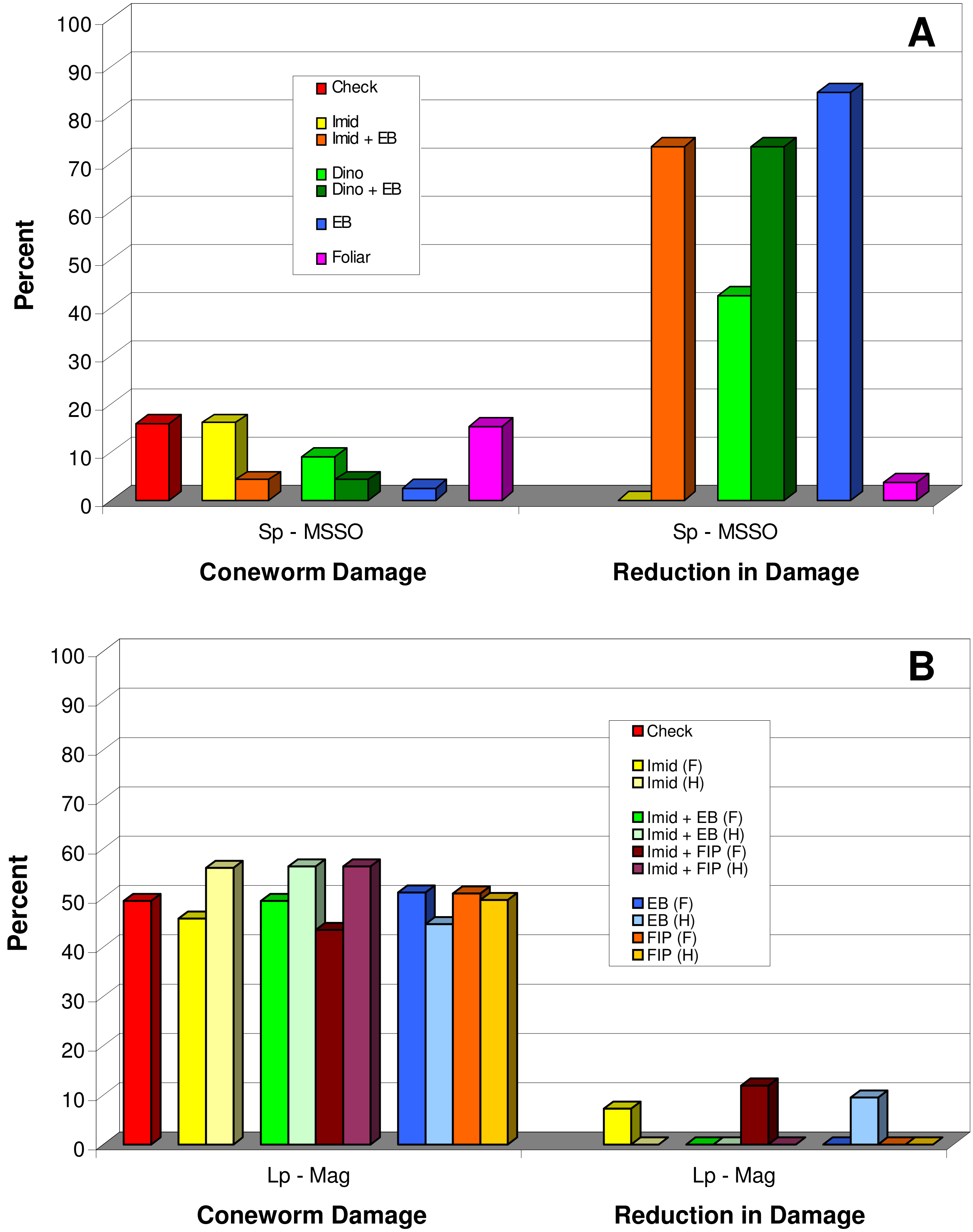
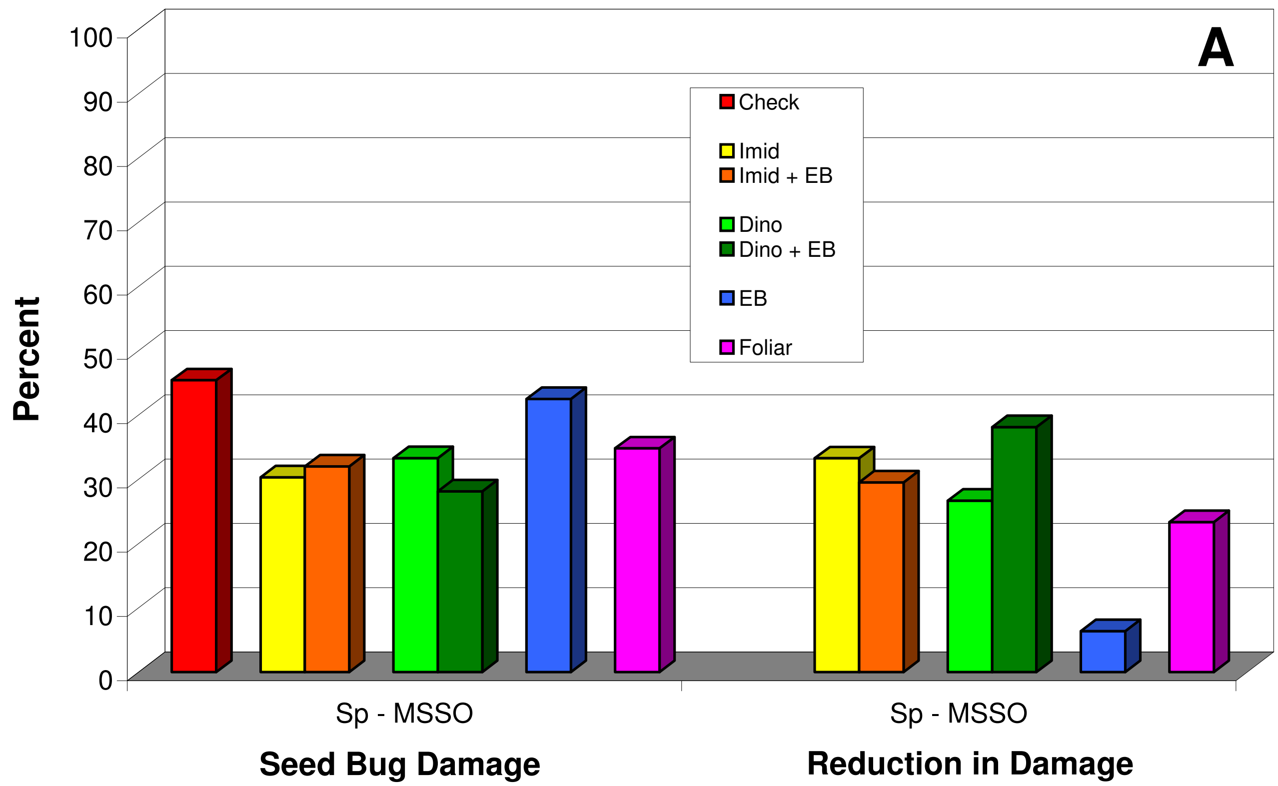


Figure 9. Percent coneworm (*Dioryctria* spp.) damage and reduction in damage on second-year slash pine (A) or loblolly pine (B) cones protected with injections of systemic insecticides or foliar treatments in Texas (A) or Arkansas (B), 2007.



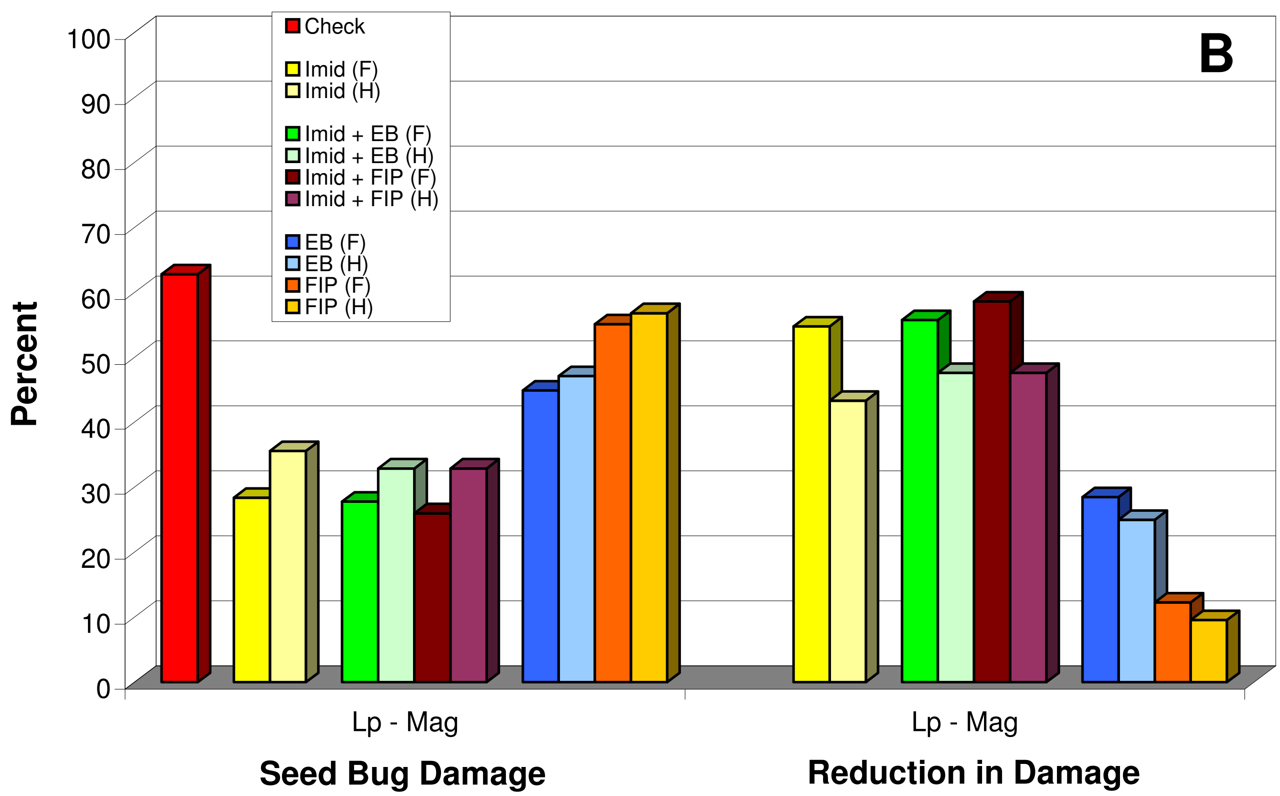
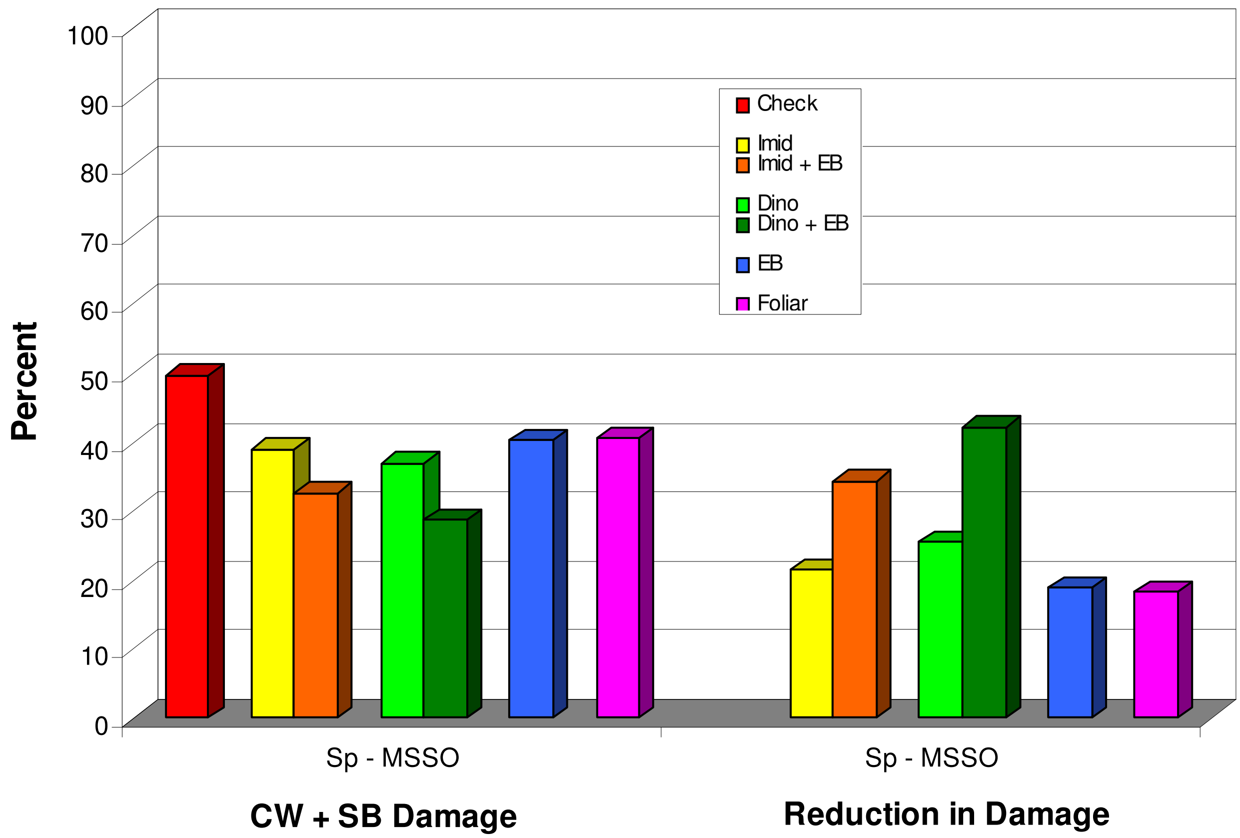


Figure 10. Percent seed bug (*Leptoglossus* sp. *and Tetyra* sp.) damage and reduction in damage to seed from second-year slash pine (A) or loblolly pine (B) cones protected with injections of systemic insecticides or foliar treatments in Texas (A) or Arkansas (B), 2007.



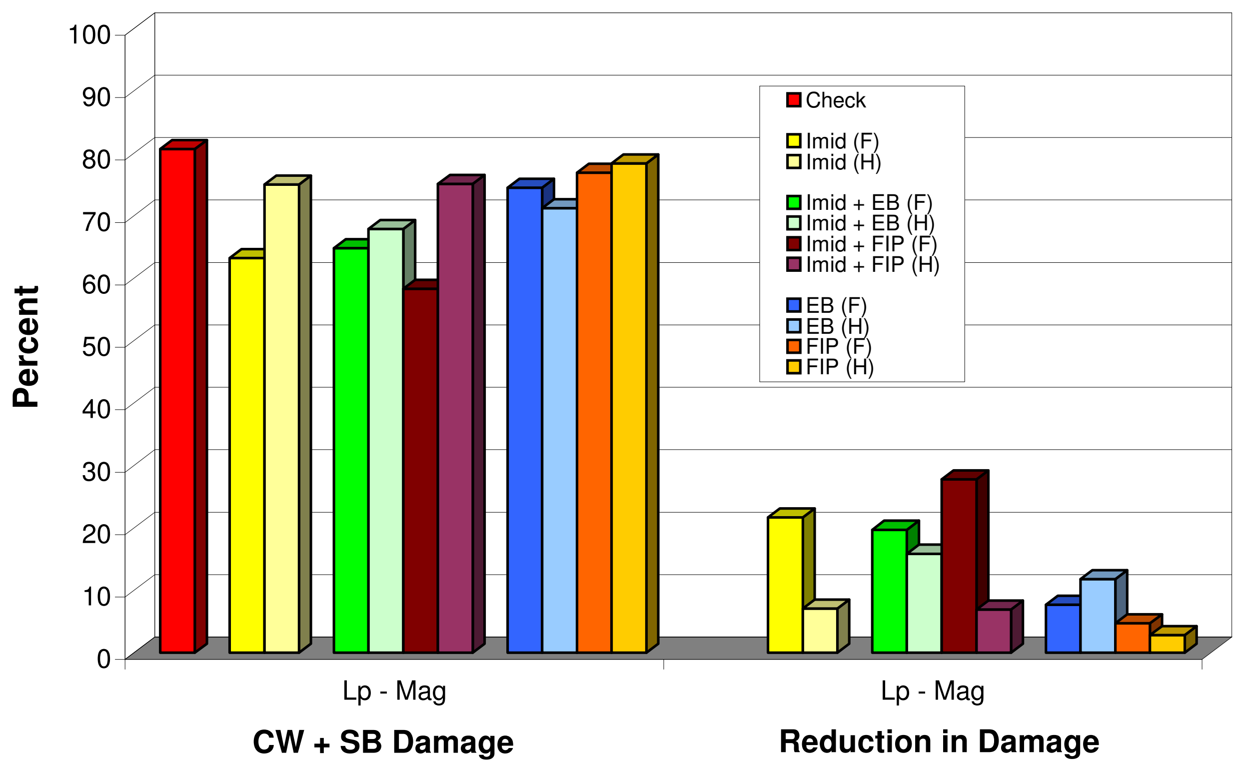


Figure 11. Percent combined damage (coneworm + seed bug) and reduction in damage to seed from second-year slash pine (A) or loblolly pine (B) cones protected with injections of systemic insecticides or foliar treatments in Texas (A) or Arkansas (B), 2007.

Table 4. Mean percentages (± SE) of surviving conelets and cones on branches of loblolly pine and slash pine protected with systemic injection of emamectin benzoate, fipronil or foliar treatments, 2007.

Site	Tree Spp.	Treatment	Application Technique, Treatment Date(s)	N	Mean Survival (%) Conelets	Mean Survival (%) Cones
AR	Loblolly pine	Imidacloprid (full)	Tree IV - Apr., '07	6	76.9 + 10.3	62.9 + 12.7
		Imidacloprid (half)	Tree IV - Apr., '07	6	79.7 + 7.5	58.3 + 16.0
		Imidacloprid (full) + Emamectin benzoate (full)	Tree IV - Apr., '07	6	95.7 + 1.3 *	64.2 + 16.7
		Imidacloprid (half) + Emamectin benzoate (half)	Tree IV - Apr., '07	6	81.8 + 9.8	77.4 + 9.8
		Imidacloprid (full) + Fipronil (full)	Tree IV - Apr., '07	6	89.2 + 2.8 *	64.3 + 12.4
		Imidacloprid (half) + Fipronil (half)	Tree IV - Apr., '07	6	74.5 + 8.9	58.5 + 13.1
		Emamectin benzoate (full)	Tree IV - Apr., '07	6	92.9 + 1.8 *	76.4 + 8.5
		Emamectin benzoate (half)	Tree IV - Apr., '07	6	86.0 + 6.9 *	79.4 + 8.1 *
		Fipronil (full)	Tree IV - Apr., '07	6	74.6 + 5.8	68.2 + 6.5
		Fipronil (half)	Tree IV - Apr., '07	6	80.5 + 5.8	69.2 + 9.6
		Check		6	70.8 + 6.8	63.8 + 10.2
TX	Slash pine	Imidacloprid	Tree IV - Apr., '07	7	85.1 + 4.0	86.6 + 4.8
		Imidacloprid + Emamectin benzoate	Tree IV - Apr., '07	7	95.6 + 1.9 *	86.7 + 10.7
		Dinotefuran	Tree IV - Apr., '07	7	88.5 + 4.6	87.2 + 4.4
		Dinotefuran + Emamectin Benzoate	Tree IV - Apr., '07	7	91.7 + 3.7 *	89.5 + 6.1
		Emamectin benzoate	Tree IV - Apr., '07	7	95.4 + 1.0 *	90.2 + 3.9
		Foliar Spray	Hydraulic 2X	7	83.4 + 2.9	82.8 + 4.1
		Check		7	84.6 + 2.0	88.7 + 2.9

† Means followed by an asteriks in each column of the same year are not significantly different from the check at the 5% level based on Fisher's Protected LSD.

Table 5. Mean percentages (+ SE) of cones killed early and late by coneworms, other-damaged cones, and healthy cones on loblolly pine or slash pine protected with systemic injections of imidacloprid (Imid), dinotefuran (Dino), emamectin benzoate (EB) or fipronil (FIP), 2007.

					Mean Coneworm Damage (%)				
Tree Spp.	Site	Treatment	Application Technique, Treatment Date(s)	N	Early (small dead)	Late (large dead and infested)	Total	Mean Other Damage (%) *	Mean Healthy (%)
Loblolly pine	AR	Imid (full)	Tree IV - Apr., '07	6	6.7 ± 2.1 †	39.1 ± 7.9	45.8 ± 8.8	0.0 ± 0.0	54.2 ± 8.8
		Imid (half)	Tree IV - Apr., '07	6	16.0 ± 7.4	40.2 ± 10.8	56.1 ± 16.4	0.3 ± 0.3	43.6 ± 16.5
		Imid + EB (full)	Tree IV - Apr., '07	6	12.0 ± 8.2	37.5 ± 8.3	49.4 ± 12.7	0.1 ± 0.1	50.4 ± 12.8
		Imid + EB (half)	Tree IV - Apr., '07	6	13.4 ± 8.1	43.0 ± 9.1	56.4 ± 13.7	0.0 ± 0.0	43.6 ± 13.7
		Imid + FIP (full)	Tree IV - Apr., '07	6	6.6 ± 2.3	37.1 ± 8.2	43.5 ± 10.1	0.0 ± 0.0	56.4 ± 10.1
		Imid + FIP (half)	Tree IV - Apr., '07	6	12.4 ± 5.3	44.1 ± 10.2	56.4 ± 13.1	0.0 ± 0.0	43.6 ± 13.1
		EB (full)	Tree IV - Apr., '07	6	3.7 ± 1.4	47.4 ± 10.8	51.1 ± 12.0	0.0 ± 0.0	48.9 ± 12.0
		EB (half)	Tree IV - Apr., '07	6	6.9 ± 3.5	37.9 ± 7.3	44.7 ± 8.6	0.1 ± 0.1	55.2 ± 8.6
		FIP (full)	Tree IV - Apr., '07	6	8.7 ± 3.2	42.2 ± 8.5	50.9 ± 10.3	0.0 ± 0.0	49.1 ± 10.3
		FIP (half)	Tree IV - Apr., '07	6	7.6 ± 2.5	42.0 ± 8.7	49.6 ± 10.6	0.0 ± 0.0	50.4 ± 10.6
		Check		6	7.7 ± 3.4	41.6 ± 8.7	49.4 ± 10.3	0.0 ± 0.0	50.6 ± 10.3
Slash pine	TX	Imid	Tree IV - Apr., '07	7	2.3 ± 1.2	13.7 ± 2.6	16.1 ± 2.6	11.1 ± 3.3	72.8 ± 4.1
		Imid + EB	Tree IV - Apr., '07	7	1.8 ± 1.0	2.4 ± 0.7 *	4.2 ± 0.9 *	8.7 ± 1.7	87.1 ± 2.0 *
		Dino	Tree IV - Apr., '07	7	2.9 ± 0.9	6.2 ± 0.9 *	9.1 ± 1.5	5.9 ± 1.6	85.0 ± 2.6
		Dino + EB	Tree IV - Apr., '07	7	0.9 ± 0.5	3.3 ± 1.1 *	4.2 ± 1.2 *	9.3 ± 1.4	86.5 ± 1.8
		EB	Tree IV - Apr., '07	7	0.8 ± 0.5	1.7 ± 0.8 *	2.4 ± 1.2 *	7.1 ± 1.6	90.4 ± 2.0 *
		Spray	Hydraulic - 2X	7	1.7 ± 0.4	13.5 ± 3.0	15.2 ± 3.1	8.9 ± 2.2	75.9 ± 5.3
		Check		7	2.0 ± 0.8	13.8 ± 3.7	15.8 ± 4.5	8.2 ± 2.0	76.0 ± 4.6

* Mortality or wounds caused by drought, pitch canker, squirrel, midge, or mechanical damage.

† Means followed by an asteriks in each column are not significantly different from the checks at the 5% level based on Fisher's Protected LSD.

Table 6. 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), emamectin benzoate (EB) and/or fiprinil (FIP) or foliar sprays (Spray), 2007.

					Mean Seed Bug Damage (%) to:					
					First-year Conelet Ovules		Second-year Cone Seed			Mean No.
			Application Technique,				Early			Filled Seed
Tree Spp.	Site	Treatment	Treatment Date(s)	N	Early (July)	Late (Sept.)	(2nd Yr Abort)	Late	Total	per Cone
Loblolly pine	AR	Imid (full)	Tree IV - Apr., '07	6	6.2 ± 2.5 *†	18.4 ± 8.6	9.0 ± 2.7 *	19.4 ± 5.1 *	28.4 ± 6.3 *	52.9 ± 7.5 *
		Imid (half)	Tree IV - Apr., '07	5	11.2 ± 3.0	21.8 ± 5.9	8.3 ± 1.2 *	27.3 ± 4.9 *	35.6 ± 5.4 *	57.7 ± 8.2 *
		Imid + EB (full)	Tree IV - Apr., '07	6	2.3 ± 1.5 *	2.1 ± 0.9 *	4.8 ± 1.4 *	23.0 ± 5.2 *	27.8 ± 6.3 *	45.9 ± 7.5 *
		Imid + EB (half)	Tree IV - Apr., '07	5	2.6 ± 2.0 *	4.7 ± 2.5 *	5.5 ± 0.9 *	27.3 ± 5.7 *	32.9 ± 6.1 *	50.6 ± 12.4 *
		Imid + FIP (full)	Tree IV - Apr., '07	6	6.6 ± 1.3 *	20.6 ± 3.5	6.3 ± 1.2 *	19.6 ± 3.5 *	26.0 ± 4.3 *	50.2 ± 9.7 *
		Imid + FIP (half)	Tree IV - Apr., '07	6	10.2 ± 2.6	7.4 ± 3.9 *	6.8 ± 1.9 *	26.1 ± 6.8 *	32.9 ± 8.4 *	42.4 ± 6.8 *
		EB (full)	Tree IV - Apr., '07	6	2.2 ± 1.3 *	3.7 ± 1.8 *	6.7 ± 1.8 *	38.2 ± 5.0	44.9 ± 5.0 *	32.1 ± 5.0
		EB (half)	Tree IV - Apr., '07	6	5.2 ± 1.9 *	9.5 ± 4.5 *	9.3 ± 3.1 *	37.8 ± 4.4	47.1 ± 6.6 *	31.4 ± 6.8
		FIP (full)	Tree IV - Apr., '07	6	20.2 ± 4.5	25.2 ± 6.3	16.2 ± 2.9	39.0 ± 4.1	55.1 ± 4.3	27.2 ± 4.5
		FIP (half)	Tree IV - Apr., '07	6	13.6 ± 3.1	30.1 ± 7.5	20.8 ± 4.1	35.9 ± 3.2	56.8 ± 3.4	31.2 ± 7.0
		Check		6	18.9 ± 4.0	29.6 ± 5.6	22.0 ± 4.2	40.8 ± 5.6	62.8 ± 3.8	23.4 ± 4.8
Slash pine	TX	Imid	Tree IV - Apr., '07	7	3.9 ± 1.8 *	13.6 ± 4.7	14.8 ± 8.3	15.5 ± 2.7 *	30.3 ± 8.9 *	41.4 ± 9.6
		Imid + EB	Tree IV - Apr., '07	7	2.3 ± 1.6 *	2.1 ± 0.9 *	14.3 ± 7.2	17.7 ± 3.9 *	32.0 ± 8.9 *	45.1 ± 10.0
		Dino	Tree IV - Apr., '07	7	4.6 ± 2.1 *	8.9 ± 4.0 *	13.3 ± 6.2	20.0 ± 2.4	33.3 ± 7.2 *	39.2 ± 9.2
		Dino + EB	Tree IV - Apr., '07	7	3.6 ± 2.1 *	2.9 ± 0.8 *	9.9 ± 5.9 *	18.2 ± 3.2 *	28.1 ± 7.9 *	48.2 ± 7.4 *
		EB	Tree IV - Apr., '07	7	8.5 ± 2.9 *	5.3 ± 2.1 *	16.0 ± 6.7	26.5 ± 2.7	42.5 ± 7.7	40.0 ± 6.6
		Spray	Hydraulic - 2X	7	7.1 ± 1.9 *	4.7 ± 1.8 *	12.1 ± 3.0	22.8 ± 4.8	34.8 ± 6.1 *	43.8 ± 7.2
		Check		7	17.2 ± 2.5	17.2 ± 4.1	19.8 ± 9.2	25.6 ± 5.3	45.4 ± 9.0	34.2 ± 7.1

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

Table 7. Mean % (+ SE) cone and seed losses from insects (coneworms and seed bugs) and reductions in damage from second-year cones of loblolly pine and slash pine protected with systemic injections of emamectin benzoate (EB) or fipronil (FIP) or foliar sprays (Spray), 2005 & 2006.

Tree Spp.	Site	Treatment	Application Technique, Treatment Date(s)	N	2007 Mean Combined Losses (%)	2007 Mean Reduction (%)
Loblolly pine	AR	Imid (full)	Tree IV - Apr., '07	6	63.2 ± 4.5 *	21.7
		Imid (half)	Tree IV - Apr., '07	6	75.0 ± 8.0	7.1
		Imid + EB (full)	Tree IV - Apr., '07	6	64.8 ± 8.9 *	19.7
		Imid + EB (half)	Tree IV - Apr., '07	6	67.9 ± 5.3	15.9
		Imid + FIP (full)	Tree IV - Apr., '07	6	58.3 ± 7.6 *	27.8
		Imid + FIP (half)	Tree IV - Apr., '07	6	75.1 ± 6.4	6.9
		EB (full)	Tree IV - Apr., '07	6	74.5 ± 5.9	7.7
		EB (half)	Tree IV - Apr., '07	6	71.2 ± 5.9	11.8
		FIP (full)	Tree IV - Apr., '07	6	76.9 ± 6.3	4.7
		FIP (half)	Tree IV - Apr., '07	6	78.4 ± 4.7	2.9
		Check		6	80.7 ± 5.2	
Slash pine	TX	Imid	Tree IV - Apr., '07	7	39.0 ± 7.1 *	21.5
		Imid + EB	Tree IV - Apr., '07	7	32.6 ± 7.4 *	34.4
		Dino	Tree IV - Apr., '07	7	37.0 ± 6.2 *	25.6
		Dino + EB	Tree IV - Apr., '07	7	28.7 ± 6.1 *	42.3
		EB	Tree IV - Apr., '07	7	40.3 ± 6.4 *	18.9
		Spray	Hydraulic - 2X	7	40.6 ± 4.3 *	18.3
		Check		7	49.7 ± 7.2	

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

Table 8. Mean % (+ SE) seed germination from seed colected from loblolly pine and slash pine protected with systemic injections of emamectin benzoate (EB) or fipronil (FIP), 2005 & 2006.

Tree Spp.	Site	Treatment	Application Technique, Treatment Date(s)	N	2007 Seed Germination (%)	2007 Mean Gain (%)
Loblolly pine	AR	Imid (full)	Tree IV - Apr., '07	6	97.7 ± 0.5	0.0
		Imid (half)	Tree IV - Apr., '07	4	98.2 ± 0.5	0.5
		Imid + EB (full)	Tree IV - Apr., '07	6	97.6 ± 0.6	-0.1
		Imid + EB (half)	Tree IV - Apr., '07	5	98.1 ± 0.6	0.4
		Imid + FIP (full)	Tree IV - Apr., '07	6	98.0 ± 0.4	0.3
		Imid + FIP (half)	Tree IV - Apr., '07	6	98.1 ± 0.4	0.4
		EB (full)	Tree IV - Apr., '07	6	97.3 ± 0.6	-0.4
		EB (half)	Tree IV - Apr., '07	6	96.3 ± 0.9	-1.4
		FIP (full)	Tree IV - Apr., '07	6	94.9 ± 2.3	-2.9
		FIP (half)	Tree IV - Apr., '07	6	96.9 ± 1.5	-0.8
		Check		6	97.7 ± 0.9	
Slash pine	TX	Imid	Tree IV - Apr., '07	7	60.7 ± 7.6	17.0
		Imid + EB	Tree IV - Apr., '07	7	54.4 ± 10.1	4.8
		EB	Tree IV - Apr., '07	7	59.2 ± 6.5	14.1
		Check		7	51.9 ± 11.5	

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

SYSTEMIC INSECTICIDE INJECTION TRIALS

Fipronil and Emamectin Benzoate Timing, Dose Rate and Volume for Single Tree Protection from Southern *Ips* Engraver Beetles – Zavalla and Rusk, TX

Highlights:

- We continued to evaluate the efficacy of formulations of fipronil, emamectin benzoate, and nemadectin for preventing attacks and brood production of *Ips* engraver beetles and wood borers on bolt sections of loblolly pine in East Texas.
- Emamectin benzoate continued to provide protection against *Ips* engraver beetles and wood borers 25 months after injections. The efficacy of lower concentrations (>0.4 g AI/") begin to fade after 20 months.
- Fipronil (at higher rates) continued to provide good protection against *Ips* engraver beetles and wood borers 20 months after injections. All four formulations of fipronil were equal in their efficacy against bark beetles and wood borers.
- High rates (0.4 g AI/") of nemadectin were still highly effective against bark beetles 14 months after injection.

Justification: In 2004 and 2005, the WGFPMC conducted injection trials in East Texas to evaluate the potential efficacy of the systemic insecticides emamectin benzoate and fipronil for protection of loblolly pine against *Ips* engraver beetles (Coleoptera: Curculionidae). The results showed that both chemicals were highly effective in preventing both the successful colonization of treated bolts by *Ips* engraver beetles and wood borers (Coleoptera: Cerambycidae) and the mortality of standing trees (see 2004 and 2005 Accomplishment Report). Additional trials are needed to determine the best timing, dosage rate and duration of emamectin benzoate and fipronil treatment. Additional chemical products, including nemadectin (Fort Dodge Animal Health) is now available and should be tested for efficacy against bark beetles and wood borers.

Objectives: 1) Evaluate the efficacy of systemic injections of emamectin benzoate, fipronil, and nemadectin in reducing colonization success of pine bark beetles and wood borer attacks 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:

Ms. Emily Goodwin	formerly with Temple-Inland Forest Products, Diboll, TX
Mr. Jason Ellis	Texas Forest Service, Jacksonville, TX
Dr. Harold Quicke	BASF, Auburn, AL
Dr. David Cox	Syngenta, Modesta, CA
Mr. Douglas Rugg	Fort Dodge Animal Health, Monmouth Junction, NJ
Mr. Joseph Doccola	Arborjet, Inc., Worchester, MA

Study Sites: Two 20-year-old, recently thinned loblolly pine plantations were selected on land owned by Temple-Inland Forest Products about 15 miles east of Diboll, Texas and the Fairchild State Forest (Rusk Co.) about 12 miles west of Rusk, TX. Trees in each plantation were injected for use in a bolt study. A staging area was set up in a third nearby plantation (Anderson

Co., about 10 miles east of Palestine, TX) where bolts were exposed to bark beetles and wood borers.

Insecticides:

Emamectin benzoate (Avajet) – an avermectin derivative

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

Nemadectin – fermentation product of *Streptomyces cyanogriseus noncyanogenus*

Treatments:

Trial 1: Established April 2005

Trt #	Chemical	Formulation	Application Timing	Rate (g ai/inch dbh)	Volume (ml/inch dbh)	No. of Trees Treated	Felling Dates
1	Emamectin benzoate	Avajet	Apr-06	0.2	5	20	May & Jul '05 & May '06 & '07
2	Emamectin benzoate	Avajet	Apr-06	0.4	10	20	May & Jul '05 & May '06 & '07
3	Untreated					20	May & Jul '05 & May '06 & '07

Trial 2: Established October 2005 and May 2006

Trt #	Chemical	Formulation	Application Timing	Rate (g ai/inch dbh)	No. of Trees Treated	Felling Dates
1	Emamectin benzoate	Avajet	Oct-05	0.016	30	Jul '06, '07 & '08
2	Emamectin benzoate	Avajet	Oct-05	0.08	30	Jul '06, '07 & '08
3	Emamectin benzoate	Avajet	Oct-05	0.4	30	Jul '06, '07 & '08
4	Fipronil	BAS 350UB 120EC	Oct-05	0.016	30	Jul '06, '07 & '08
5	Fipronil	BAS 350UB 120EC	Oct-05	0.08	30	Jul '06, '07 & '08
6	Fipronil	BAS 350UB 120EC	Oct-05	0.4	30	Jul '06, '07 & '08
7	Emamectin benzoate	Avajet	May-06	0.016	30	Jul '06, '07 & '08
8	Emamectin benzoate	Avajet	May-06	0.08	30	Jul '06, '07 & '08
9	Emamectin benzoate	Avajet	May-06	0.4	30	Jul '06, '07 & '08
10	Nemadectin		May-06	0.016	30	Jul '06, '07 & '08
11	Nemadectin		May-06	0.08	30	Jul '06, '07 & '08
12	Nemadectin		May-06	0.4	30	Jul '06, '07 & '08
13	Untreated				30	Jul '06, '07 & '08
14	Untreated	Plug only	May-06		30	Jul '06, '07 & '08

Trial 3: Established April 2007

Trt #	Chemical	Formulation	Application Timing	Rate (g ai/inch dbh)	No. of Trees Treated	Felling Dates
1	Fipronil	BAS 350 PWi	Apr-07	0.2	15	May, July & Sept. '07
2	Fipronil	BAS 350 UKi	Apr-07	0.2	15	May, July & Sept. '07
3	Fipronil	BAS 350 PSi	Apr-07	0.2	15	May, July & Sept. '07
4	Fipronil	BAS 2.5 EC	Apr-07	0.2	15	May, July & Sept. '07
5	Untreated				15	May, July & Sept. '07

Treatment Methods and Evaluation:

Trial 1: Loblolly pine trees (60), 15 – 20 cm diameter at breast height (DBH), were selected in March 2005. Twenty trees were each injected with one of two emamectin benzoate treatments. Each injection treatment (1 & 2) consisted of a single insecticide formulation injected into four cardinal points about 0.3 m above the ground on each tree in April using the new Arborjet Tree IV™ microinfusion system (Arborjet, Inc. Woburn, MA).

After 1 (May '05), 3 (July '05), 13 (May '06) and 25 (May '07) months post-injection, 5 trees of each emamectin benzoate treatment were felled and one 1.5 m-long bolts were removed from the 3 m height of the bole.

Trial 2: Loblolly pine trees (450), 15 – 20 cm diameter at breast height (DBH), were selected in September 2005. Thirty trees were each injected with one of three treatments: emamectin benzoate (October 2005 and May 2006), fipronil (October 2005), or nemadectin (May 2006). Each injection treatment (1 - 12) consisted of a single insecticide formulation injected into four cardinal points about 0.3 m above the ground on each tree in April using the Arborjet Tree IV™.

After 2 (July '06), 14 (July '07) and 26 (July '08) months post-injection, 10 trees of each emamectin benzoate, fipronil, and nemadectin treatment were/will be felled and one 1.5 m-long bolts were/will be removed from the 3 m height of the bole.

At the time of tree felling in 2006, smaller bolts (46 cm) also were cut from the 5 m (= 16 ft) and 11 m (= 36 ft) height of the bole of each emamectin benzoate and fipronil tree. In addition, foliage (100 needles) and cone (5) samples were collected from the crown of each emamectin benzoate tree. All samples were brought back in the laboratory. Phloem tissue (50 g) was collected from each emamectin benzoate and fipronil bolt. Xylem tissue (50 g) was also collected from the emamectin benzoate bolts. All samples were temporarily placed in a freezer before being sent in dry ice to either the Syngenta or BASF laboratory. In 2007, a second series of plant tissues (phloem and xylem from 5m and 1st and 2nd year foliage) were collected from each emamectin benzoate tree. The 2006 and 2007 samples are being analyzed for chemical concentrations.

Trial 3: Loblolly pine trees (75), 15 – 20 cm diameter at breast height (DBH), were selected in March 2007. Fifteen trees were each injected with one of four fipronil treatments. Each injection treatment (1-4) consisted of a single insecticide formulation injected into four cardinal points about 0.3 m above the ground on each tree in April using the Arborjet Tree IV™.

After 1 (May '07), 3 (July '07), and 5 (September '07) months post-injection, 5 trees of each fipronil treatment were felled and one 1.5 m-long bolts were removed from the 3 m height of the bole.

For each trial, the 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 we observed many cerambycid egg niches 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:

Trial 1 (Duration of EB):

<u>*Ips* Attack Success</u> – In 2007, the total number of attacks (nuptial chambers constructed) by male *Ips* engraver beetles did not differ among the treatments (Table 9). Nearly all nuptial chambers were successfully constructed on untreated bolts - with at least one egg gallery radiating from each nuptial chamber. In contrast, on emamectin benzoate-treated bolts evaluated in May 2007, most attacks were unsuccessful (78 - 82%). However, it does appear that there has been a decline in efficacy since the September 2005 evaluation (Table 9). Treatment efficacy was not influenced by chemical rate.

In May 2007, emamectin benzoate treatments (0.2g and 0.4g) continued to reduce the total number (73% and 84%) and length (81% and 91%) of egg galleries compared to check trees (Table 10 & 11). The few egg galleries that were constructed also had some developing brood.

<u>Cerambycid Larval Feeding</u> – There was no difference in the attack level of wood borers (egg niches) in May 2007. Cerambycid larvae were found to have fed upon 98% of the phloem area on untreated bolts during the 3 weeks period between tree felling and bolt evaluation (Table 12). In contrast, >30% of phloem was consumed on emamectin benzoate-treated bolts. Overall, the 0.2g and 0.4g treatments reduced feeding damage on bolts by 83% and 70%, respectively.

<u>Trial 2 (Timing, Rate & Concentration in Tissue):</u>

<u>*Ips* Attack Success</u> – After more than a year (14 – 20 months), the total number of attacks (nuptial chambers constructed) by male *Ips* engraver beetles did not differ among the treatments (Table 13). Most (76%) of the nuptial chambers were successfully constructed on untreated

bolts - with at least one egg gallery radiating from each nuptial chamber. In contrast, all emamectin benzoate -treated bolts (both seasons and all rates), two fipronil, and two nemadectin treatment had significantly fewer nuptial chambers with egg galleries (Tables 13, 17 & 21). Nearly all treatments reduced the total number and length of egg galleries compared to check trees (Tables 14, 15, 18, 19, 22 & 23). However, emamectin benzoate continued to provide the best overall protection against bark beetles compared to the other treatments.

Cerambycid Larval Feeding – The attack level of wood borers (egg niches) on logs from injected trees was often significantly greater than that on check logs (Table 16, 20 & 24). Relatively little cerambycid feeding (20%) occurred on untreated bolts during the 3 weeks period between tree felling and bolt evaluation (Table 16, 20 & 24). All emamectin benzoate treatments and the high rate nemadectin significantly reduced the amount of larval feeding and development compared to the check. Emamectin benzoate provided the best overall protection against wood borers compared to the other treatments.

Concentration in Tissue: - As of December 2007, the plant tissue samples collected from emamectin benzoate trees in 2006 had been analyzed, but data analysis is on-going. The 2007 emamectin benzoate samples and 2006 fipronil samples are to be analyzed in the near future.

Trial 3 (Fipronil Formulation):
Ips Attack Success – The total number of attacks (nuptial chambers constructed) by male *Ips* engraver beetles did not differ among the treatments for the first and third log series (Table 25). For the second series, the number of attacks was significantly higher on all treated logs compared to the check. Nearly all nuptial chambers were successfully constructed on untreated bolts - with at least one egg gallery radiating from each nuptial chamber. The effects of all fipronil treatments improved with time. Most attacks were unsuccessful (71 - 90%) by the 3rd month after injection. Treatment efficacy was not influenced by chemical formulation.

All fipronil formulations were effective in reducing the total number (87% and 90%) and length (94% and 97%) of egg galleries compared to check trees by the third month after injection (Table 26 & 27). The few egg galleries that were constructed had very few developing brood.

Cerambycid Larval Feeding – There was no difference in the attack level of wood borers (egg niches) in July and September 2007. Cerambycid larvae were found to have fed upon 78 - 96% of the phloem area on untreated bolts during the 3 weeks period between tree felling and bolt evaluation (Table 28). In contrast, >15% of phloem was consumed on all fipronil-treated bolts.

Conclusions:

All chemical formulations were quickly injected into the study trees for all three trials using the Arborjet Tree IV system. Evaluation of the phloem and xylem surrounding the injection points revealed that none of the formulations caused the development of lesions.

Trials 1 and 2 continue to show that emamectin benzoate was highly effective in preventing successful attacks by *Ips* bark beetles and cerambycids 20 and 25 months after injection. The adults showed some limited success in constructing extended (> 1") egg galleries. However, the treatments still were able to prevent bark beetle brood and cerambycid larval development (Table 11 & 12). Trial 1 is complete, but ten additional emamectin benzoate treated trees each will be felled as part of Trial 2 in 2008 (26 and 32 months after injection) to further determine the duration of treatment efficacy.

Trial 2 revealed no significant difference in the efficacy of emamectin benzoate applied in the fall (20 months prior to exposure) compared to the same chemical applied in the spring (13 months prior to exposure). However, there was an apparent inverse rate effect on treatment efficacy with the number and length of egg galleries with brood larvae decreasing with increasing emamectin benzoate rate.

Fipronil and nemadectin injections showed poor to good activity (particularly at higher rates) against bark beetles in the bolt trial. The fipronil treatments were not able to completely protect the logs, although the high rate was close. Nemadectin showed a dramatic rate effect (low rate was ineffective versus high rate was very effective. Nemadectin showed good activity against cerambycid larvae, particularly at higher rates. In contrast, all fipronil and lower rate nemadectin exhibited little activity against cerambycids.

Trial 3 showed that all fipronil formulations were nearly equal in their efficacy against bark beetles. All were effective in preventing the successful colonization of Ips in cut logs. As in the past, it took nearly 3 months for all fipronil injections to completely protect the trees.

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Table 9: Trial 1 - Attack success and gallery construction of *Ips* engravers beetles on loblolly pine bolts cut 1, 3, 5, 12 0r 25 months after trunk injection with different rates of emamectin benzoate (EB); Lufkin, Texas, 2005 - 2007.

Evaluation period	Treatment	N	Mean # of nuptial chambers without egg galleries		Mean # of nuptial chambers with egg galleries		Mean total # of nuptial chambers
			No.	% of total	No.	% of total	
1 Month Post-Injection (May '05)	EB 0.2g, 5ml/" dbh	5	2.6 **a***	81	0.6 **a**	19	3.2 **a**
	EB 0.4g 10ml/"dbh	5	1.4 **a**	88	0.2 **a**	13	1.6 **a**
	Check	5	2.5 **a**	18	11.2 **b**	82	13.7 **b**
3 Months Post-Injection (July '05)	EB 0.2g, 5ml/" dbh	5	2.6 **a**	100	0.0 **a**	0	2.6 **a**
	EB 0.4g 10ml/"dbh	5	1.6 **a**	100	0.0 **a**	0	1.6 **a**
	Check	5	0.7 **a**	18	3.2 **b**	82	3.9 **a**
5 Months Post-Injection (Sept. '05)	EB 0.2g, 5ml/" dbh	2	2.0 **a**	100	0.0 **a**	0	2.0 **a**
	EB 0.4g 10ml/"dbh	2	1.5 **a**	100	0.0 **a**	0	1.5 **a**
	Check	5	0.2 **a**	3	6.0 **b**	97	6.2 **a**
13 Months Post-Injection (May '06)	EB 0.2g, 5ml/" dbh	6	5.3 **a**	78	1.5 **a**	22	6.8 **a**
	EB 0.4g 10ml/"dbh	6	3.5 **a**	62	2.2 **a**	38	5.7 **a**
	Check	6	0.2 **b**	3	6.2 **b**	97	6.3 **a**
25 Months Post-Injection (May '07)	EB 0.2g, 5ml/" dbh	4	8.0 **a**	78	2.3 **a**	22	10.3 **a**
	EB 0.4g 10ml/"dbh	4	6.8 **a**	82	1.5 **a**	18	8.3 **a**
	Check	6	0.5 **b**	7	6.8 **a**	93	7.3 **a**

* Means followed by the same letter within a monitoring period are not significantly different at the 5% level based on Fisher's Protected LSD.

Table 10: Trial 1 - Mean number of egg galleries constructed by *Ips* engravers beetles in loblolly pine bolts cut 1, 3, 5, 13 or 25 months after trunk injection with different rates of emamectin benzoate (EB); Lufkin, Texas, 2005 - 2007.

Evaluation period	Treatment	N	Without larvae No.	Without larvae % of total	With larvae No.	With larvae % of Total	Total #
1 Month Post-Injection (May '05)	EB 0.2g, 5ml/" dbh	5	1.0 **a***	0	0.0 **a**	0	1.0 **a**
	EB 0.4g 10ml/"dbh	5	0.0 **a**	0	0.0 **a**	0	0.0 **a**
	Check	5	12.8 **b**	43	17.0 **b**	57	29.8 **b**
3 Months Post-Injection (July '05)	EB 0.2g, 5ml/" dbh	5	0.0 **a**	0	0.0 **a**	0	0.0 **a**
	EB 0.4g 10ml/"dbh	5	0.0 **a**	0	0.0 **a**	0	0.0 **a**
	Check	5	4.2 **b**	36	7.4 **b**	64	11.6 **b**
5 Months Post-Injection (Sept. '05)	EB 0.2g, 5ml/" dbh	2	0.0 **a**	0	0.0 **a**	0	0.0 **a**
	EB 0.4g 10ml/"dbh	2	4.0 **a**	100	0.0 **a**	0	4.0 **b**
	Check	5	2.0 **a**	11	19.0 **b**	90	21.0 **c**
13 Months Post-Injection (May '06)	EB 0.2g, 5ml/" dbh	6	2.3 **a**	100	0.0 **a**	0	2.3 **a**
	EB 0.4g 10ml/"dbh	6	3.8 **a**	100	0.0 **a**	0	3.8 **a**
	Check	6	6.2 **a**	30	14.3 **b**	70	20.5 **b**
25 Months Post-Injection (May '07)	EB 0.2g, 5ml/" dbh	4	1.8 **a**	30	4.0 **a**	70	5.8 **a**
	EB 0.4g 10ml/"dbh	4	2.3 **a**	69	1.0 **a**	31	3.3 **a**
	Check	6	2.3 **a**	11	18.7 **b**	89	21.0 **a**

* Means followed by the same letter within each monitoring period are not significantly different at the 5% level based on Fisher's Protected LSD.

Table 11: Trial 1 - Mean length of egg galleries constructed by *Ips* engravers beetles in loblolly pine bolts cut 1, 3, 5, 13 or 25 months after trunk injection with different rates of emamectin benzoate (EB); Lufkin, Texas, 2005 - 2007.

			Length of egg galleries				
			Without larvae		With larvae		
Evaluation period	Treatment	N	cm	% of Total	cm	% of Total	Total length
1 Month Post-Injection (May '05)	EB 0.2g, 5ml/" dbh	5	1.0 **a**	100	0.0 **a**	0	1.0 **a**
	EB 0.4g 10ml/"dbh	5	0.0 **a**	0	0.0 **a**	0	0.0 **a**
	Check	5	40.4 **b**	38	65.4 **b**	62	105.8 **b**
3 Months Post-Injection (July '05)	EB 0.2g, 5ml/" dbh	5	0.0 **a**	0	0.0 **a**	0	0.0 **a**
	EB 0.4g 10ml/"dbh	5	0.0 **a**	0	0.0 **a**	0	0.0 **a**
	Check	5	13.8 **b**	27	37.4 **b**	73	51.2 **b**
5 Months Post-Injection (Sept. '05)	EB 0.2g, 5ml/" dbh	2	0.0 **a**	0	0.0 **a**	0	0.0 **a**
	EB 0.4g 10ml/"dbh	2	3.0 **a**	100	0.0 **a**	0	3.0 **a**
	Check	5	7.8 **a**	4	208.5 **b**	96	216.3 **b**
13 Months Post-Injection (May '06)	EB 0.2g, 5ml/" dbh	6	8.2 **a**	100	0.0 **a**	0	8.2 **a**
	EB 0.4g 10ml/"dbh	6	10.3 **a**	100	0.0 **a**	0	10.3 **a**
	Check	6	38.5 **b**	16	205.2 **b**	84	243.7 **b**
25 Months Post-Injection (May '07)	EB 0.2g, 5ml/" dbh	4	5.3 **a**	15	28.8 **a**	85	34.0 **a**
	EB 0.4g 10ml/"dbh	4	5.5 **a**	34	10.5 **a**	66	16.0 **a**
	Check	6	9.7 **a**	6	164.7 **b**	94	174.3 **b**

* Means followed by the same letter within each monitoring period are not significantly different at the 5% level based on Fisher's Protected LSD.

Table 12: Trial 1 - Extent of feeding by cerambycid larvae (per 1000 cm^2) in loblolly pine bolts cut 1, 3, 5, 13 and 25 months after trunk injection with different rates of emamectin benzoate (EB); Lufkin, Texas - 2005 & 2006.

Evaluation period	Treatment	N	No. of cerambycid egg niches on bark	Percent phloem area consumed by larvae
1 Month Post-Injection (May)	EB 0.2g 20ml	5	1.8	0.2 *
	EB 0.4g 20ml	5	3.0	0.0 *
	Check	6	5.0	6.2
3 Months Post-Injection (July)	EB 0.2g 20ml	5	5.0	0.0 *
	EB 0.4g 20ml	5	2.2 *	0.0 *
	Check	5	8.6	##
5 Months Post-Injection (Sept.)	EB 0.2g 20ml	2	4.5	0.0 *
	EB 0.4g 20ml	2	###	0.0 *
	Check	7	6.4	##
13 Months Post-Injection (May)	EB 0.2g 20ml	6	###	0.0 *
	EB 0.4g 20ml	6	8.7	0.0 *
	Check	6	###	##
25 Months Post-Injection (May)	EB 0.2g 20ml	6	###	## *
	EB 0.4g 20ml	6	###	## *
	Check	6	###	##

* Means followed by an asteriks in each columnof each evaluation period are significantly different from the check at the 5% level based on Fisher's Protected LSD.

Table 13: Trial 2 - Attack success and gallery construction of *Ips* engravers beetles on loblolly pine bolts cut 2 - 20 months after Fall (Oct.) and Spring (May) trunk injections with different rates of emamectin benzoate (EB); Lufkin, TX, 2006 & 2007.

			Mean # of nuptial chambers without egg galleries		Mean # of nuptial chambers with egg galleries		
Evaluation period	Season/Yr Injected	Treatment	No.	% of total	No.	% of total	Mean total # of nuptial chambers
2 Months Post-Injection (Jul. '06)	Spring 2006	EB 0.016g	3.9	69.6	1.7 *	30.4	5.6
		EB 0.08g	2.6	96.3	0.1 *	3.7	2.7 *
		EB 0.4g	3.7	97.4	0.1 *	2.6	3.8
8 Months Post-Injection (Jul. '06)	Fall 2005	EB 0.016g	6.6 *	91.7	0.6 *	8.3	7.2
		EB 0.08g	5.3 *	85.5	0.9 *	14.5	6.2
		EB 0.4g	4.4 *	97.8	0.1 *	2.2	4.5
		Check	2.6	36.1	4.6	63.9	7.2
14 Months Post-Injection (Jul. '07)	Spring 2006	EB 0.016g	7.5 *	85.2	1.3 *	14.8	8.8
		EB 0.08g	5.0 *	92.6	0.4 *	7.4	5.4
		EB 0.4g	4.8 *	98.0	0.1 *	2.0	4.9 *
20 Months Post-Injection (Jul. '07)	Fall 2005	EB 0.016g	6.1 *	77.2	1.8 *	22.8	7.9
		EB 0.08g	4.8 *	87.3	0.7 *	12.7	5.5
		EB 0.4g	5.6 *	84.8	1.0 *	15.2	6.6
		Check	0.9	10.3	7.8	89.7	8.7

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

Table 14: Trial 2 - Mean number of egg galleries constructed by *Ips* engravers beetles in loblolly pine bolts cut 2 - 20 months after Fall (Oct.) and Spring (May) trunk injections with different rates of emamectin benzoate (EB); Lufkin, TX, 2006 & 2007.

			Number of egg galleries				
			Without larvae		With larvae		
Evaluation period	Season/ Yr. Injected	Treatment	No.	% of total	No.	% of Total	Total #
2 Months Post-Injection (Jul. '06)	Spring 2006	EB 0.016g	1.0 *	37.0	1.7 *	63.0	2.7 *
		EB 0.08g	0.2 *	100.0	0.0 *	0.0	0.2 *
		EB 0.4g	0.1 *	100.0	0.0 *	0.0	0.1 *
8 Months Post-Injection (Jul. '06)	Fall 2005	EB 0.016g	1.1 *	84.6	0.2 *	15.4	1.3 *
		EB 0.08g	1.4 *	100.0	0.0 *	0.0	1.4 *
		EB 0.4g	0.1 *	100.0	0.0 *	0.0	0.1 *
		Check	3.1	29.0	7.6	71.0	10.7
14 Months Post-Injection (Jul. '07)	Spring 2006	EB 0.016g	2.5	100.0	0.0 *	0.0	2.5 *
		EB 0.08g	0.6 *	100.0	0.0 *	0.0	0.6 *
		EB 0.4g	0.2 *	100.0	0.0 *	0.0	0.2 *
20 Months Post-Injection (Jul. '07)	Fall 2005	EB 0.016g	4.2	95.5	0.2 *	4.5	4.4 *
		EB 0.08g	1.3 *	100.0	0.0 *	0.0	1.3 *
		EB 0.4g	2.6 *	100.0	0.0 *	0.0	2.6 *
		Check	5.7	24.4	17.7	75.6	23.4

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

Table 15: Trial 2 - Mean length of egg galleries constructed by *Ips* engravers beetles in loblolly pine bolts cut 2 - 20 months after Fall (Oct.) and Spring (May) trunk injections with different rates of emamectin benzoate (EB); Lufkin, TX, 2006 & 2007.

			Length of egg galleries				
			Without larvae		With larvae		
Evaluation period	Season/ Yr. Injected	Treatment	cm	% of Total	cm	% of Total	Total length
2 Months Post-Injection (Jul. '06)	Spring 2006	EB 0.016g	3.7 *	36.6	6.4 *	63.4	10.1 *
		EB 0.08g	0.7 *	100.0	0.0 *	0.0	0.7 *
		EB 0.4g	0.5 *	100.0	0.0 *	0.0	0.5 *
8 Months Post-Injection (Jul. '06)	Fall 2005	EB 0.016g	5.6 *	80.0	1.4 *	20.0	7.0 *
		EB 0.08g	4.8 *	100.0	0.0 *	0.0	4.8 *
		EB 0.4g	0.9 *	100.0	0.0 *	0.0	0.9 *
		Check	23.9	26.6	65.9	73.4	89.8
14 Months Post-Injection (Jul. '07)	Spring 2006	EB 0.016g	7.4 *	100.0	0.0 *	0.0	7.4 *
		EB 0.08g	2.3 *	100.0	0.0 *	0.0	2.3 *
		EB 0.4g	0.9 *	100.0	0.0 *	0.0	0.9 *
20 Months Post-Injection (Jul. '07)	Fall 2005	EB 0.016g	19.7	87.2	2.9 *	12.8	22.6 *
		EB 0.08g	2.9 *	100.0	0.0 *	0.0	2.9 *
		EB 0.4g	6.5 *	100.0	0.0 *	0.0	6.5 *
		Check	39.9	22.6	136.7	77.4	176.6

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

Table 16: Trial 2 - Extent of feeding by cerambycid larvae in loblolly pine bolts cut 2 - 20 months after Fall (Oct.) and Spring (May) trunk injections with different rates of emamectin benzoate (EB); Lufkin, TX, 2006 & 2007.

Evaluation period	Season/Yr. Injected	Treatment	No. of egg niches on bark	% phloem area consumed by larvae
2 Months Post-Injection (Jul. '06)	Spring 2006	EB 0.016g	4.5	0.2 *
		EB 0.08g	5.5	0.2 *
		EB 0.4g	4.2	0.0 *
8 Months Post-Injection (Jul. '06)	Fall 2005	EB 0.016g	7.9	0.0 *
		EB 0.08g	7.0	0.0 *
		EB 0.4g	6.0	0.0 *
		Check	6.6	8.1
14 Months Post-Injection (Jul. '07)	Spring 2006	EB 0.016g	9.4	0.8 *
		EB 0.08g	12.2 *	0.0 *
		EB 0.4g	11.0	0.0 *
20 Months Post-Injection (Jul. '07)	Fall 2005	EB 0.016g	11.5	0.1 *
		EB 0.08g	14.0 *	1.3 *
		EB 0.4g	11.3 *	0.0 *
		Check	7.1	19.6

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

Table 17: Trial 2 - Attack success and gallery construction of *Ips* engravers beetles on loblolly pine bolts cut 8 and 20 months after Fall (Oct. 2005) trunk injection, with different rates of fipronil (FIP); Lufkin, TX, 2006 & 2007.

Injection season / Evaluation period	Treatment	Mean # of nuptial chambers without egg galleries		Mean # of nuptial chambers with egg galleries		Mean total # of nuptial chambers
		No.	% of total	No.	% of total	
Fall (Oct) / 8 Months Post-Injection (July)	FIP 0.02g	3.6	69.2	1.6	30.8	5.2
	FIP 0.1g	3.3	49.3	3.4	50.7	6.7
	FIP 0.4g	5.3 *	81.5	1.2 *	18.5	6.5
	Check	2.6	36.1	4.6	63.9	7.2
Fall (Oct) / 20 Months Post-Injection (July)	FIP 0.02g	1.2	23.1	4.0 *	76.9	5.2
	FIP 0.1g	3.4 *	40.5	5.0	59.5	8.4
	FIP 0.4g	3.3 *	44.0	4.2 *	56.0	7.5
	Check	0.9	10.3	7.8	89.7	8.7

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

Table 18: Trial 2 - Mean number of egg galleries constructed by *Ips* engravers beetles in loblolly pine bolts cut 8 and 20 months after Fall (Oct. 2005) trunk injection with different rates of fipronil (FIP); Lufkin, TX, 2006 & 2007.

Injection season / Evaluation period	Treatment	Number of egg galleries: Without larvae No.	Without larvae % of total	With larvae No.	With larvae % of Total	Total #
Fall (Oct) / 8 Months Post-Injection (July 2006)	FIP 0.02g	1.0 *	50.0	1.0 *	50.0	2.0 *
	FIP 0.1g	4.1	62.1	2.5 *	37.9	6.6
	FIP 0.4g	2.0 *	74.1	0.7 *	25.9	2.7 *
	Check	3.1	29.0	7.6	71.0	10.7
Fall (Oct) / 20 Months Post-Injection (July 2007)	FIP 0.02g	8.8	64.7	4.8 *	35.3	13.6
	FIP 0.1g	7.8	69.0	3.5 *	31.0	11.3
	FIP 0.4g	6.1	81.3	1.4 *	18.7	7.5 *
	Check	5.7	24.4	17.7	75.6	23.4

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

Table 19: Trial 2 - Mean number and length of egg galleries constructed by *Ips* engravers beetles in loblolly pine bolts cut 8 and 20 months after Fall (Oct. 2005) trunk injection with different rates of fipronil (FIP); Lufkin, TX, 2006 & 2007.

Injection season / Evaluation period	Treatment	Length of egg galleries				
		Without larvae		With larvae		
		cm	% of Total	cm	% of Total	Total length
Fall (Oct) / 8 Months Post-Injection (July 2006)	FIP 0.02g	4.3 *	32.3	9.0 *	67.7	13.3 *
	FIP 0.1g	9.1	53.8	7.8 *	46.2	16.9 *
	FIP 0.4g	10.1 *	72.7	3.8 *	27.3	13.9 *
	Check	23.9	26.6	65.9	73.4	89.8
Fall (Oct) / 20 Months Post-Injection (July 2007)	FIP 0.02g	38.7	53.7	33.4 *	46.3	72.1 *
	FIP 0.1g	31.2	61.2	19.9 *	39.0	51.0 *
	FIP 0.4g	28.6	82.4	6.1 *	17.6	34.7 *
	Check	39.9	22.6	136.7	77.4	176.6

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

Table 20: Trial 2 - Extent of feeding by cerambycid larvae in loblolly pine bolts cut 8 and 20 months after Fall (Oct. 2005) trunk injection with different rates of fipronil (FIP); Lufkin, TX, 2006 & 2007.

Injection season / Evaluation period	Treatment	No. of egg niches on bark	% phloem area consumed by larvae
Fall (Oct) / 8 Months Post-Injection (July)	FIP 0.02g	4.0	4.6
	FIP 0.1g	6.4	3.3 *
	FIP 0.4g	9.9	0.9 *
	Check	6.6	8.1
Fall (Oct) / 8 Months Post-Injection (July)	FIP 0.02g	12.8 *	26.5
	FIP 0.1g	17.7 *	28.4
	FIP 0.4g	13.6 *	15.7
	Check	7.1	19.6

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

Table 21: Trial 2 - Attack success and gallery construction of *Ips* engravers beetles on loblolly pine bolts cut 2 or 14 months after Spring (May 2006) trunk injection with different rates of nemadectin; Lufkin, TX, 2006 & 2007.

Injection season / Evaluation period	Treatment	Mean # of nuptial chambers without egg galleries		Mean # of nuptial chambers with egg galleries		Mean total # of nuptial chambers
		No.	% of total	No.	% of total	
Spring (May) / 2 Months Post-Injection (July)	Nemadectin 0.02g	3.9	72.2	1.5 *	27.8	5.4
	Nemadectin 0.1g	5.9 *	83.1	1.2 *	16.9	7.1
	Nemadectin 0.4g	5.4 *	71.1	2.2	28.9	7.6
	Check	2.6	36.1	4.6	63.9	7.2
Spring (May) / 14 Months Post-Injection (July)	Nemadectin 0.02g	0.5	8.1	5.7	91.9	6.2
	Nemadectin 0.1g	2.7 *	38.6	4.3 *	61.4	7.0
	Nemadectin 0.4g	6.0 *	98.4	0.1 *	1.6	6.1
	Check	0.9	10.3	7.8	89.7	8.7

* Means followed by an asteriks in each column are significantly different from the check at the 5% level

Table 22: Trial 2 - Mean number of egg galleries constructed by *Ips* engravers beetles in loblolly pine bolts cut 2 or 14 months after Spring (May 2006) trunk injection with different rates of nemadectin; Lufkin, TX, 2006 & 2007.

		Number of egg galleries				
		Without larvae		With larvae		
Injection season / Evaluation period	Treatment	No.	% of total	No.	% of Total	Total #
Spring (May) / 2 Months Post-Injection (July)	Nemadectin 0.02g	2.2	57.9	1.6 *	42.1	3.8 *
	Nemadectin 0.1g	0.9 *	29.0	2.2 *	71.0	3.1 *
	Nemadectin 0.4g	1.8	42.9	2.4 *	57.1	4.2 *
	Check	3.1	29.0	7.6	71.0	10.7
Spring (May) / 14 Months Post-Injection (July)	Nemadectin 0.02g	4.3	32.8	8.8	67.2	13.1
	Nemadectin 0.1g	7.0	81.4	1.6 *	18.6	8.6 *
	Nemadectin 0.4g	0.2 *	100.0	0.0 *	0.0	0.2 *
	Check	5.7	24.4	17.7	75.6	23.4

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

Table 23: Trial 2 - Mean length of egg galleries constructed by *Ips* engravers beetles in loblolly pine bolts cut 2 or 14 months after Spring (May 2006) trunk injection with different rates of nemadectin; Lufkin, TX, 2006 & 2007.

		Length of egg galleries				
		Without larvae		With larvae		
Injection season / Evaluation period	Treatment	cm	% of Total	cm	% of Total	Total length
Spring (May) / 2 Months Post-Injection (July)	Nemadectin 0.02g	14.2	52.8	12.7 *	47.2	26.9 *
	Nemadectin 0.1g	3.8 *	34.5	7.2 *	65.5	11.0 *
	Nemadectin 0.4g	5.1 *	39.8	7.7 *	60.2	12.8 *
	Check	23.9	26.6	65.9	73.4	89.8
Spring (May) / 14 Months Post-Injection (July)	Nemadectin 0.02g	26.3	24.8	79.7	75.2	106.0
	Nemadectin 0.1g	36.0	72.9	13.4 *	27.1	49.4 *
	Nemadectin 0.4g	0.5 *	100.0	0.0 *	0.0	0.5 *
	Check	39.9	22.6	136.7	77.4	176.6

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

Table 24: Trial 2 - Extent of feeding by cerambycid larvae in loblolly pine bolts cut 2 or 14 months after Spring (May 2006) trunk injection with different rates of nemadectin; Lufkin, TX, 2006 & 2007.

Injection season / Evaluation period	Treatment	No. of egg niches on bark	% phloem area consumed by larvae
Spring (May) / 2 Months Post-Injection (July)	Nemadectin 0.02g	5.8	0.9 *
	Nemadectin 0.1g	5.3	1.6 *
	Nemadectin 0.4g	5.1	4.8
	Check	6.6	8.1
Spring (May) / 14 Months Post-Injection (July)	Nemadectin 0.02g	8.3	41.7
	Nemadectin 0.1g	11.5 *	22.8
	Nemadectin 0.4g	11.2 *	8.9 *
	Check	7.1	19.6

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

Table 25: Trial 3 - Attack success and gallery construction of *Ips* engravers beetles on loblolly pine bolts cut 1, 3 and 5 months after trunk injection with different formulations of fipronil; Fairchild State Forest, Rusk Co., Texas - 2007.

Evaluation period	Treatment	N	Mean # of nuptial chambers without egg galleries: No.	Mean # of nuptial chambers without egg galleries: % of total	Mean # of nuptial chambers with egg galleries: No.	Mean # of nuptial chambers with egg galleries: % of total	Mean total # of nuptial chambers
1 month Post-Injection (May)	PW	5	10.6 **b** *	78	3.0 **ab**	22	13.6 **a**
	PS	5	5.8 **b**	66	3.0 **a**	34	8.8 **a**
	UK	5	8.0 **b**	77	2.4 **a**	23	10.4 **a**
	2.5 Regent	5	6.0 **b**	55	5.0 **ab**	45	11.0 **a**
	Check	5	0.2 **a**	3	7.2 **b**	97	7.4 **a**
3 months Post-Injection (July)	PW	5	5.2 **b** *	81	1.2 **a**	19	6.4 **b**
	PS	5	6.8 **b**	87	1.0 **a**	13	7.8 **b**
	UK	5	5.6 **b**	90	0.6 **a**	10	6.2 **b**
	2.5 Regent	5	4.4 **b**	71	1.8 **ab**	29	6.2 **b**
	Check	5	0.0 **a**	0	4.0 **b**	100	4.0 **a**
5 months Post-Injection (Sept)	PW	5	2.8 **b** *	100	0.0 **a**	0	2.8 **a**
	PS	5	3.4 **b**	85	0.6 **a**	15	4.0 **a**
	UK	5	3.6 **b**	95	0.2 **a**	5	3.8 **a**
	2.5 Regent	5	3.4 **b**	85	0.6 **a**	15	4.0 **a**
	Check	5	0.8 **a**	19	3.4 **b**	81	4.2 **a**

* Means followed by the same letter within each evaluation period are not significantly different at 5% level based on Fisher's Protected LSD.

Table 26: Trial 3 - Mean number and length of egg galleries constructed by *Ips* engravers beetles (per 1000 cm^2) in loblolly pine bolts cut 1, 3 and 5 months after trunk injection with different formulations of fipronil; Fairchild State Forest, Rusk Co., Texas - 2007.

			Number of egg galleries				
			Without larvae		With larvae		
Evaluation period	Treatment	N	No.	% of total	No.	% of Total	Total #
1 Month Post-Injection (May)	PW	5	5.0 **ab***	57	3.8 **a**	43	8.8 **ab**
	PS	5	1.4 **a**	14	8.8 **ab**	86	10.2 **ab**
	UK	5	2.2 **ab**	31	4.8 **a**	69	7.0 **a**
	2.5 Regent	5	12.0 **b**	73	4.4 **a**	27	16.4 **ab**
	Check	5	1.8 **a**	9	18.8 **b**	91	20.6 **b**
3 Month Post-Injection (July)	PW	5	1.8 **a***	100	0.0 **a**	0	1.8 **a**
	PS	5	1.6 **a**	89	0.2 **a**	11	1.8 **a**
	UK	5	2.0 **a**	100	0.0 **a**	0	2.0 **a**
	2.5 Regent	5	2.2 **a**	100	0.0 **a**	0	2.2 **a**
	Check	5	2.6 **a**	15	14.6 **b**	85	17.2 **b**
5 Month Post-Injection (Sept)	PW	5	0.0 **a***	#####	0.0 **a**	#####	0.0 **a**
	PS	5	1.0 **a**	100	0.0 **a**	0	1.0 **a**
	UK	5	0.2 **a**	100	0.0 **a**	0	0.2 **a**
	2.5 Regent	5	0.6 **a**	100	0.0 **a**	0	0.6 **a**
	Check	5	0.4 **a**	3	12.2 **b**	97	12.6 **b**

* Means followed by the same letter within each evaluation period are not significantly different at the 5% level based on Fisher's Protected LSD.

Table 27: Trial 3 - Mean length of egg galleries constructed by *Ips* engravers beetles (per 1000 cm^2) in loblolly pine bolts cut 1, 3 and 5 months after trunk injection with different formulations of fipronil; Fairchild State Forest, Rusk Co., Texas - 2007.

			Length of egg galleries				
			Without larvae		With larvae		
Evaluation period	Treatment	N	cm	% of Total	cm	% of Total	Total length
1 Month Post-Injection (May)	PW	5	22.2 **ab**	42	30.8 **a**	58	53.0 **a**
	PS	5	4.0 **a**	6	58.2 **a**	94	62.2 **a**
	UK	5	17.2 **ab**	23	57.4 **a**	77	74.6 **a**
	2.5 Regent	5	40.6 **b**	49	42.8 **a**	51	83.4 **a**
	Check	5	8.6 **ab**	4	185.2 **b**	96	193.8 **b**
3 Month Post-Injection (July)	PW	5	4.4 **a**	100	0.0 **a**	0	4.4 **a**
	PS	5	7.4 **a**	79	2.0 **a**	21	9.4 **a**
	UK	5	8.4 **a**	100	0.0 **a**	0	8.4 **a**
	2.5 Regent	5	10.0 **a**	100	0.0 **a**	0	10.0 **a**
	Check	5	16.2 **a**	9	154.6 **b**	91	170.8 **b**
5 Month Post-Injection (Sept)	PW	5	0.0 **a**	#####	0.0 **a**	#####	0.0 **a**
	PS	5	3.0 **a**	100	0.0 **a**	0	3.0 **a**
	UK	5	0.6 **a**	100	0.0 **a**	0	0.6 **a**
	2.5 Regent	5	2.0 **a**	100	0.0 **a**	0	2.0 **a**
	Check	5	1.6 **a**	1	141.0 **b**	99	142.6 **b**

* Means followed by the same letter within each evaluation period are not significantly different at the 5% level based on Fisher's Protected LSD.

Table 28: Trial 3 - Extent of feeding by cerambycid larvae (per 1000 cm^2) in loblolly pine bolts cut 1, 3 and 5 months after trunk injection with different formulations of fipronil; Fairchild State Forest, Rusk Co., Texas - 2007.

		No of cerambycid egg niches on bark			Percent phloem area consumed by larvae		
Treatment	N	1 month post injection (May)	3 month post injection (July)	5 month post injection (Sept)	1 month post injection (May)	3 month post injection (July)	5 month post injection (Sept)
PW	5	24.0 **b**	16.6 **a**	11.4 **a**	9.4 **a**	1.4 **a**	0.2 **a**
PS	5	19.2 **ab**	19.0 **a**	12.8 **a**	12.8 **a**	2.2 **a**	0.0 **a**
UK	5	25.0 **b**	19.0 **a**	13.0 **a**	3.6 **a**	0.6 **a**	0.0 **a**
2.5 Regent	5	17.8 **ab**	12.4 **a**	22.2 **a**	14.8 **a**	0.0 **a**	0.4 **a**
Check	5	14.4 **a**	12.8 **a**	16.0 **a**	85.8 **b**	96.0 **b**	77.6 **b**

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

SYSTEMIC INSECTICIDE INJECTION TRIALS

Emamectin Benzoate and Fipronil for Protection of High-Value Southern and Western Conifers from Bark Beetles – MS, AL, CA, ID, UT, CO & BC

Highlights:

- We continued evaluating the efficacy of fipronil and emamectin benzoate for preventing mortality of conifers by *Dendroctonus* beetles (Coleoptera: Curculionidae, Scolytinae) in Alabama, California, Idaho, Utah, Colorado and British Columbia, as well as establishing a new trials in Alabama.
- Final results indicate that fipronil and emamectin benzoate were effective in reducing/preventing tree mortality by southern pine beetle (AL), western pine beetle (CA), mountain pine beetle (ID) in the second year after treatment and by southern pine beetle (AL) during the first year.
- Preliminary results indicate that fipronil and emamectin benzoate were ineffective in reducing/preventing tree mortality by mountain pine beetle (BC) or spruce beetle (UT). Treatment failure is likely due to cold climates and not allowing sufficient time between treatment application and beetle attack.

Justification: Bark beetles (Curculionidae, Scolytinae) such as the southern pine beetle (SPB), *Dendroctonus frontalis* Zimmermann, mountain pine beetle (MPB), *D. ponderosae* Hopkins, western pine beetle (WPB), *D. brevicomis* LeConte, and spruce beetle (SB), *D. rufipennis* (Kirby), are responsible for extensive conifer mortality throughout North America including Alaska. 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 WGFPMC 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 pine wood nematode, *Bursaphelenchus xylophilis*, and coneworms, *Dioryctria* spp. Fipronil also is efficacious against coneworms as well as the Nantucket pine tip moth, *Rhyacionia frustrana*. The results from the 2004 trials with *Ips* bark beetles have shown that both emamectin benzoate and fipronil were 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). Trials are needed to confirm efficacy against SPB, MPB, WPB, SB and other bark beetle species as well as to determine duration of treatment efficacy.

Objectives: 1) Evaluate the efficacy of systemic injections of new formulations of fipronil and emamectin benzoate for preventing mortality of conifers by *Dendroctonus* bark beetles found in the southeastern and western regions of the United States; 2) evaluate affect 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. Carl Jorgensen	USDA Forest Service – FHP R4, Boise, Idaho
Mr. Gary Severson	Colorado Council of Governments, Breckenridge, CO
Ms. Meg Halford	Colorado State Forest Service, Walden, CO
Mr. Leo Rankin	British Columbia Ministry of Forests, Williams Lake, BC
Dr. David Cox	Syngenta, Modesta, CA
Dr. Harold Quicke	BASF, Auburn, AL
Mr. Joseph Doccola	Arborjet, Inc., Worchester, MA

Study Sites: The study is being conducted at ten sites:

1) DeSoto National Forest, Chickasawhay Ranger District in Wayne and Green Co., Mississippi with southern pine beetle (SPB), Ips engraver beetles, and black turpentine beetle (BTB) attacking loblolly pine,
2) Private timberland owned by Sierra Pacific Industries (SPI) in Calaveras Co. California, with western pine beetle (WPB) attacking ponderosa pine;
3) Challis National Forest, Yankee Ranger District in Custer Co. Idaho, with mountain pine beetle (MPB) attacking lodgepole pine;
4) Manti-LaSal National Forest, Sanpete Ranger District in Carbon and Emery Counties, Utah with spruce beetle (SB) attacking Engelmann spruce,
5) Provincial timberland near 100 Mile House, British Columbia with MPB attacking lodgepole pine,
6) Talladega National Forest, Oakmulgee Ranger District in Bibbs and Perry Co., Alabama with SPB attacking loblolly pine,
7) Provincial timberland near 100 Mile House, British Columbia with Douglas-fir beetle (DFB) attacking Douglas-fir,
8) Private timberland owned by Mr. Gary Severson in Summit Co., Colorado with MPB attacking lodgepole pine, and
9) State Forest State Park in Jackson Co., Colorado with MPB attacking lodgepole pine.
10) Bankhead National Forest, Bankhead Ranger District in Green Co., Alabama with SPB attacking loblolly pine

Treatments:

1) Emamectin benzoate injection at 0.08 – 0.16 g AI per cm (0.2 – 0.4 g AI per in) DBH,
2) Fipronil injection at 0.08 – 0.16 g AI per cm (0.2 – 0.4 g AI per in) DBH,
3) carbaryl or bifenthrin bole spray (standard) at 0.06% AI or 2.0% AI, respectively (*)
4) Untreated (control) - used to assess beetle pressure during each summer (2005 - 2007)

(*) The standard treatment was excluded in Mississippi, Alabama, Utah and British Columbia.

Treatment Methods and Evaluation:

Each insecticide (injection or spray) treatment was applied to 30-35 randomly assigned trees. A similar number of trees were used for each set of the untreated checks (3 sets (by year) total). Test trees will be located in areas with recent beetle activity, spaced >100m apart, 23 to 52 cm dbh, and within 75m of an access road to facilitate treatment.

Each systemic insecticide treatment was injected with Arborjet Tree IV™ microinfusion system (Arborjet, Inc. Woburn, MA) into 4 cardinal points 0.3 m above the ground. The injected trees are generally allowed one to two months (depending on water availability) to translocate chemicals prior to being challenged by the application of synthetic pheromone baits. Due to the short season because elevation, the trees in Utah were not baited until 2006 (Table 29). One group of trees in British Columbia was injected in the fall 2005. A second set of trees also was injected in the spring 2006.

The standard (bifenthrin or carbaryl) spray was applied at the same time as the injections in CA and ID, respectively. Insecticides were applied with a trailer-mounted hydraulic sprayer (300 psi, #8 oriface), which allowed treatment of the entire bole of each tree, until saturation, to a height of >10m. Approximately 8 to 15 liters of formulated material was required per tree. All treatments were applied between 0600 and 1100 when wind speeds average <10 mph.

All test trees and the first set of untreated check trees were be baited with appropriate species-specific lures (Phero Tech Inc., Delta, BC or Synergy Semiochemical, Delta, BC) for 2 to 4 weeks in 2005, 2006 and/or 2007. The surviving treated trees in each treatment (if there are no more than 6 killed by the bark beetle challenge), and the second set of check trees will be baited again for the same length of time in 2006 and 2007.

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 will be assessed in August for multiple, consecutive years until efficacy is diminished. The period between pheromone removal and mortality assessment will be sufficient for trees to "fade," an irreversible symptom of pending mortality. Presence of species-specific galleries will be verified in each tree classified as dead or dying.

Treatments will be considered to have sufficient beetle pressure if ≥60% of the untreated control trees dies from beetle attack during each year. Insecticide treatments 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 (Shea et al., 1984).

Results:

The Tree IV system (Arborjet Inc.) was successfully used to inject all chemical formulations. The installation of the system on each tree (drilling holes, installing plugs, pressurizing the system, and installing needles) usually took about 5 minutes when using 3 systems in tandem. At most sites injections were completed in just a 10-20 minutes. However, in British Columbia where drought conditions prevailed and temperatures often hovered around the freezing point, injections averaged 60 minutes per tree.

<u>Southern Pine Beetle/Ips engraver beetle on loblolly pine (MS)</u>

2005 - Although the pheromone baits were left on the study trees for several weeks, relatively few bark beetle attacks were observed on most trees. Based on this observation we concluded that SPB populations were likely insufficient to cause 60% or better mortality of the check trees. Each tree was ranked as to the level of SPB attacks and tree mortality. Check trees had a much greater number of trees with high levels of attack and mortality than did emamectin benzoate- or fipronil-treated trees (Figure 12). Given that SPB populations were relatively low in 2005, it was surprising that two each of the emamectin benzoate- and fipronil-treated trees had died. All dead trees were cut down to determine the cause of tree mortality. In contrast to the check trees that were killed by SPB, the colonization of injected trees by SPB was unsuccessful (no galleries or brood were produced). Instead tree mortality appeared to be caused by the introduction of blue stain fungus by the unsuccessful SPB and possibly attack by ambrosia beetles.

2006 – All remaining study trees were initially baited with SPB pheromones. However, within two weeks it became apparent that SPB populations were insufficient to cause mortality. Subsequently, treatment of trees with Vapam and DMSO made them more susceptible to bark beetle attack. Baiting the area around the study trees with *Ips* pheromone resulted in >66% mortality of check trees (Figure 12). In contrast, fipronil- and emamectin benzoate-treated trees experienced 53% and 33% mortality, respectively. Assessment of beetle attack success on logs from killed trees revealed that both injection treatments prevented gallery construction by adults and brood development and emergence but did not prevent inoculation of bluestain fungi (Table 30). A secondary evaluation of dead study trees showed that both injection treatments significantly reduced adult black turpentine beetle gallery construction and brood development and emergence compared to untreated trees (Table 31).

<u>Southern Pine Beetle on loblolly pine (AL)</u>

2006 at Oakmulgee NF - The study trees were initially baited with the standard frontalin and turpentine mix. However, few SPB attacks were observed after the first 2 weeks. Subsequently, a third bait component (endo-brevicomin) was added, resulting in a dramatic increase in attack levels on most trees. Periodic assessments were made throughout the summer and fall. The final results showed nearly 69% the check trees exhibited fading crowns (Figure 13). In contrast, 31% and 14% of fipronil- and emamectin benzoate-treated trees had faded. All dead trees were cut down to determine the cause of tree mortality. In contrast to the check trees that were killed by SPB, the colonization of injected trees by SPB was unsuccessful (no galleries or brood were produced) (Table 30). Instead tree mortality again appeared to be caused by the introduction of blue stain fungus by the unsuccessful SPB. A secondary evaluation of dead study trees showed that both injection treatments significantly reduced black turpentine beetle brood emergence compared to untreated trees, but only emamectin benzoate reduced adult gallery construction and brood development (Table 31).

2007 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 nearly 87% the check trees exhibited fading crowns by December 2007 (Figure 13). In contrast, 43% and 33% of the remaining fipronil- and emamectin benzoate-treated trees had faded, respectively. All dead trees were cut down to determine the cause of tree mortality. Again, beetles successfully attacked and produced brood in untreated trees, but were unsuccessful in emamectin- and fipronil- treated trees. Over the two-year period, only 7% of the checks survived SPB attack and fungal infections. In contrast, 38% of the fipronil-injected trees and 57% of the EB-injected trees survived.

2007 at Bankhead NF – The study trees were baited with the three-component bait (frontalin, turpentine and endo-brevicomin) from the start (May). The results showed nearly 83% the check trees exhibited fading crowns by December 2007 (Figure 14). In contrast, 63% and 43% of the fipronil- and emamectin benzoate-treated trees had faded, respectively. All dead trees were cut down to determine the cause of tree mortality. Mortality of check trees was caused by a combination of SPB activity and blue-stain fungi infection (Figure 15). Similarly, 6 of 22 (27%) fipronil trees had died due to the same causes. On the other hand, SPB were unsuccessful in 16 of 22 (73%), but all were infected with blue stain fungi. The same pattern of unsuccessful SPB colonization, but successful blue stain introduction was present in most (13 of 15; 87%) of the dead EB-treated trees. The remaining two trees had no successful SPB attacks or blue stain fungal infection. Instead, tree mortality was likely due to the severe drought conditions occurring in the area.

<u>Western Pine Beetle on ponderosa pine (CA)</u>

2005 - Nearly all baited trees, except for those sprayed with bifenthrin, were heavily attacked by WPB within 3 weeks. A preliminary assessment of potential tree mortality was conducted in October. At that time, better than 53% the check trees exhibited fading crown or were so heavily attacked by bark beetles it was presumed that the trees would die. In contrast, 20%, 13% and 3% of fipronil-, emamectin benzoate- and bifenthrin-treated trees, respectively, had faded or were expected to die. A final assessment in 2006 showed that in fact only 43% of the checks were killed, while 17%, 0% and 0% of fipronil-, emamectin benzoate- and bifenthrin-treated trees had actually faded, respectively (Figure 16).

2006 – Again, nearly all baited trees, except for those sprayed with bifenthrin, were heavily attacked by WPB within 3 weeks. A final assessment of potential tree mortality was conducted in October. At that time, 40% the check trees exhibited fading crowns or were so heavily attacked by bark beetles it was presumed that the trees would die (Figure 16). In contrast, 9%, 3% and 3% of fipronil-, emamectin benzoate- and bifenthrin-treated trees, respectively, had faded.

2007 - The study trees experienced greater beetle pressure this year. Preliminary results suggest that 51% of the check trees will die (Figure 16). In contrast, all treatments provided good protection against WPB. As of October 2007, only 10%, 0%, and 7% of the fipronil-, emamectin-, and bifenthrin-treated trees had died. If these numbers hold, only 53% of the checks survived WPB attack and fungal infections. In contrast, 68% of the fipronil-injected, 90% of the bifenthrin-treated and 97% of the EB-injected trees survived.

<u>Mountain Pine Beetle on lodgepole pine (ID)</u>

2005 - Bark beetle populations were exceptionally high in the study site area. In a matter of just 5 days after baits were deployed, nearly all check and injected trees were heavily attacked. In contrast, very few carbaryl-sprayed trees were attacked. A final assessment was made in September 2006. At that time, nearly 53% the check trees exhibited true crown fade (Figure 17). In turn, 37%, 37% and 0% of fipronil-, emamectin benzoate- and carbaryl-treated trees, respectively, had faded.

2006 - Bark beetle populations were again high in the study site area. Nearly all check and injected trees were heavily attacked. In contrast, very few carbaryl-sprayed trees were attacked. A final assessment was made in September 2007. At that time, nearly 53% the check trees exhibited true crown fade (Figure 17). In contrast, only 0%, 11% and 10% of the remaining fipronil-, emamectin benzoate- and carbaryl-treated trees, respectively, had faded. Although, the cumulative mortality was fairly high for both injection treatments (37% for fipronil and 43% for

EB), nearly all occurred in the first year. This indicates that more time was needed after injection for the chemicals to circulate. The trees that survived the first attack in 2005 had adequate time to circulate chemical before the second attack in 2006.

Spruce Beetle on Engelmann spruce (UT)

2006 - Treated and untreated trees were baited in April 2006. Baits were left on trees throughout the beetle flight period (June – August). A preliminary assessment in February 2007 indicated that beetle populations were very high, resulting in over 94% mortality of untreated check trees (Figure 18). The assessment also found high levels of probable mortality (93% and 66%) to fipronil and emamectin benzoate-treated trees, respectively. However, the final assessment made in August 2007 showed that actual mortality was 100% for both check and fipronil trees and close to that (94%) for EB trees. It appears that the very short growing season and extreme cold temperatures slowed down the movement of both chemicals to the extent that the trees were not fully protected during the beetle flight in 2006.

Mountain Pine Beetle on lodgepole pine (BC) One set of trees was treated in fall 2005. A second set was treated in May 2006. In anticipation of epidemic population levels, trees were left unbaited during the MPB flight period (July – September) in 2006. A preliminary assessment in August indicated that nearly all trees had been attacked by beetles, but no prediction could be made of probable mortality. However, due to the short season in British Columbia, the final assessment was not made until late 2007. We await the final data.

Mountain Pine Beetle on lodgepole pine (CO) One set of trees were treated on each of two sites in fall 2006. Additional trees at the Colorado State Forest site were treated in May 2007. In anticipation of epidemic population levels, trees were left unbaited during the MPB flight period (July – September) in 2007. Due to the short season at higher elevations in Colorado, the final assessment will not be made until 2008.

Conclusions: Final first year evaluations at both the MS and CA sites showed that there was insufficient beetle (SPB and WPB, respectively) pressure to cause the required amount of check tree mortality (60%). However, the level of attack on check trees was markedly greater than that on injected trees, suggesting that the treatments had an affect on SPB and WPB attraction and attack success.
Although, preliminary data from ID and UT indicate that both injection treatments were ineffective in reducing mountain pine beetle- and spruce beetle-caused mortality, respectively, the reason most likely is due to low temperatures and insufficient time between injection and beetle attack (5 weeks) for chemicals to move throughout tree systems. This hypothesis was confirmed in the second year of the ID trial when very few additional injected trees died after a second baiting.

In contrast, two year data from Oakmulgee NF, AL and first year data from Bankhead NF, AL both conclusively showed that emamectin benzoate was effective in preventing the successful attack by SPB. Although, a few (5) EB trees died the first year (2006 at Oakmulgee), the primary cause was most likely the result of numerous inoculations of bluestain fungi by the hundreds (perhaps thousands) of bark beetle adults that tried to attack the trees. In 2007, it appears that tree mortality was due to a combination of fungal infections as well as additional stress due to severe drought conditions at both study sites.

The baiting of trees with pheromones causes a false extended attack on trees. Under natural conditions (without baits) it is surmised that female WPB and SPB that initiate attacks would be either deterred or killed upon penetration into the phloem layer and exposure to the active ingredient. Any pheromone production by females as they burrow through the bark is halted prematurely. Without these pheromones, very few, if any, males were attracted to the host material or entered the galleries to mate. The halting of pheromone production upon female contact with the phloem layer also halted the attraction of additional females, thus preventing the mass attack of the host tree. Some of these females may introduce bluestain fungi at the points of attack. However, if the number of attacks is relatively few, the trees should be able to compartmentalize the fungi quickly and prevent tree mortality.

Acknowledgements: Many thanks go to our cooperators: Chris Fettig, Steve Clarke, Steve Munson, Carl Jorgensen, Leo Rankin, Gary Severson and Meg Halford for their efforts on the project. We appreciate the chemical donations and injection equipment loans made by Arborjet, Inc, BASF, and Syngenta and field assistance of Chris Dabney, Robert Borys, Jason Helvey, Teresa Krause, Doris Oberlander, Genie Michiel, and Blake Smith. These trials were supported by funds from the WGFPMC, Western Bark Beetle Initiative, Southern Pine Beetle Initiative and BASF.

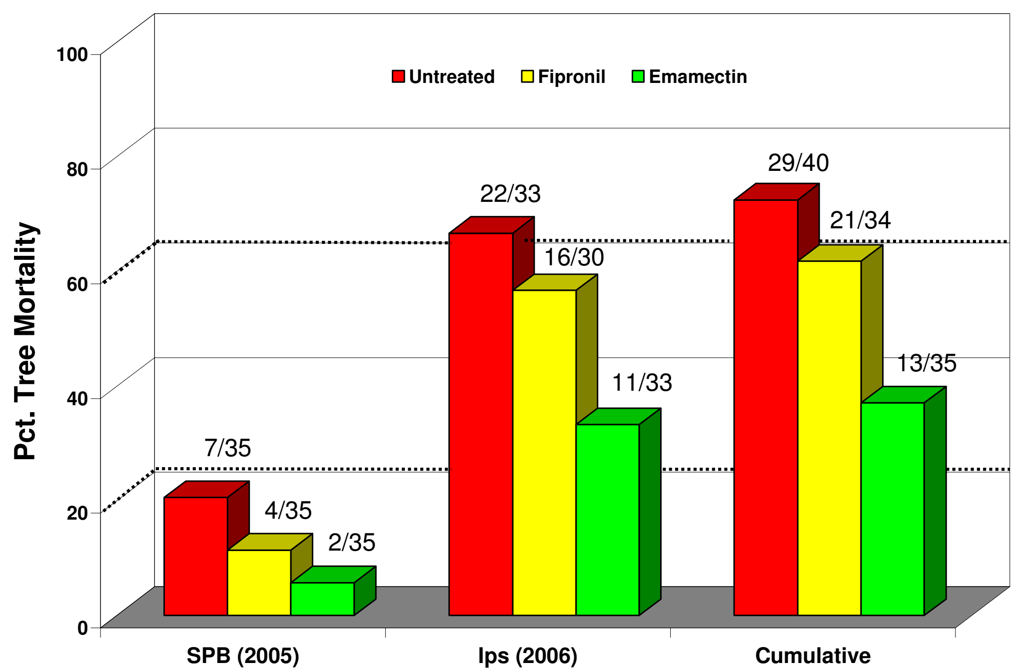


Figure 12. Yearly and cumulative effects of injection treatments on loblolly pine mortality caused by southern pine beetle (2005) and Ips engraver beetle (2006), Chickasawhay, Ranger District, DeSoto National Forest, MS. The dashed line at 60% cumulative mortality is the level of control tree mortality necessary for a valid test; the dashed line at 20% cumulative mortality is the maximum allowable mortality of treatments to be considered efficacious.

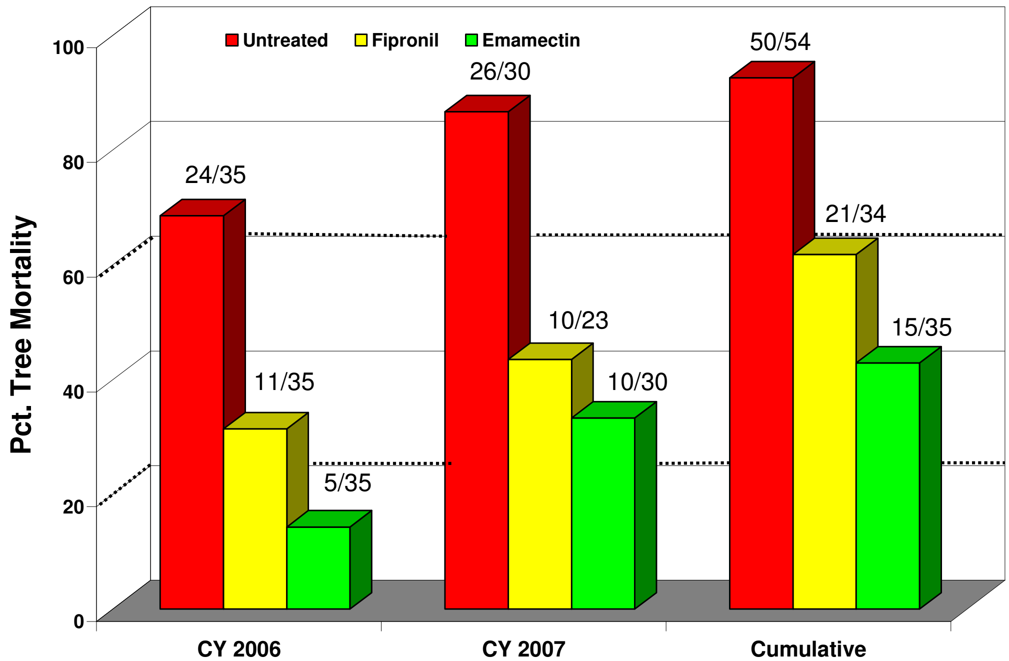


Figure 13. Effects of injection treatments on loblolly pine mortality caused by southern pine beetle (2006 & 2007), Oakmulgee Ranger District, Talladega National Forest, AL. The dashed line at 60% cumulative mortality is the level of control tree mortality necessary for a valid test; the dashed line at 20% cumulative mortality is the maximum allowable mortality of treatments to be considered efficacious.

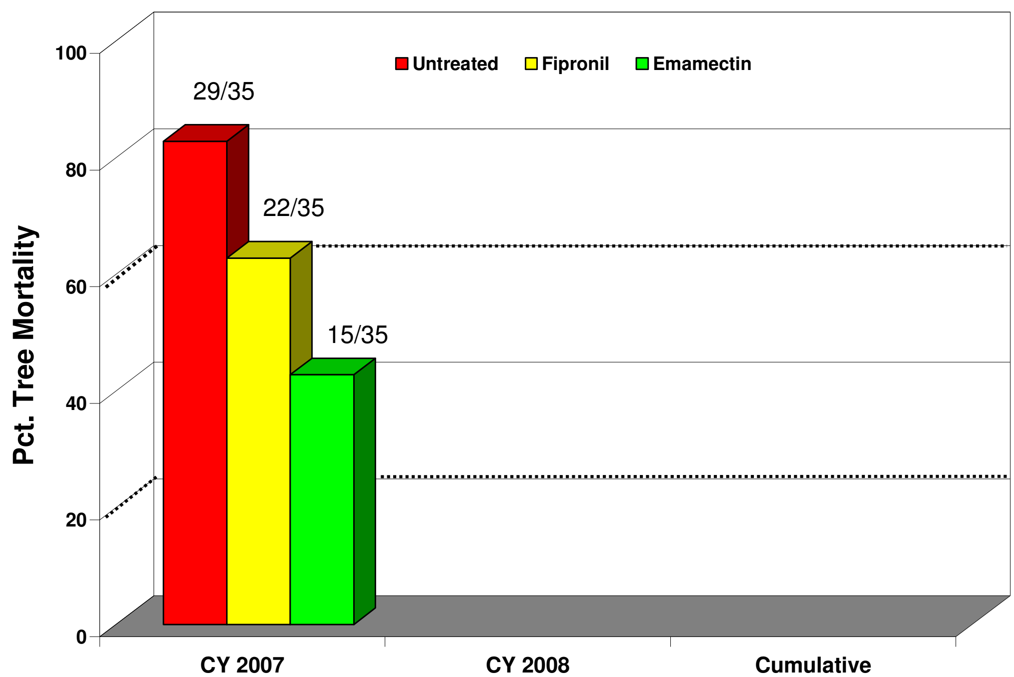


Figure 14. Effects of injection treatments on loblolly pine mortality caused by southern pine beetle (2007), Bankhead Ranger District, Bankhead National Forest, AL. The dashed line at 60% cumulative mortality is the level of control tree mortality necessary for a valid test; the dashed line at 20% cumulative mortality is the maximum allowable mortality of treatments to be considered efficacious.

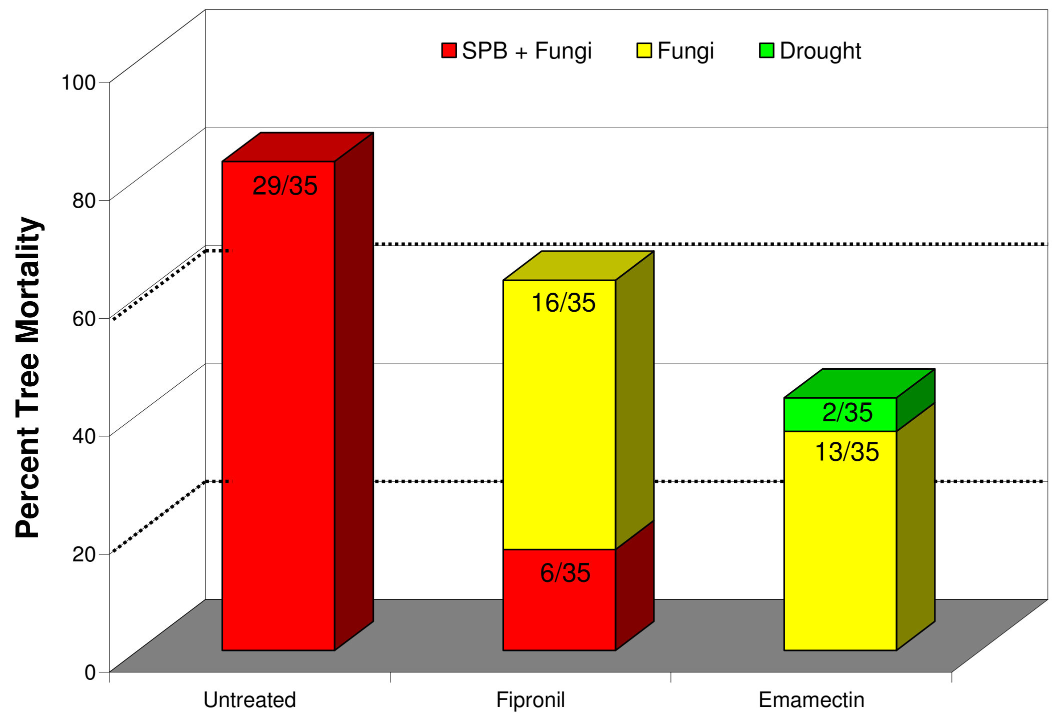


Figure 15. Effects of injection treatments on loblolly pine mortality caused by southern pine beetle (2006), Bankhead Ranger District, Bankhead National Forest, AL.

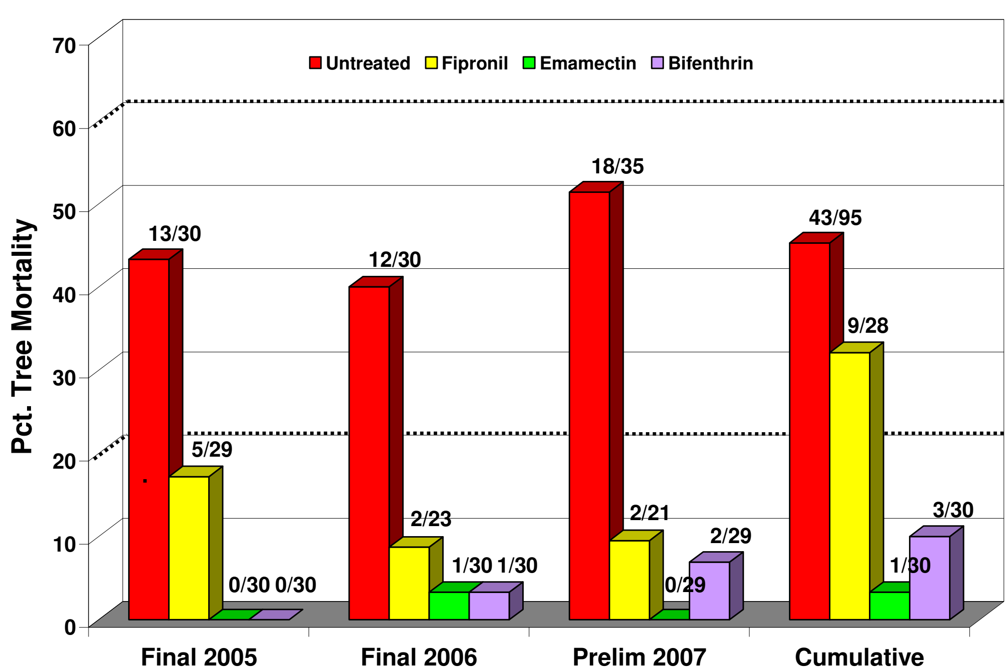


Figure 16. Yearly and cumulative effects of injection treatments on ponderosa pine mortality caused by western pine beetle as of November 2007, Sierra Pacific Industries (SPI) land in Calaveras Co., California. The dashed line at 60% cumulative mortality is the level of control tree mortality necessary for a valid test; the dashed line at 20% cumulative mortality is the maximum allowable mortality of treatments to be considered efficacious.

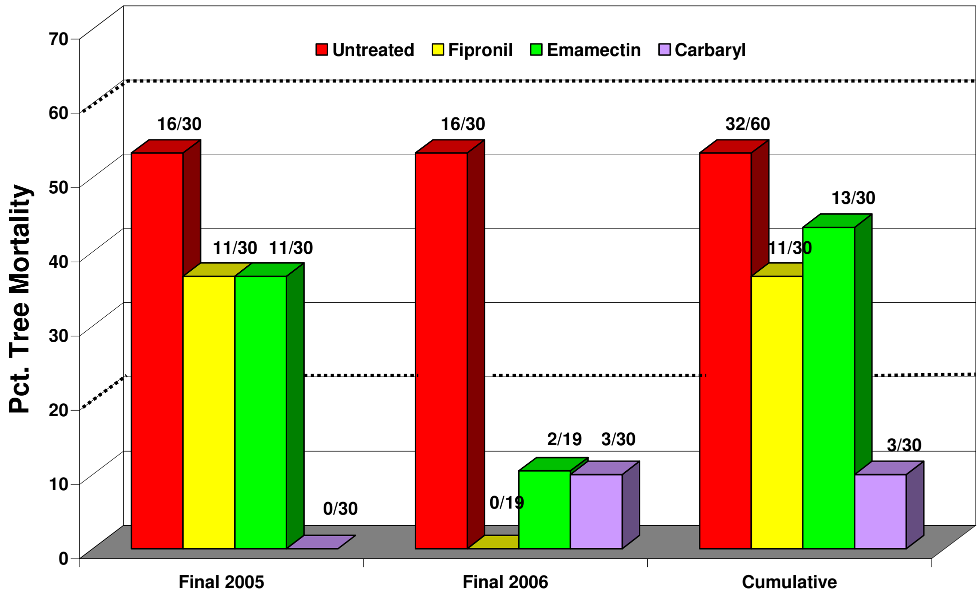


Figure 17. Yearly and cumulative effects of injection treatments on lodgepole pine mortality caused by mountain pine beetle as of September 2007, Challis National Forest, Yankee Ranger District in Custer Co., Idaho. The dashed line at 60% cumulative mortality is the level of control tree mortality necessary for a valid test; the dashed line at 20% cumulative mortality is the maximum allowable mortality of treatments to be considered efficacious.

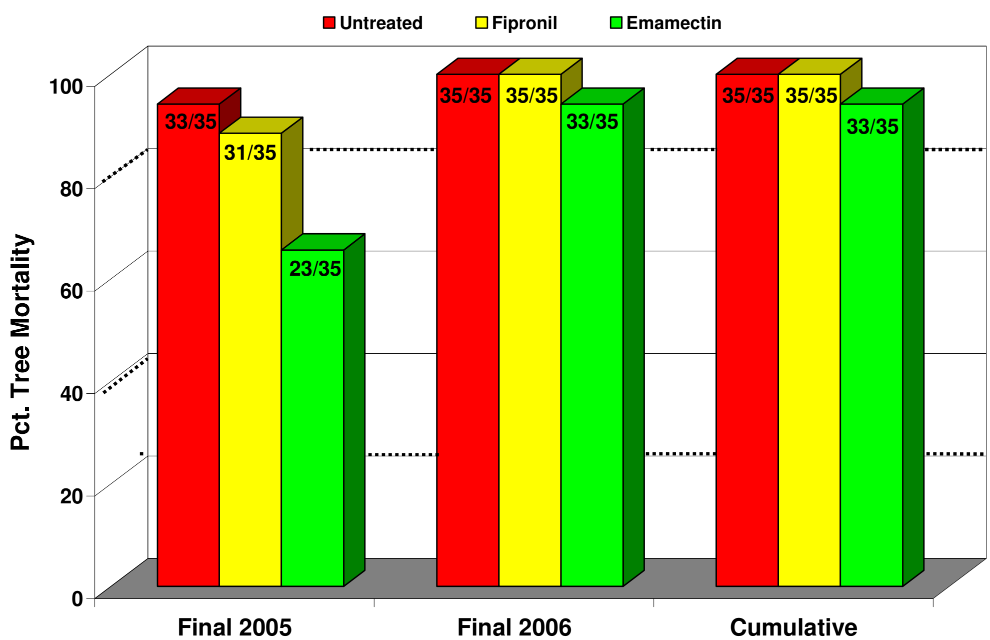


Figure 18. Preliminary and final effects of injection treatments on Engelmann spruce mortality caused by spruce beetle, Manti-LaSal National Forest in Emery and Carbon Co., Utah. The dashed line at 60% cumulative mortality is the level of control tree mortality necessary for a valid test; the dashed line at 20% cumulative mortality is the maximum allowable mortality of treatments to be considered efficacious.

Table 29. Scheduled Injection, Baiting and Evaluation Dates for Nine *Dendroctonus* Bark Beetle Trials

	SPB, Ips & BTB (MS)	SPB & BTB (AL)	WPB (CA)	MPB (ID)	SB (UT)	MPB (BC)	MPB (CO)
Project Leader(s)	Grosman & Clarke	Grosman & Clarke	Fettig	Jorgenson	Munson	Rankin	Doccola
Injection Dates	April, 2005	April, 2006	May, 2005	June, 2005	August, 2005	September, 2005 May, 2006	September, 2006 May, 2007
Baiting Period	May - July, 2005 May - June, 2006	May - June, 2006 May - June, 2007	July - August, 2005 July - August, 2006 July - August 2007	July, 2005 July, 2006	April - July 2006	---------	---------
Prelim Evaluation	August 2005 August 2006	June - July 2006 June - July 2007	October 2005 October 2006 October 2207	August 2005 August 2006	February 2007	November 2006	November 2007
Final Evaluation	December 2005 December 2006	December 2006 December 2007	June 2006 June 2007 June 2008	June 2006 June 2007	June 2007	April 2007	August 2008

SPB = Southern pine beetle; Ips = Ips engraver beetle; BTB = Black turpentine beetle; WPB = Western pine beetle; MPB = Mountain pine beetle; SP = Spruce Beetle

Table 30 - Effects of Emamectin Benzoate and Fipronil Injection Treatments on Mean (± SE) of Success of Bark Beetle Adult Attack and Brood Development and Emergence and Presence of Blue Stain Fungi Inoculation.

				Ranking (Many or All = 1.0, Around Half = 0.5, Few or None = 0.0)					
Site	Treatment	N	No. of Bark Beetle Attacks per 1000 cm^2	Bark Beetle Galleries (Length > 1 in) Present	Bark Beetle Brood Present	Bark Beetle Emergence Holes Present	Blue Stain Fungi Present	No. of Cerambycid Egg Niches per 1000 cm2	No. of Cerambycid Larval Galleries per 1000 cm^2
			Southern Pine Beetle						
AL	Emamectin	5	11.0 ± 1.8 **a**†	0.00 ± 0.00 **a**	0.00 ± 0.00 **a**	0.00 ± 0.00 **a**	1.00 ± 0.00 **a**	17.8 ± 5.2 **b**	0.4 ± 0.4 **a**
	Fipronil	11	11.8 ± 1.8 **a**	0.45 ± 0.11 **b**	0.46 ± 0.11 **b**	0.36 ± 0.12 **b**	1.00 ± 0.00 **a**	11.5 ± 1.5 **a**	4.8 ± 1.3 **b**
	Check	24	12.1 ± 0.9 **a**	1.00 ± 0.04 **c**	1.00 ± 0.04 **c**	1.00 ± 0.04 **c**	0.98 ± 0.02 **a**	8.9 ± 0.8 **a**	10.4 ± 0.6 **c**
			Ips Engraver Beetles						
MS	Emamectin	11	9.3 ± 1.5 **a**	0.00 ± 0.00 **a**	0.00 ± 0.00 **a**	0.00 ± 0.00 **a**	1.00 ± 0.00 **a**	22.8 ± 4.5 **a**	0.5 ± 0.5 **a**
	Fipronil	17	9.7 ± 0.9 **a**	0.22 ± 0.05 **b**	0.06 ± 0.04 **a**	0.06 ± 0.04 **a**	1.00 ± 0.00 **a**	20.1 ± 1.8 **a**	2.0 ± 0.8 **a**
	Check	22	9.5 ± 0.7 **a**	1.00 ± 0.00 **c**	1.00 ± 0.00 **b**	1.00 ± 0.00 **b**	1.00 ± 0.00 **a**	16.9 ± 2.3 **a**	11.3 ± 0.7 **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.

Table 31. Effects of Emamectin Benzoate and Fipronil Injection Treatments on Mean (± SE) Success of Black Turpentine Beetle (Dendroctonus terebrans, BTB) Adult Attack, Brood Development, and Emergence.

Site	Treatment	N	No. of BTB Attacks	Ranking (Many or All = 1.0, Around Half = 0.5, Few or None = 0.0): BTB Galleries (Length > 1 in) Present	Ranking: BTB Brood Present	Ranking: BTB Emergence Holes Present
AL	Emamectin	5	1.6 ± 0.7 **a**†	0.20 ± 0.20 **a**	0.20 ± 0.20 **a**	0.00 ± 0.00 **a**
	Fipronil	11	2.6 ± 1.0 **a**	0.64 ± 0.15 **b**	0.64 ± 0.15 **b**	0.18 ± 0.12 **a**
	Check	20	4.4 ± 1.2 **a**	0.90 ± 0.07 **b**	0.90 ± 0.07 **b**	0.90 ± 0.07 **b**
MS	Emamectin	11	10.0 ± 1.7 **a**	0.00 ± 0.00 **a**	0.00 ± 0.00 **a**	0.00 ± 0.00 **a**
	Fipronil	17	9.5 ± 1.5 **a**	0.41 ± 0.12 **b**	0.29 ± 0.11 **a**	0.06 ± 0.06 **a**
	Check	18	13.4 ± 1.5 **a**	0.94 ± 0.06 **c**	0.94 ± 0.06 **b**	0.94 ± 0.06 **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.

SYSTEMIC INSECTICIDE INJECTION TRIALS

Evaluation of Injection Systems for Application of Emamectin Benzoate in Loblolly Pine

Highlights:

- Seven injection systems were evaluated based on their characteristics for their potential to inject emamectin benzoate (EB) into pine; four systems were found capable of injecting product. The Tree IV system ranked best overall, followed by Quick-jet, Portle and Sidewinder (backpack).
- EB treatments made by these four systems were evaluated for their ability to protect logs against *Ips* engravers and wood borers one month after injection. All treatments were highly and equally effective against both insect groups.

Justification: Injection trials conducted by the Western Gulf Forest Pest Management Cooperative from 1999 – 2005 have shown that different formulations of emamectin benzoate (EB) such as Shot Wan, Denim & "Ava-jet" when injected into loblolly pine, are highly effective against several forest insects including coneworm and/or bark beetles. Arborjet, Inc (Woburn, MA) in cooperation with Syngenta has developed a new EB formulation (Ava-jet) that will be submitted for registration by EPA in the near future. Applications of emamectin benzoate have been made almost exclusively through the use of Arborjet's Tree IV system. Syngenta, the AI manufacturer, is interested in knowing if the EB formulation can be applied to pine trees using other available injection/infusion systems and are these applications effective in preventing/reducing insect damage.

Objectives: 1) Evaluate system's ability inject EB formulation based on time to prepare/load, install and treat each tree and safety; 2) Evaluate speed of uptake based on control 30days after injection, and then yearly for 2 more years.

Cooperators

Mr. Jason Ellis	Texas Forest Service, Jacksonville, TX
Dr. David Cox	Syngenta, Modesta, CA
Mr. Joseph Doccola	Arborjet, Inc., Worchester, MA

Research Approach: Seven injection/infusion systems included:

Mauget System (Mauget; contact: Marianne Waindle) low volume (4 ml/inj pt); low pressure (10 psi)

M3 System (Rainbow Treecare Scientific Advancements; contact: Shawn Bernick); moderate volume (30 ml/inj pt); low pressure (20 - 30 psi)

Portle (prototype) System (ArborSystems; contact: Chip Doolittle) – moderate volume (10 – 20+ ml/inj pt); high pressure (500+ psi)

Quick-jet (prototype) System (Arborjet, Inc.; contact: Joe Doccola) – moderate volume (5 – 20+ ml/inj pt); moderate pressure (50+ psi)

Sidewinder Systems – backpack and Bug Buster - (Sidewinder; contact: Geoff Eldridge) high volume (50+ ml/inj pt); high pressure (500+ psi)

Tree IV System (Arborjet, Inc.; contact: Joe Doccola) – high volume (125+ ml/inj pt); moderate pressure (60 psi)

Information about the systems was requested from each manufacturer. In particular, information was requested on the recommended procedures for installation and injection of trees. Each system was ranked on the following criteria with potential points in parentheses:

1) system cost (10 pts)
2) need for peripheral parts (plugs, needles, battery chargers) (5 pts)
3) system capacity (volume of product) (3 pts)
4) Is system disposable or reusable? (2 pts)
5) Does chemical come prepackaged; can you inject product undiluted or is it necessary to dilute with water? (5 pts)
6) Time and ease to fill system with chemical product (5 pts)
7) Time and ease to install system on tree (5 pts)
8) Number of injection points required per tree (5 pts)
9) Can the system be left alone on tree or does the applicator need to manually operate system continuously? (5 pts)
10) Time and ease to inject X amount of product. (10 pts)
11) Cumulative time applicator spends at each tree. (10 pts)
12) Potential for chemical exposure. (10 pts)
13) Time and ease to clean system. (10 pts)
14) Weather restrictions (moisture, temperature) (5 pts)
15) Effectiveness of treatment 1 month after treatment (10 pts)

Treatment Methods and Evaluation:

This study was conducted in a loblolly pine plantation (about 20 years old) that had been recently thinned in Fairchild State Forest, Rusk Co.,Texas. Test trees (135), ranging from 15 to 23cm dbh, were selected. Fifteen (15) trees were each injected with the same AI concentration (0.2g/ inch diameter of tree) but at one of two volume rates (low = 5ml/in dia. or high = 10ml/in dia) of EB (Arborjet, Inc.) using each system in late March and early April 2007 (Table 32). Fifteen trees served as untreated controls. The application procedure used to inject the EB formulation was based on the recommendations of each system manufacturer. The injected trees were allowed at least 1 month to translocate chemicals prior to being challenged by bark beetles.

Table 1. Volume (ml) of Emamectin benzoate formulation injected per tree diameter class

Tree Diameter		Low Volume: 1 EB (0.2 g/" dia) undilute				High Volume: 1 EB (0.2 g/" dia): 1 Water			
Inches	cm	EB ml	Water ml	Total ml	mls/ Inj Pt	EB ml	Water ml	Total ml	mls/ Inj Pt
1	2.5	5	0	5	1	5	5	10	3
2	5.1	10	0	10	3	10	10	20	5
3	7.6	15	0	15	4	15	15	30	8
4	10.2	20	0	20	5	20	20	40	10
5	12.7	25	0	25	6	25	25	50	13
6	15.2	30	0	30	8	30	30	60	15
7	17.8	35	0	35	9	35	35	70	18
8	20.3	40	0	40	10	40	40	80	20
9	22.9	45	0	45	11	45	45	90	23
10	25.4	50	0	50	13	50	50	100	25
11	27.9	55	0	55	14	55	55	110	28
12	30.5	60	0	60	15	60	60	120	30

Groups of five (5) trees for each treatment were/will be felled at 1 month, 1 year and 2 years after injections. One 1.5 m-long bolt were/will be removed from the 5 m height of the bole. The bolts were transported to a nearby plantation that had been recently thinned and contained fresh slash material. Bolts were randomly placed 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 Semiochemical, Delta, BC, Canada) were attached to 1 m stakes evenly spaced in the study area.

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

1) Number of bark beetle pitch tubes and cerambycid egg niches on bark surface.
2) Number of unsuccessful attacks – penetration to phloem, but no egg galleries.
3) Number of successful attacks – construction of nuptial chamber and at least one egg gallery extending from it.
4) Number and lengths of egg galleries with larval galleries radiating from them.
5) Number and lengths of egg galleries without larval galleries.
6) 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 were determined by comparing the number of *Ips* beetle attacks, the number and total length of *Ips* egg galleries and the area of cerambycid feeding for each treatment and application timing. Data were 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:

Field evaluations of systems were performed between March 30 and April 5, 2007. Four (Portle, Quick-jet, Tree IV and Sidewinder - backpack) of the seven systems were found to be capable of injecting the desired amount of emamectin benzoate into a study tree (Table 33). Of the remaining systems, two (Mauget and M3) had insufficient pressure to push the chemical past the tree's resin pressure and the third system (Sidewinder – Bug Buster) malfunctioned and could not be repaired.

Based on the time needed to inject product, it was determined it was quicker to inject an undiluted (low volume) with the Quick-jet, Portle and Sidewinder then to inject a dilute (high volume) solution. In contrast, it was quicker to inject a diluted (high volume mix) with the Tree IV compared to an undiluted product. Although the average injection rate for the Sidewinder (6.6 ml/minute) was 29% or more faster compared to that of the Quick-jet (4.7 ml/min), Tree IV™ (4.6 ml/minute), and Portle (4.1 ml/min), the cumulative time spent at a given tree with the Tree IV was 1.5 – 3.9 minutes shorter than the other systems.

Table 34 compares the seven tested injection systems relative to fifteen criteria (cost, peripheral parts, capacity, reusablity, can it be left alone, prepackaged or mix, weather restrictions, ease/time to fill system, number of injection points, ease/time to install system, ability of system to inject product, cumulative time spent at tree, ease/time to clean system, potential for chemical exposure, effectiveness of treatment). The criterion had a value ranging from 2 to 10 points.

The Tree IV system (Arborjet) accumulated the greatest number of points (81) based on the fact it was very consistent in its ability to inject emamectin benzoate into conifers, it can be install and left alone on a tree and there is very little chance of chemical exposure. Other attractive features include that it is a fairly inexpensive system that is reusable, it has a large chemical capacity (1000 ml), require few injection points to treat the tree, and is not limited to any great extent by weather restrictions. Some important limitations include a need to install plugs and manage spaghetti tubing, the need to mix product with water prior to injection, and the need to measure product and fill system for each tree

The Quick-jet system (Arborjet) was close behind with 79 points. It has several attractive features including that the emamectin benzoate product can be effectively applied undiluted under most conditions, it also has a large volume capacity, one load can be used to treat several trees, it requires few injection points to treat the tree, and it's reusable and easy to clean. Some limitations include the fact that the applicator has to remain with the system during the injection, there is some potential for chemical exposure and the need to install plugs in each tree.

The Portle System (ArborSystem) was third with 71 points. Its attractive features are that the system is has a large product capacity (1000 ml), the product would be prepackaged, and the system is reusable and easy to install on the tree. Some important limitations include the need for several more injection points compared to other systems (more time and effort), that the applicator has to remain with the system during the injection, there is some potential for chemical exposure and fairly high cost.

The Sidewinder™ backpack system was fourth with 68 points. The system has a large product capacity (1000 ml), can be installed quickly and easily, and the product is quickly injected into the tree under most conditions. However, the cost is high, a need to change and recharge batteries, the model tested had a tendency to leak around injections points and for chemical to get on the surfaces of the drill and pump handle. Thus, the potential for chemical exposure was fairly high and cleaning the system took longer than should be expected.

All four of the above systems were effective in injecting the desired amount of product into each of 15 trees. The evaluation of the first series of logs taken one month after injection revealed that all treatments were highly effective in protecting logs from bark beetle and wood borer attacks regardless of the system used (Tables 35 – 37)

The other systems (Mauget, M3 and Sidewinder - Bug Buster) each have some attractive features. However, the EB product could not be effectively and consistently injected with any of these systems because either the system pressure was too low (Mauget & M3) or the system malfunctioned (Sidewinder – Bug Buster).

Conclusions:

Four injection systems (Tree IV, Quick-jet, Portle and Sidewinder) were found to be operationally effective in the injection of emamectin benzoate into loblolly pine. However, the seed orchard manager or arborist needs to consider several factors (cost, convenience, injection rate, safety, etc.) before selecting a system to use.

The development of new and/or improved injection systems is anticipated in the near future with the realization that protection of trees and crops with systemic chemicals is an economically viable option. Arborjet™ continues to upgrade their Tree IV system and has just released the new less Quick-jet system. Also, upgrades of the Sidewinder™ system will reduce chemical leaks and exposure and the system can be connected to a compressed air injector pump on a single tractor or any other suitable mobile power source to improve treatment efficiency. Lastly, a new Eco-ject system (not tested) is being developed by BioForest Technologies base on Dr. Blair Helson's STIT concept.

Table 33: Comparison of Injection System Characteristics during Operational Use.

System Evaluated:	Tree IV		Quick-jet		Portle		Sidewinder	
Volume	Low	High	Low	High	Low	High	Low	High
No. Trees	5	15	15	5	15	5	15	5
DBH	6.3	6.8	6.6	6.6	6.4	6.4	6.6	6.8
Actual Volume Needed	32	68	33	70	32.5	64	33	70
No. Units used at a time	3	3	1	1	1	1	1	1
Time (min) needed to fill system unit with chemical product:	1	1.1	0.2	0.2	NA	NA	0.2	0.2
Number of injection points required:	4	4	4	6.6	6.8	10.8	3.9	4.6
Time (min) needed to install system on tree:	4.7	4.2	1.5	2.8	1.2	2.8	1.4	1.6
Time (min) required to inject/infuse X-amount of product:	25.8	14.6	7.0	8.6	7.9	14.7	5.0	7.0
Cumulative time at tree (min):	5.7	5.2	8.7	11.5	9.1	17.5	6.6	8.8
Time (min) needed to clean system units	13.5	13.5	2.2	2.2	6.8	6.8	7.3	7.3

NA = Not applicable

Table 34: Comparison of characteristics of several injection systems that may be compatible with emamectin benzoate.

	System													
Characteristics (Potential Points)	Mauget		M3		Tree IV		Quick-jet		Portle		Sidewinder (Backpack)		Sidewinder (Bug Buster)	
Manufacturer	Mauget		Rainbow TreeCare		Arborjet		Arborjet		ArborSystems		Sidewinder		Sidewinder	
Retail Cost (10)	$6.20/ unit @ 8 per 10" tree	10	$299/ kit @ up to 16 per tree	8	$300/ unit @ 1 per tree	8	$359/ unit @ 1 per tree	7	$884/ unit @ 1 per tree	5	$1562/ unit @ 1 per tree	3	~$2000/ unit @ 1 per tree	2
Need for Peripheral Parts (5)	No	5	No	5	Yes: Plugs: $0.65 ea	3	Yes: Plugs: $0.65 ea	3	Yes: Needles: $6.25 ea	4	Yes: Plugs, Battery charger	3	Yes: Plugs, Battery charger	2
Sysem Capacity (3)	4 ml	1	30 ml	3	1000 ml	4	1000 ml	5	1000 ml	5	1000 ml	5	1000 ml	5
System Reusable? (2)	No	1	Yes	2	Yes	2	Yes	2	Yes	2	Yes	2	Yes	2
Can System be Left Alone on Tree? (5)	Yes	4	Yes	4	Yes	4	No	3	No	3	No	3	No	3
Chemical Prepackaged, Undilute, or Mixed (5)	prepackaged	5	undilute	3	mixed w/ water	2	undilute	3	prepackaged	5	mixed w/ water	2	mixed w/ water	2
Weather restriction(s) (5)	cold and dry	2	cold and dry	2	cold and dry	4	cold and dry	3	cold and dry	4	cold and dry	4	cold and dry	4
Ease/time to fill system with chemical product (5)	prepackaged	5	each unit needs to be filled separately as it is installed on tree	2	need to fill system for each tree	3	single system fill for several trees	4	if prepackaged	5	single system fill for several trees	4	single system fill for several trees	4
No. of injection points required per tree (5)	8 points	2	4 points	5	4 points	5	4 points	5	7 points	3	5 points	4	5 points	4
Ease/time of system installation on tree (5)	generally easy	4	generally easy, but several steps involved	3	installation of plugs, sphagetti	3	installation of plugs	4	generally easy, but needle often bends	4	easy	5	easy	5
Ability to push product into tree (10)	generally unable under most conditions	1	generally unable under most conditions	1	effectively applied almost always	9	effectively applied under most conditions	8	effectively applied under most conditions	7	effectively applied under most conditions	7	system malfunctioned	2
Cumulative time spent at each tree (10)	considerable	3	considerable	3	present at tree only to install and remove	9	fast, but must remain at tree	7	moderately fast, but must remain at tree	6	quick, but must remain at tree	8	quick, but must remain at tree	8
Ease/time to clean system (10)	disposable	8	need to clean several units	6	need to clean several units	7	easy to clean unit	9	should be easy flush, but chemical was also on outer surface	5	should be easy flush, but chemical was also on outer surface of drill and pump handle	4	fairly easy to clean	8
Potential for chemical exposure (10)	very little exposure potential	9	little potential for exposure	8	very little exposure potential	9	some potential exposure	6	frequent leaks from and around needles	3	several leaks around injection point or chemical on or dripping from	4	few leaks around injection point; little chemical on or dripping from	6
Effectiveness of treatment 1 month after injection (10)	NA	0	NA	0	very good	9	excellent	10	excellent	10	excellent	10	NA	0
Total Score (out of 100 possible points)	**60**		**55**		**81**		**79**		**71**		**68**		**57**	

NA = Not Applicable or Available

Excellent Good Fair Poor Bad

Scored 80% or higher

Table 35: Attack success and gallery construction of *Ips* engravers beetles on loblolly pine bolts cut 1 month after trunk injection with emamectic benzoate using different injection systems; Lufkin, Texas - 2006.

Evaluation period	System	Rate	N	Mean # of nuptial chambers without egg galleries		Mean # of nuptial chambers with egg galleries		Mean total # of nuptial chambers
				No.	% of total	No.	% of total	
1 month Post-Injection (June)	Tree IV	Low (5ml / "dbh)	5	5.8	81	1.4	19	7.2
	Quick-jet		5	2.6	100	0.0 *	0	2.6 *
	Portle		5	6.6 *	100	0.0 *	0	6.6
	Sidewinder		5	4.8	96	0.2 *	4	5.0
	Tree IV	High (10ml / "dbh)	5	9.4 *	96	0.4 *	4	9.8
	Quick-jet		5	5.0	100	0.0 *	0	5.0
	Portle		5	4.4	100	0.0 *	0	4.4
	Sidewinder		5	5.6	93	0.4 *	7	6.0
	Check		5	3.4	44	4.4	56	7.8

* Means followed by an asterisk are not significantly different from the check at the 5% level based on Fis

Table 36: Mean number and length of egg galleries constructed by *Ips* engravers beetles (per 1000 cm^2) in loblolly pine bolts cut 1 month after trunk injection with emamectin benzoate using different injection systems; Lufkin, Texas - 2007.

Evaluation period	System	Rate	N	Number of egg galleries: Without larvae No.	Without larvae % of total	With larvae No.	With larvae % of Total	Total #	Length of egg galleries: Without larvae cm	Without larvae % of Total	With larvae cm	With larvae % of Total	Total length
1 Month Post-Injection (May)	Tree IV	Low (5ml / "dbh)	5	2.0	77	0.6 *	23	2.6 *	7.6	56	6.0 *	44	13.6 *
	Quick-jet		5	0.0 *	####	0.0 *	####	0.0 *	0.0 *	####	0.0 *	####	0.0 *
	Portal		5	0.0 *	####	0.0 *	####	0.0 *	0.0 *	####	0.0 *	####	0.0 *
	Sidewinder		5	0.2 *	100	0.0 *	0	0.2 *	1.0 *	100	0.0 *	0	1.0 *
	Tree IV	High (10ml / "dbh)	5	0.8	80	0.2 *	20	1.0 *	4.6	70	2.0 *	30	6.6 *
	Quick-jet		5	0.0 *	####	0.0 *	####	0.0 *	0.0 *	####	0.0 *	####	0.0 *
	Portal		5	0.0 *	####	0.0 *	####	0.0 *	0.0 *	####	0.0 *	####	0.0 *
	Sidewinder		5	0.4 *	100	0.0 *	0	0.4 *	1.8	100	0.0 *	0	1.8 *
	Check		5	4.2	27	11.2	73	15.4	15.2	13	98.8	87	114.0

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

Table 37: Extent of feeding by cerambycid larvae (per 1000 cm^2) in loblolly pine bolts cut 1 month after trunk injection with emamectin benzoate using different injection systems; Lufkin, Texas - 2007.

System	Rate	N	No of cerambycid egg niches on bark	Percent phloem area consumed by larvae
Tree IV	Low (5ml / "dbh)	5	11.6	0.0 *
Quick-jet		5	18.2	0.0 *
Portal		5	10.4	0.0 *
Sidewinder		5	18.4	0.0 *
Tree IV	High (10ml / "dbh)	5	20.0	0.0 *
Quick-jet		5	11.4	0.0 *
Portal		5	16.2	0.0 *
Sidewinder		5	13.4	0.0 *
Check		5	11.4	6.8

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

SYSTEMIC INSECTICIDE INJECTION TRIALS

Summary and Registration Status of Tested Systemic Insecticides

One of the initial goals of the Western Gulf Forest Pest Management Cooperative (WGFPMC) was to develop alternative control options for cone and seed insects in light of the potential lose 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 in 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.

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.

Emamectin Benzoate - Over a six 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 damage of 80% compared to checks. The data suggest that a single injection of emamectin benzoate can protect trees against coneworm for 72 months or longer. A second injection is not necessary during the second growing season to improve efficacy. It 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 WGFPMC has proven that emamectin benzoate is highly effective in protecting cone crops. Unfortunately, because seed orchard use constitutes a very small market (only ~9,000 acres in the South), the primary chemical manufacturer, Syngenta, had been reluctant to support an injection use registration in the U.S.

Since 2002, an attempt had being made to expand the forestry market of emamectin benzoate through trials with other tree and pest species. Recently, in 2004, injected emamectin benzoate (Denim®) was tested for efficacy against southern pine engraver beetles. Emamectin benzoate 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 emamectin benzoate, 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 emamectin benzoate. Arborjet created a non-toxic, low viscosity formulation for injection use (Joe Doccola, Arborjet™, personal communication).

Three WGFPMC trials were established in 2005, with some ongoing in 2007, to evaluate the new formulation of emamectin benzoate 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, and 3) efficacy against aggressive bark beetles in the South (southern pine beetle) and West (mountain pine beetle, western pine beetle and spruce beetle). All trials showed that the new emamectin benzoate formulation could be quickly injected into trees, was non-toxic, and, where results were available, effective against different species of coneworms and bark beetles; in some cases, for two 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 ran the required toxicology tests and submitted a request to EPA in January 2008 for full label registration. A decision by EPA on this request is expected as soon as July 2008. However, a request is being made by Michigan to obtain a 24C (Special Local Need) registration for use against emerald ash borer by April 2008. This may encourage EPA review the full registration package and result in quicker decision. **Cross your fingers!**

Fipronil – In light of the discovery that fipronil has systemic activity in loblolly pine against pine tip moth in 2002 (see 2003 Annual Report), an experimental EC formulations of fipronil was injected into trees as part of a seed orchard trial (2003) and 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 bark beetles (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 emamectin benzoate in the three 2005 WGFPMC trials mentioned above. Although fipronil tends to require more time to move throughout the tree, it is nearly as effective as emamectin benzoate in most trials.

The BAS 350 UB formulation, 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 highly and equally effective against Ips bark beetles. Additional trials were established in the West to test against western and mountain pine beetles. Results are pending. At this time, registration of fipronil for injection use is not expected before 2010.

Imidacloprid – Imidacloprid is another neonictinoid chemical tested by the WGFPMC in our 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 was not nearly as effective as emamectin benzoate (94%) in the first year after injection. In contrast, imidacloprid was more effective against seed bugs (82% reduction) than was emamectin benzoate (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 unattractive. 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™). A trial was established in 2007 to evaluate this formulation alone or combined with their new emamectin benzoate formulation. Ima-jet did significantly reduce seed bug damage but had no real effect against coneworm and efficacy was not enhanced by emamectin benzoate. The duration of these treatments will be evaluated in 2008.

Dinotefuran - Dinotefuran (Valent) is a "3rd generation" neonicotinoid insecticide with primary activity against sucking insects as well as Coleoptera (beetles). Although dinotefuran (0.2g/DBH") was not found to be active against bark beetles in our 2004 trial, it was found by Arborjet (at 0.4g/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 emamectin benzoate for seed orchard use. The trial in 2007 showed that this chemical can reduce seed bug damage but had little effect against coneworm. The duration of these treatments will be evaluated in 2008.

Nemadectin - Nemadectin (Fort Dodge Animal Health) is a fermentation product of *Streptomyces cyanogriseus noncyanogenus* and closely related to emamectin benzoate. A preliminary trial was conducted in 2005 to determine if nemadectin has similar efficacy against bark beetle. The results suggest some activity, but treatment and evaluation earlier in the year should provide more conclusive evidence. Additional tests in 2006 confirmed that nemadectin has moderate activity against *Ips* engraver beetles. The trial was continued in 2007 and showed that nemadectin at the highest rate (0.4 g AI / inch dia.) has very good efficacy against *Ips* engravers and wood borers 14 months after injection. This trial will be completed in 2008.

PINE TIP MOTH TRIALS

Impact Study – Western Gulf Region

Highlights:

- Thirteen new impact plots were established in 2007, bringing the total to 88 plots established since 2001.
- Nantucket pine tip moth damage levels on first-year check trees increased markedly in 2007 and had the highest average (24%) over the seven years of the study. Damage levels on second-year check trees in 2006 also were high (26%).
- Periodic applications of Mimic® to first- and second-year trees in 2007 provided good protection against tip moth on a few sites, but poor on most others. This resulted in overall damage reductions of 35 and 49 percent, respectively, compared to untreated checks.
- Protected trees did not experience improved tree growth compared to check when tip moth damage levels were <10% of shoots infested. In contrast, growth of protected trees increased 30% and 64% when damage levels were moderate (11 – 20%) or high (>20%), respectively.
- Mimic-treated trees in most age groups (1-5 years old) continued to show improved differences in growth measurements compared to untreated checks. Fifth-year trees, previously treated with Mimic®, were on average 33 cm (1.1 ft) taller, had 0.5 cm greater diameter and 8,292 cm^3 (0.29 ft^3) greater volume compared to check trees.

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

Cooperators:

Mr. Conner Fristoe	Plum Creek Timber Co., Crossett, AR
Dr. Nick Chappell	Potlatch Forest Holdings, Warren, AR
Valerie Sawyer & Peter Birks	Weyerhaeuser Co., Columbus, MS
Ms. Emily Goodwin	formerly with Temple Inland Forest Products, Diboll, TX
Mr. Jeff Hall	Forest Investment Associates, Jackson, MS
Mr. Andy Burrow	Potlatch Forest Holdings, Moscow, ID

Study Sites: Several WGFPMC members have established 10 or more impact study sites by 2006. In most plantation sites, one to two areas were selected and divided into 2 plots each - 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.

Design: 57 sites X 1-2 plots X 2 treatments X 50 trees = 8,800 monitored trees.

Treatments:
1) Mimic® 2F applied once per generation at 0.08 oz. / gal.
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 to all 126 trees to within the designated Mimic® plot (treatment area) on first- and second-year sites. Application dates were based on Fettig's 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.

Tip Moth Damage Survey: Tip moth infestation levels were determined in each plot 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 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. Trees also were surveyed a final time in November or December. At this time, data also were collected on tree height and diameter at 6 inches 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.

Results: Figure 19 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. For the sixth year in row, trap catches in the Lufkin, TX area indicate four full generations with at least a partial fifth generation developing late in the summer. 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 19), 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. Unfortunately, overall protection on several first and second year sites was again poor in 2007 (Table 38). It will be necessary to either change the insecticide used and/or adjust spray timing to improve protection.

Thirteen new impact plots were established in 2007; bringing the total number of plots established since 2001 to 88. Figure 20 shows the distribution of the 88 first- thru seventh-year impact study sites in the Western Gulf Region.

<u>Group 1 - Seventh-year sites (12)</u>:
Trees on these sites were not measured in 2007. Their next measurements are scheduled for 2008.

<u>Group 2 - Sixth-year sites (4 new)</u>:
Trees on these sites were not measured in 2007. Their next measurements are scheduled for 2009.

<u>Group 3 - Fifth-year sites (8 new; 24 total)</u>:
Three years after the last Mimic® spray the difference in growth (height, diameter and volume) between Group 3 Mimic-treated and untreated trees has not expanded (Table 39). When combined with Group 1 & 2 sites, five-year old Mimic-treated trees are on average 33 cm (1.1 ft) taller, had 0.5 cm greater diameter at breast height and 8,292 cm^3 (0.29 ft^3) greater volume compared to check trees (Table 39 and Figures 21 - 23). This is an improvement compared to

the 23 cm (0.8 ft) greater height, 0.44 cm greater diameter at breast height and 7,166 cm^3 (0.253 ft^3) greater volume compared to check trees calculated for the Group 1 & 2 sites alone.

Group 4 - Fourth-year sites (5 new):
Trees on these sites were not measured in 2007. Their next measurements are scheduled for 2008.

Group 5 - Third-year sites (6 new; 40 total):
As with fifth year sites, the difference in growth (height, diameter and volume) between Mimic-treated and untreated trees continues to expand even after Mimic sprays are halted. This group of sites Mimic trees averaging 20 cm (0.7 ft) taller, had 0.68 cm greater diameter at breast height, and 1,446 cm^3 (0.047 ft^3) greater volume compared to check trees. These "moderate" differences in growth, after only 3 years, are likely the result of better protection against tip moth both in the first and second years (Table 39). Overall (40 sites), Mimic-treated trees were on average 25 cm (0.8 ft) taller, had 0.5 cm greater diameter at breast height and 1,293 cm^3 (0.038 ft^3) greater volume compared to check trees.

To determine if there is a threshold of tip moth damage that impacts tree growth, the 40 sites were divide into three groups based on level of mean shoots infested over the first two year (i.e., ≤ 10%, 11 – 20%, and > 20%). The Mimic treatment did not improve growth when tip moth pressure was low (≤ 10% shoots infested) (Figure 24). In contrast, the protective treatment allowed trees to grow significantly more volume (30 % more) when tip moth pressure was moderate (11 – 20% shoots infested) and 64% more volume when pressure was high (> 20%).

Group 6 - Second-year sites (22 new; 64 total):
Tip moth infestation levels on untreated second-year trees was considerably higher (26% of shoots infested) in 2007 compared to similar aged trees in 2006 (16% of shoots infested) (Table 38). Overall protection of second-year trees was relatively poor, with Mimic® reducing damage to shoots by only 49%. Combined, these factors have resulted in a smaller than expected gains in the height (11%), diameter (9%) and volume (21%) of Mimic®-treated trees compared to check trees (Table 39).

Group 7 - First-year sites (13 new; 88 total):
Overall, tip moth infestation levels on untreated first-year seedlings were considerably higher (24% of shoots infested) in 2007 compared to the levels (14% of shoots infested) in 2006 (Table 38). Mimic® protection during the first generation was poor on most sites throughout the year (35% average) with reductions in damage dropping below 75% on only 3 of 13 sites. Mimic®-treated trees on only 4 of 13 sites show significant gains in height, diameter and volume compared to untreated check trees. Overall, Mimic®-treated seedlings saw gains in height, diameter and volume of only 5%, 3% and 13%, respectively compared to check trees (Table 39). This is in stark contrast to the 20%, 35% and 116% gains in height, diameter and volume growth, respectively, obtained in 2005.

Conclusions: Overall tip moth populations and damage levels increased markedly in 2007 compared to the 2006. Although we received close to average rainfall in 2007, the extensive drought conditions that continued to occur in the Western Gulf Region through in 2005 and most of 2006 may have allowed populations to build. Multiple applications of Mimic® were able to significantly reduce tip moth infestation levels on a few one- and two-year old sites in

2007. However, most sites in Arkansas and Texas received poor protection from the Mimic applications. Whereas, Mimic® treatments did significantly improve tree growth on first-year sites in 2001, 2003, 2005 & 2006 and second-year sites in 2002, 2005 & 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 40 sites 3 years of age or older showed that two year mean tip moth damage levels (percent shoots infested) need to exceed 10% before there is a significant impact on tree growth in a given year.

Fettig (et al. 2000) concluded that tip moth damage occurring during the first generation has the greatest impact on growth. This may be true on second-year sites when first generation damage is fairly high. However, very little damage has occurred recently in the Western Gulf region on first year sites during the first generation: 1) because the moth is just beginning to colonize the area and populations are very low, and 2) the first flush of growth after transplant is usually much shorter than future flushes. During the first year, the effects of second and third tip moth generations appear to be most crucial. This supported by the fact that first year trees in 2002 had good protection (85% reduction) from Mimic® during the first generation, while only moderate protection (68% and 59% reduction) was obtained during the second and third generations, respectively. The result was that the treatments over the course of the year had no impact on tree growth. In contrast, first year trees in 2003 had relatively poor protection (49% reduction) during the first generation, but excellent protection the second and third generation (90% reduction for both generations). The result was significant growth gains with Mimic® treatments.

The question remains, at what damage threshold does protection treatments become cost effective to apply to forest plantations? Data presented below is currently being evaluated by Dr. Weihuan Xu, economist with the Texas Forest Service 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 2008. Also, it is important to continue treatments on second-year sites and monitor tip moth damage and impact on third- and fifth-year sites in 2008.

Acknowledgments: We greatly appreciate the efforts of Valerie Sawyer (Weyerhaeuser), Jeff Earl (independent contractor for Plum Creek), Al Cook (independent contractor for International Paper and Plum Creek), Nick Chappell (Potlatch), Conner Fristoe (Plum Creek), Emily Goodwin (Temple-Inland), 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 Andy Burrows, Potlatch, for volunteering his time to assist us in 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.

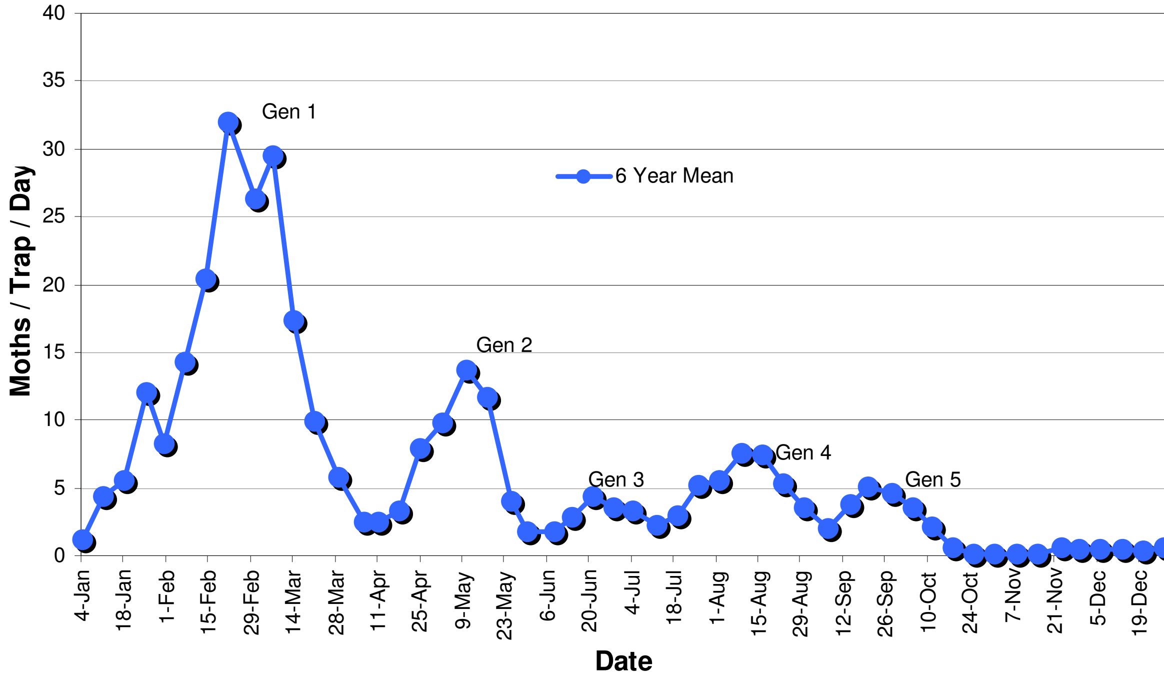


Figure 19. Mean number of pine tip moth adults captured per trap per day in the Lufkin, TX area (2001 - 2007).

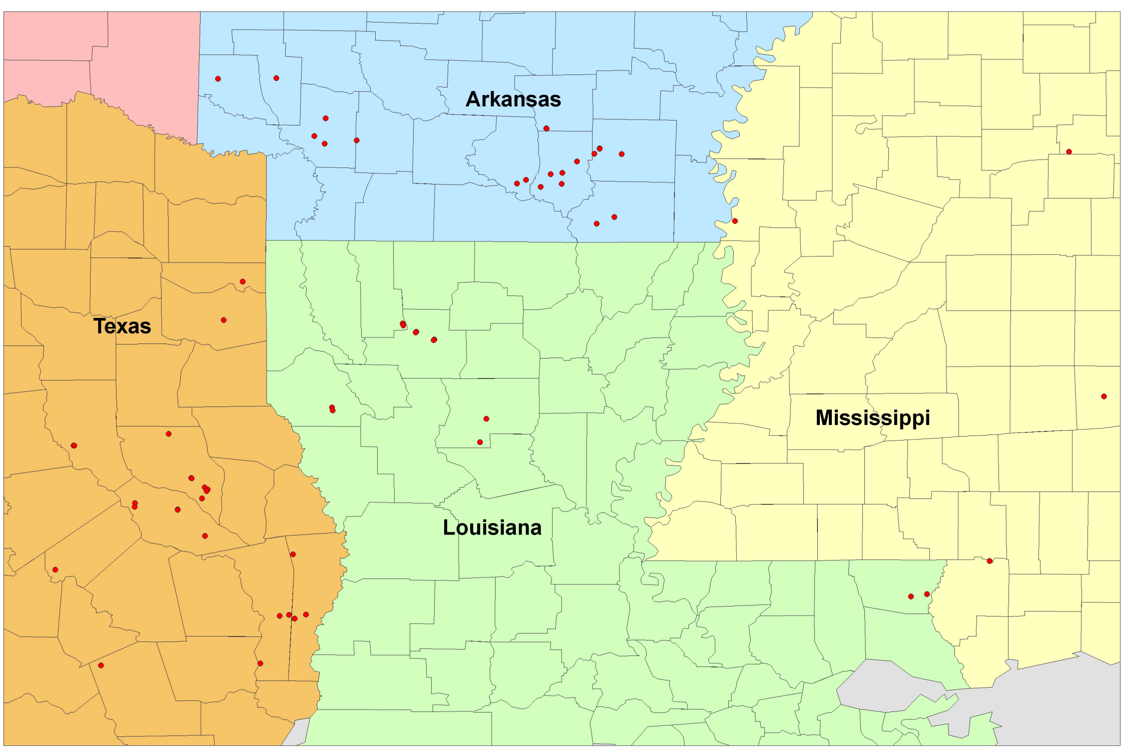


Figure 20. Distribution of 88 one- to five-year old impact sites (●) from 2001 – 2007 in the Western Gulf Region.

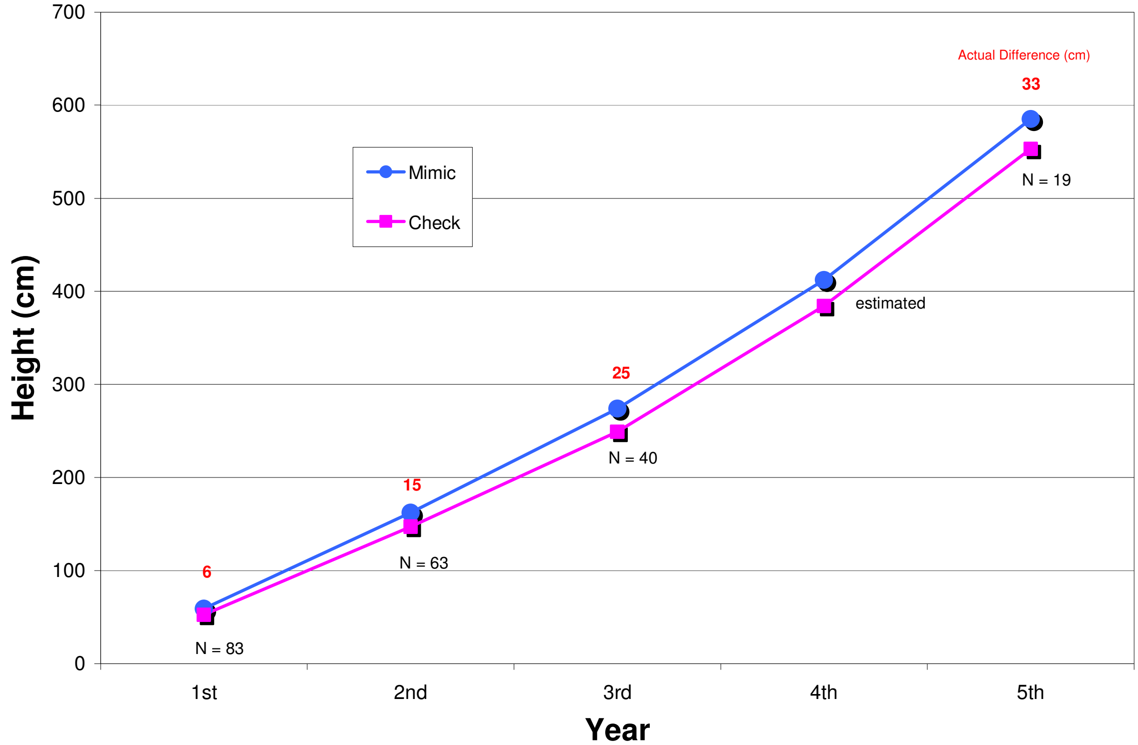


Figure 21. Mean height (cm) of one- to five-year old loblolly pine treated with Mimic® compared to untreated trees on all Western Gulf sites: 2001 – 2006.

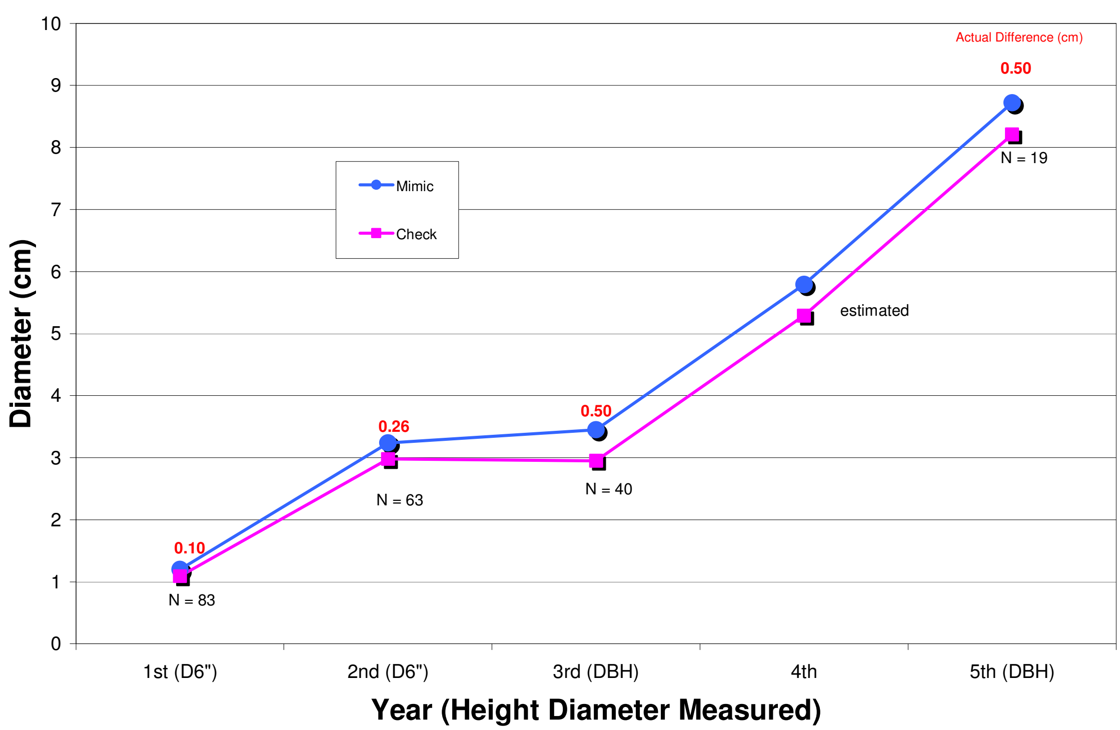


Figure 22. Mean diameter (cm) of one- to five-year old loblolly pine treated with Mimic® compared to untreated trees on all Western Gulf sites: 2001 – 2007.

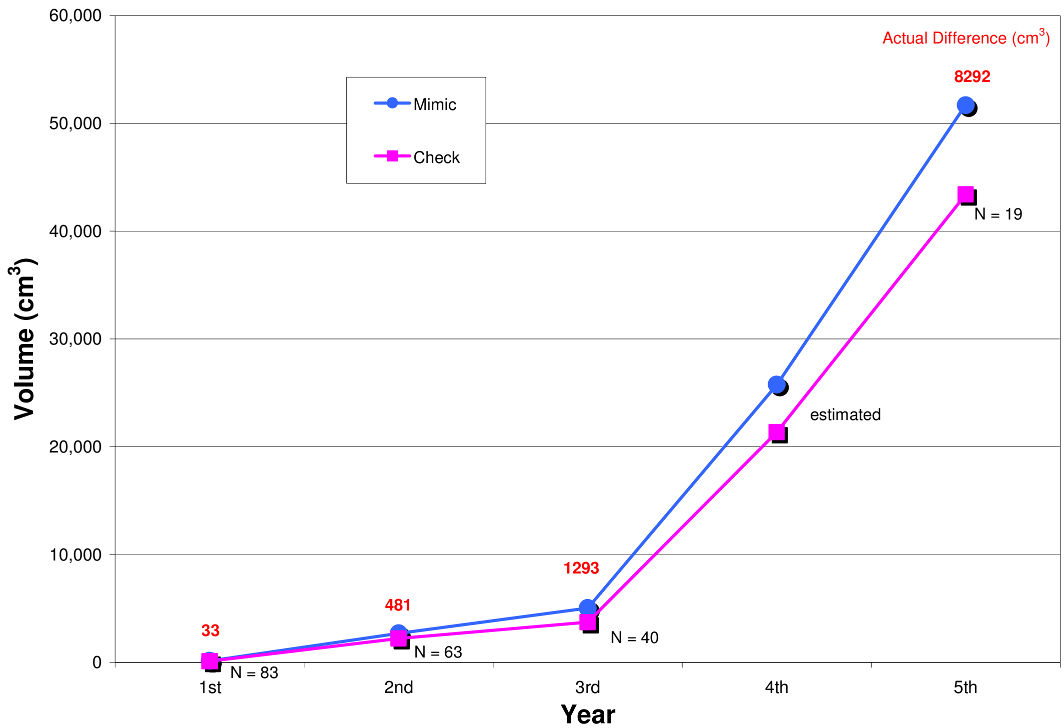


Figure 23. Mean volume index (cm^3) of one- to five-year old loblolly pine treated with Mimic compared to untreated trees on all Western Gulf sites: 2001 – 2007.

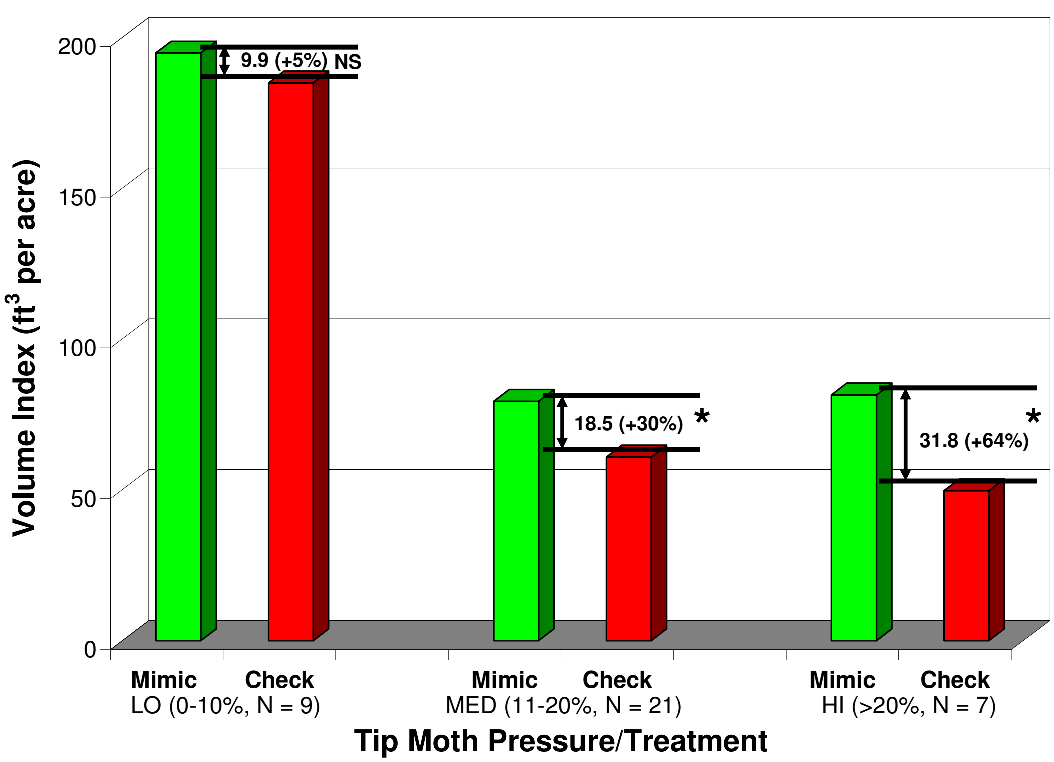


Figure 24. Differences in 3rd-year volume index (ft^3/acre) of protected and unprotected loblolly pine exposed to different tip moth pressures.

Table 38: Mean percent of pine shoots (in top whorl) infested by Nantucket pine tip moth on one- and two-year old loblolly pine trees following treatment with Mimic® after 4 - 5 generations; Arkansas, Lousiana, Mississippi and Texas sites, 2001 - 2007.

	Planted 2001 (N =16)		Planted 2002 (N = 7)		Planted 2003 (N= 10)		Planted 2004 (N= 7) (N= 6)		Planted 2005 (N= 6)		Planted 2006 (N=29)(N=22)		Planted 2007 (N= 13)		Mean Year 1	Mean Year 2
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	Yr 1	Yr 2	(N= 88)	(N= 67)
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	15.5		4.6	6.6
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	24.0		15.9	19.7
% Reduction	92	83	80	75	90	90	87	88	78	54	65	49	35		**71**	**67**

Table 39: 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 - 2007.

Treatment	Mean: Year 1 (N= 7524 trees on 83 sites)	Year 2 (N= 6016 trees on 63 sites)	Year 3 (N= 3907 trees on 40 sites)	Year 5 (N= 1822 trees on 19 sites)	
	Height (cm)			(cm)	(ft)
Mimic® spayed (protected)	58.4	162	274	585	19.2
Check (unprotected)	52.5	147	249	553	18.1
Actual Diff. In Growth (cm **or** ft)	6	15	25	33	1.1
Pct. Gain Compared to Check	**11**	**10**	**10**	**6**	**6**
	Diameter (cm)				
	at 6"	at 6"	at DBH	DBH (cm)	DBH (ft)
Mimic® spayed (protected)	1.20	3.24	3.45	8.72	0.286
Check (unprotected)	1.09	2.98	2.95	8.21	0.269
Actual Diff. In Growth (cm **or** ft)	0.10	0.26	0.50	0.50	0.02
Pct. Gain Compared to Check	**9**	**9**	**17**	**6**	**6**
	Volume Index (cm^3)			(cm^3)	(ft^3)
Mimic® spayed (protected)	142	2692	5028	51691	1.826
Check (unprotected)	109	2212	3735	43399	1.53
Actual Diff. In Growth (cm **or** ft)	33	481	1293	8292	0.29
Pct. Gain Compared to Check	**31**	**22**	**35**	**19**	**19**

Volume Index = Height X $Diameter^2$

PINE TIP MOTH TRIALS

Hazard Rating Study – Western Gulf Region

Highlights:

- Data on site characteristics were collected from 42 plots (13 - first-year and 29 - second-year) in the Western Gulf Region in 2007. In total, 120 hazard-rating plots have been established since 2001.
- A revised hazard-rating model developed by Andy Burrow in early 2007 indicates that depth to B horizon, texture of B horizon and drainage class have the greatest influence on tip moth occurrence and severity. In the Western Gulf Region, sites having deep, excessively, well or somewhat poorly drained soils are at high risk for tip moth damage.
- Validation of this revised hazard-rating model with 2007 data is ongoing.

Objective: Identify abiotic factors that influence the occurrence and severity of Nantucket pine tip moth infestations.

Cooperators:

Mr. Conner Fristoe	Plum Creek Timber Co., Crossett, AR
Dr. Nick Chappell	Potlatch Forest Holdings, Warren, AR
Valerie Sawyer & Peter Birks	Weyerhaeuser Co., Columbus, MS
Ms. Emily Goodwin	formerly with Temple Inland Forest Products, Diboll, TX
Mr. Jeff Hall	Forest Investment Associates, Jackson, MS
Mr. Andy Burrow	Potlatch Forest Holdings, Moscow, ID

Study Sites: WGFPMC members selected from one or five new first-year plantations in 2007. 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 - 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 42 Western Gulf plots (13 - first-year and 29 - second-year) in 2007 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 6 inch 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 (< 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 12 inches of the main stem of each tree.

Data Analysis: Mr. Andy Burrow, Potlatch, volunteered in 2004 to help develop the model. With a Masters in Biometrics and minor in statistics, Mr. Burrows has the expertise the WGFPMC needs to get the job done. The data (four years' worth; 2001- 2004) was consolidated and sent to Mr. Burrows by the end of December 2005. The data was analyzed using Classification and Regression Tree analysis to create a classification tree (STATISTICA, 2005, StatSoft, Inc.). Additional data (two years' worth), collected through 2006, was sent to Mr. Burrows in February 2007.

Results: Figure 25 shows the distribution of all 120 hazard-rating sites established in the Western Gulf Region from 2001 to 2007.

Mr. Burrow's analyses of first set of data from 57 sites in 2005 resulted in a working model that indicates that, individually, site index, soil texture, soil drainage class, depth to 'B' horizon and stand history are the five important factors that influence the occurrence and severity of pine tip moth on a site. However, the two factor model that included site index and soil texture provide the best explanation of site variability (Figure 26).

Data from the second series sites (2005 – 2006) were used to upgrade the model. The new model indicates that depth to 'B' horizon, texture of 'B' horizon, drainage class, percent silt, sand and clay, and site index are the primary factors influencing tip moth (Figure 27). Specifically, "good" sites with moderate B horizon depth (30 – 60 cm), good drainage and texture mix are low hazard for tip moth damage (mean annual percent of shoots infested < 10%). On these sites, soil nutrients, texture and water are usually at levels that encourage good growth and allow the trees to resist tip moth attack.

As site characteristics become more extreme, the hazard for tip moth occurrence and damage becomes moderate (11 – 20% shoots infested) and then high (> 20% shoots infested). Such sites will likely have deep or shallow soils with high percentages of sand, silt or clay and tend to be excessively or somewhat poorly drained. Trees growing on such sites are more likely to experience stressful conditions, e.g., poor nutrient availability or anaerobic or drought conditions. A stressed tree would be less able to resist tip moth attack. Thus tip moth damage levels would be higher and impact on growth and form greater.

The model will be validated using 2007 data (ongoing). Additional sites will be installed in 2008 on sites with variable characteristics.

Acknowledgments: We greatly appreciate the efforts of Valerie Sawyer (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), 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 Burrows, Potlatch, for volunteering his time to assist in the development of a hazard-rating model.

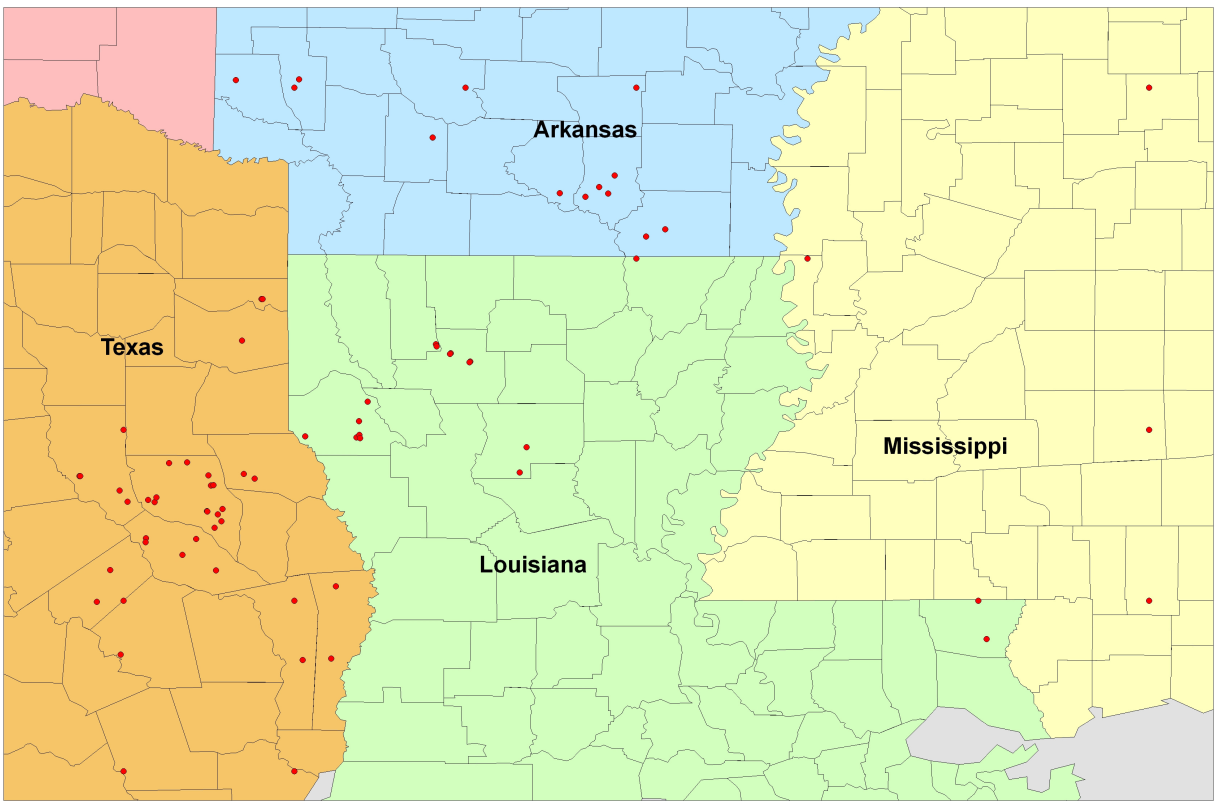


Figure 25. Distribution of 120 hazard-rating plots (●) established from 2001 - 2007 in the Western Gulf Region.

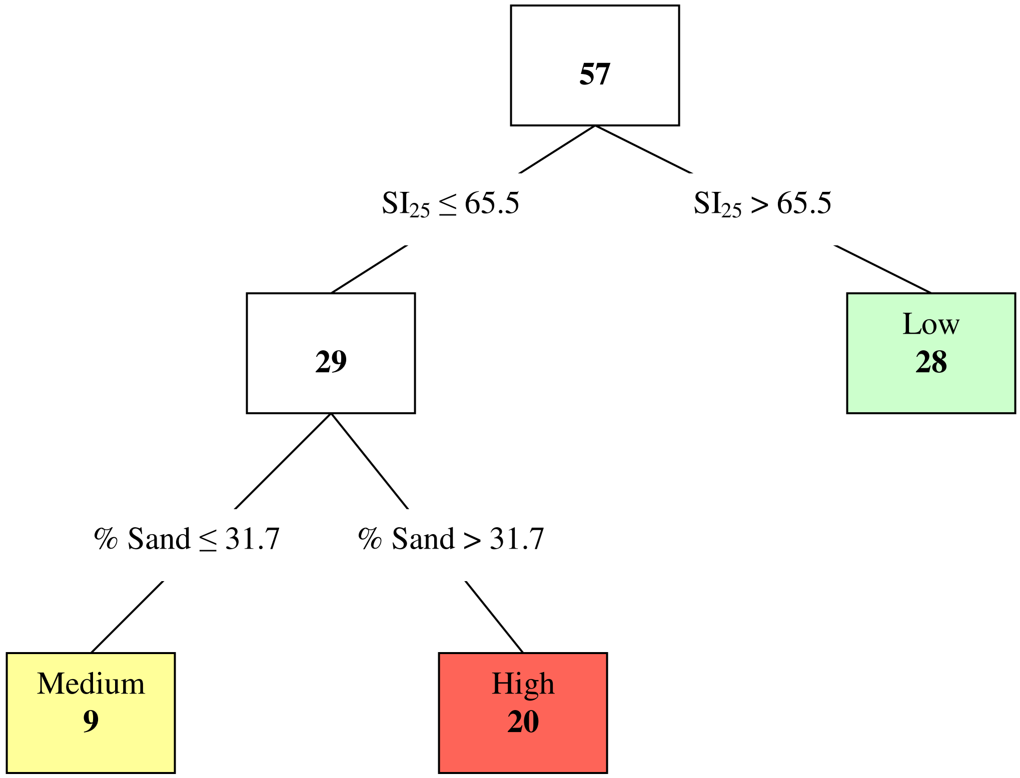


Figure 26. Classification tree describing a hazard rating system for tip moth infestation in one (1) and two (2) year old pine plantations. Bold numbers represent the number of sample points at each node.

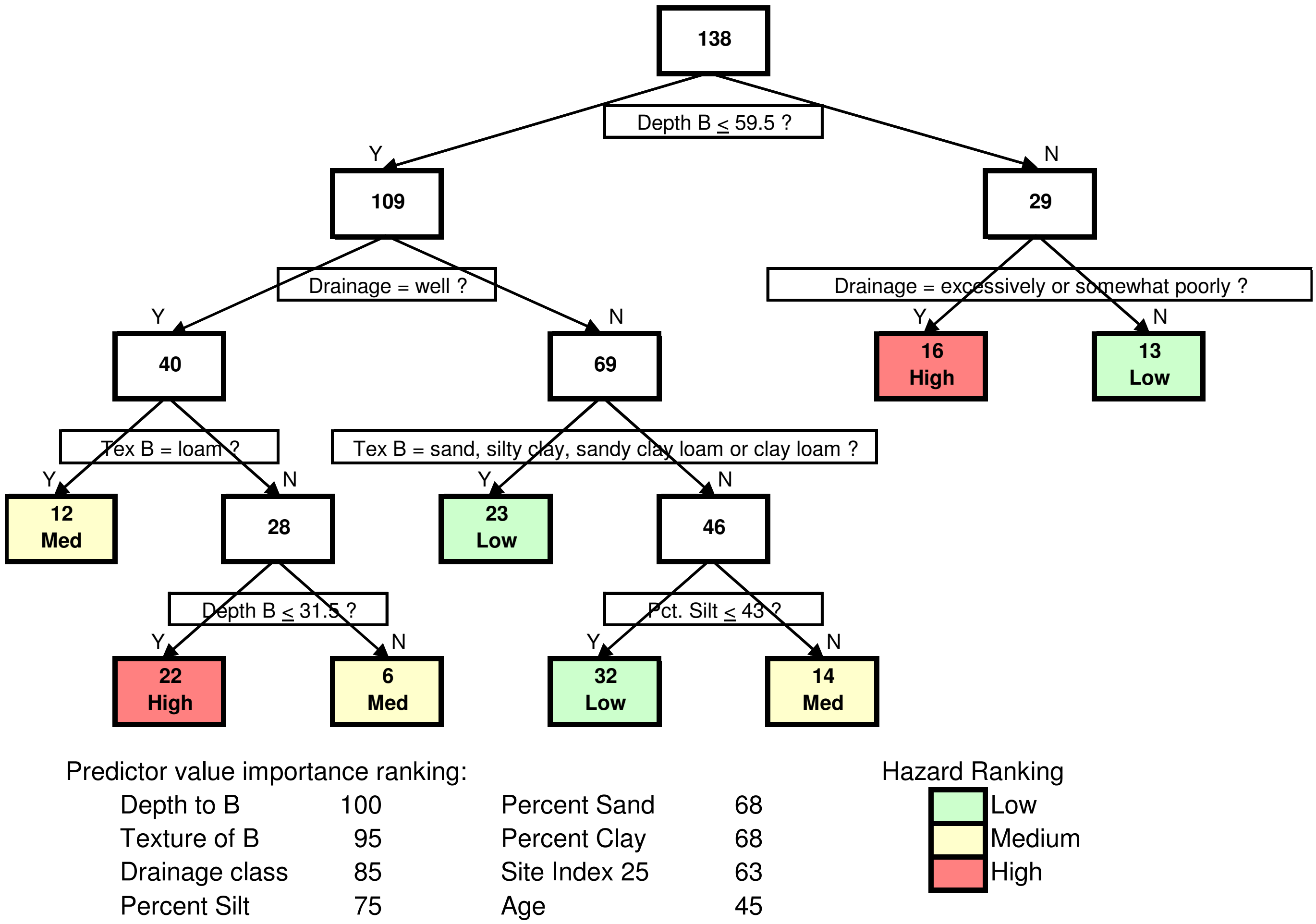


Figure 27. Revised classification tree describing a hazard rating system for tip moth infestation in one (1) and two (2) year old pine plantations. Bold numbers represent the number of sample points at each node; Y is Yes and N is No.

PINE TIP MOTH TRIALS

Fipronil Soil Injection Treatment Studies – East Texas

Highlights:

- All fipronil soil injection treatments significantly reduced tip moth damage during most generations in the second year after planting. Overall damage was reduced by 45 - 60% compared to check trees. None of the treatments significantly improved tree growth.

Objectives: 1) Determine the efficacy of fipronil applied post-plant by soil injection in reducing pine tip moth infestation levels on loblolly pine seedlings, and 3) determine the duration of chemical activity.

Cooperators:

Mr. Hubert Sims	Texas Forest Service, Kirbyville, TX
Mr. Conner Fristoe	Plum Creek Timber Co., Crossett, AR
Dr. Harry Quicke	BASF Co., Auburn, AL

Study Sites: Two first-year plantations (2006) were selected, one in Texas on the Seicke State Forest and one near Winnfield, Louisiana. The plots contained 6 treatments and 300 trees (5 rows X 50 trees).

Insecticides:

Fipronil – Regent® 4SC (4.0 lbs ai/gal),

Design: Randomized complete block design 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 sites X 6 treatments X 50 trees = 300 monitored trees.

Treatments:

1) **Regent® 4SC** (0.3%) applied by soil injector at **3**ml solution/seedling
2) **Regent® 4SC** (0.3%) applied by soil injector at **6**ml solution/seedling
3) **Regent® 4SC** (0.3%) applied by soil injector at **12**ml solution/seedling
4) **Regent® 4SC** (0.3%) applied by soil injector at **24**ml solution/seedling
5) Foliar application (5X in ’06 & ‘07) of pine seedlings with Mimic® 2LV (0.6 ml / liter of water)
6) Check (lift and plant)

Treatment Methods: Trial 1: A single family (Advanced Generation) of loblolly pine bare-root seedlings was selected at the TFS Indian Mounds Nursery, Alto, TX. The seedlings were lifted in late-January 2006 in a manner to cause the least breakage of roots, culled of small and large caliper seedlings, grouped in bundles of 60, root-dipped in Terrasorb™ and stored temporarily in a cooler until planting. When ready, fifty seedlings from each treatment were planted on two sites (TFS - Seicke and Plum Creek near Winnfield) in February 2006 at 605 trees per acre (6’ X 12’ spacing). All soil injection treatments were applied just after planting using the Kioritz soil injector (Figure

20). 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 hole was covered with soil to prevent root desiccation.

Treatment Evaluation: Tip moth damage was evaluated after each tip moth generation (3-4 weeks after peak moth flight; 4 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 6") and height in winter 2006 and 2007.

Results:

In 2006, severe drought conditions occurred through much of the year. Due to high seedling mortality and no tip moth damage on check trees, the Seicke (TX) site data was not included in the analysis. On the LA site, tip moth populations were very low during the first and second generation with an average of <1% and 0% of the shoots infested on check trees, respectively. 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 these generations (Table 40). All fipronil treatments, regardless of volume applied, provided excellent protection against tip moth during 3^{rd}, 4^{th} and 5^{th} generations. Overall reduction in damage compared to checks ranged from 87% to 95%. 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 (Tables 41).

In 2007, tip moth populations were markedly higher during the first and second generation with an average of 5% and 13% of the shoots infested on check trees, respectively. As a result, most of the treatments significantly reduced tip moth infestation of top whorl shoots compared to the check during these generations (Table 40). All fipronil treatments, regardless of volume applied, provided good protection against tip moth during the 3^{rd}, 4^{th} and 5^{th} generations. Overall reduction in damage compared to checks ranged from 45% to 60%. 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 (Tables 41).

Acknowledgments: Thanks go to Hubert Sims, Texas Forest Service, and Conner Fristoe, Plum Creek Timber Company for providing research sites in TX and LA, respectively. Al Cook, private contractor, monitored and measured trees on the LA site. We also thank Dr. Harry Quicke, BASF, for providing the fipronil formulation, Regent®, for the project.

Figure 28. Grosman with Kioritz soil injector.

Table 40. Effect of fipronil application technique and rate on pine tip moth infestation of loblolly pine shoots (top whorl) after each of 5 generations in the first two seasons on one site in the Western Gulf region - Est. 2006.

			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		
2006	Fip Inj 3ml	50	1.2	**-47**		0.0	**###**		1.1	**89**	*	1.2	**93**	*	0.0	**100**	*	0.5	**93**	*
	Fip Inj 6ml	50	1.7	**-120**		1.3	**###**		0.0	**100**	*	2.3	**85**	*	0.7	**95**	*	1.0	**87**	*
	Fip Inj 12ml	50	0.9	**-8**		0.0	**###**		0.0	**100**	*	0.0	**100**	*	1.0	**94**	*	0.4	**95**	*
	Fip Inj 24ml	50	0.6	**28**		0.0	**###**		2.5	**77**	*	0.0	**100**	*	2.0	**87**	*	1.1	**87**	*
	Mimic spray	50	0.0	**100**		0.0	**###**		0.0	**100**	*	0.0	**100**	*	0.0	**100**	*	0.0	**100**	*
	Check	50	0.8			0.0			10.5			15.9			15.0			7.9		
2007	Fip Inj 3ml	50	1.7	**64**		10.4	**25**		13.1	**66**	*	32.6	**34**	*	41.5	**45**	*	19.9	**45**	*
	Fip Inj 6ml	50	0.0	**100**	*	8.5	**39**		17.5	**54**	*	16.7	**66**	*	34.5	**54**	*	15.4	**57**	*
	Fip Inj 12ml	50	0.0	**100**	*	4.1	**70**	*	9.7	**75**	*	24.8	**50**	*	36.4	**51**	*	15.4	**57**	*
	Fip Inj 24ml	50	0.0	**100**	*	4.8	**66**	*	6.9	**82**	*	22.5	**54**	*	35.5	**53**	*	14.4	**60**	*
	Mimic spray	50	0.0	**100**	*	0.0	**100**	*	5.3	**86**	*	3.2	**93**	*	2.7	**96**	*	2.3	**94**	*
	Check	50	4.8			13.8			38.3			49.1			74.9			36.2		

§ Fip Inj = Fipronil Soil Injection [shaded box] = 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 parameters and tree survival after the first year on one site in Western Louisiana - Est. 2006

Year	Treatment §	N	Mean End of Season Tree Measurements (**Growth Difference (cm or cm³) Compared to Check**) Height (cm)		Diameter (cm)		Volume (cm³)		Mean % Tree Survival (**Pct. Gain Compared to Check**)	
2006	Fip Inj 3 ml	50	30.2 *	**-7.4**	0.39 *	**-0.2**	6.1 *	**-9.3**	86	**39**
	Fip Inj 6ml	50	38.9	**1.3**	0.56	**0.01**	16.9	**1.4**	74	**19**
	Fip Inj 12ml	50	44.1	**6.5**	0.63	**0.08**	22.7	**7.2**	70	**13**
	Fip Inj 24 ml	50	33.0	**-4.6**	0.42	**-0.1**	7.7 *	**-7.8**	66	**6**
	Mimic Spray	50	36.4	**-1.2**	0.53	**0.0**	13.5	**-2.0**	76	**23**
	Check	50	37.6		0.55		15.4		62	
2007	Fip Inj 3 ml	50	116.1 *	**-7.3**	1.79 *	**-0.1**	486.6 *	**-75.6**	58	**-6**
	Fip Inj 6ml	50	125.2	**1.8**	1.79	**-0.12**	561.3	**-1.0**	70	**13**
	Fip Inj 12ml	50	123.5	**0.1**	1.77	**-0.14**	486.8	**-75.4**	70	**13**
	Fip Inj 24 ml	50	120.8	**-2.6**	1.63	**-0.3**	387.2 *	**-175.1**	66	**6**
	Mimic Spray	50	126.4	**3.0**	1.93	**0.0**	661.8	**99.6**	74	**19**
	Check	50	123.4		1.91		562.2		62	

§ Fip Inj = Fipronil Soil Injection
* Means followed by an asterik are significantly different from checks at the 5% level based on Fisher's Protected LSD.

PINE TIP MOTH TRIALS

Fipronil Operational Soil Injection Study - Western Gulf

Highlights:

- Fipronil applied by hand only marginally reduced tip moth damage in the second year after application. The treatment still had no effect on tree growth.
- A soil injection system, designed for a machine planter, was successfully used to treat series of plots on three sites. The machine-applied fipronil treatment was as nearly effective (74%) as Mimic sprays (77%) in reducing tip moth damage. The hand-applied fipronil was less effective than the machine application.

Objective: Site 1: 1) Determine the efficacy of fipronil in reducing area-wide pine tip moth infestation levels on loblolly pine seedlings; 2) evaluate this product applied via soil injection by hand; and 3) determine the duration of protection provided by this insecticide application. **Site 2, 3 & 4:** 1) Evaluate the efficacy of fipronil applied via soil injection by machine planter in reducing pine tip moth infestation levels on loblolly pine seedlings; and 2) determine the duration of protection provided by this insecticide application.

Cooperators:

Ms. Valerie Sawyer	Weyerhaeuser Co., Columbus, MS
Mr. Randy Winston,	Private land owner, Lufkin, TX
Ms. Lou Ann Miller	Private land owner, Nacogdoches, TX
Mr. Jim Rogers and Mr. Lane Day	Precision Machine Services, Lufkin, TX
Dr. Harry Quicke	BASF Co., Auburn, AL

Study Sites: One first-year plantation was selected near Crossroads, AR in February 2006 and three others, two in Texas near Lufkin and Nacogdoches in November 2006 and one in AR near Oak Grove, in February 2007.

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

Design: Randomized complete block design at each site with site areas serving as blocks, i.e., each treatment was randomly selected for placement in an area. For each treatment, fifty seedlings were monitored in each of four subplots.

Treatments:
Site 1:

1) HF = Seedling hand planted; afterwards fipronil applied at 0.1g ai (in 3 ml water) per seedling by Kioritz soil injector.
2) HFS = seedlings hand planted; foliar spray (Pounce® or Mimic®2LV (0.6 ml / liter of water)) applied (5X)
3) HC = seedlings hand planted; no additional treatment (Check).

Sites 2, 3 & 4:

1) MF = seedlings machine planted with fipronil applied at 0.1g active ingredient (in 37 ml water) per seedling as they are planted.
2) MHF = seedlings machine planted; afterwards fipronil applied at 0.1g ai (in 3 ml water) per seedling by Kioritz soil injector.
3) MFS = seedlings machine planted; afterwards foliar spray (Pounce® or Mimic®2LV (0.6 ml / liter of water)) applied (5X)
4) MC = seedlings machine planted; no additional treatment (Check).

Research Approach:

A single family of loblolly pine bare-root seedlings was selected at Weyerhaeuser Nursery in Magnolia, AR in 2006 for Site 1 and in 2007 for Site 4. Seedlings were lifted in February in a manner to cause the least breakage of roots, culled of small and large caliper seedlings, root-sprayed with clay slurry, bagged and stored briefly in cold storage. For sites 2 & 3, International Paper's containerized loblolly pine seedlings from Bullard, TX were used.

When ready, seedlings were hand- or machine-planted (spacing is dependent on practices of participating members) in each plantation - preferably near a young (< 4 years old) plantation.

All tracts (40 - 50 acres in size) were selected in the AR or TX based on uniformity of soil, drainage and topography in each pair of stands. All tracts were intensively site prepared, i.e., subsoil, bedding, and/or herbicide.

Initially, to evaluate the effects of treatment on large area tip moth damage levels a randomized complete block design, with sites as blocks, was used. Site 1 plantation was initially divided in half (Fig. 29). One half was operationally hand planted (1.8 X 3.6 m (= 6 X 12 ft) spacing) by a contracted crew. Immediately after planting, this half of the plantation was divided in half again and each seedling in one quarter of the plantation was treated with fipronil (0.3% ai in 3 ml volume) using the Kioritz soil injector or modified drench applicator (Figs. 31 and 32). Using the injector, the chemical solution was injected 4-5 inches below the soil surface near the seedling root ball. The number of trees treated and the time required to treat these trees was recorded at each site.

The other section of the plantation also was to be divided in half and machine planted. Unfortunately, development of the soil injection system was delayed and could not be operationally tested until the following fall (2006).

To further evaluate the effects of treatment on tip moth damage levels, an internal randomized block design, with quarter plots as blocks, was used. At each site, 4 – 0.5 acre plots were established. Each treatment was randomly assigned to one of the four internal plots in each main treatment plot quarter (Fig 29).

For sites 2, 3 & 4 the study design was modified to focus on fipronil treatments applied by machine planting. A C&G planter (owned by Acorn Outdoor Services, Lufkin, TX) was fitted with a 50-gallon tank, electrical pump, tubing and valves (designed by Lane Day and Jim Rogers, Precision Machine Services, Lufkin, TX) (Figs. 33 – 35). At each site, 4 replicates of 4 – 0.5 acre plots (16 plots total) were established (Fig. 30). On 4 preselected plots, the fitted machine planter

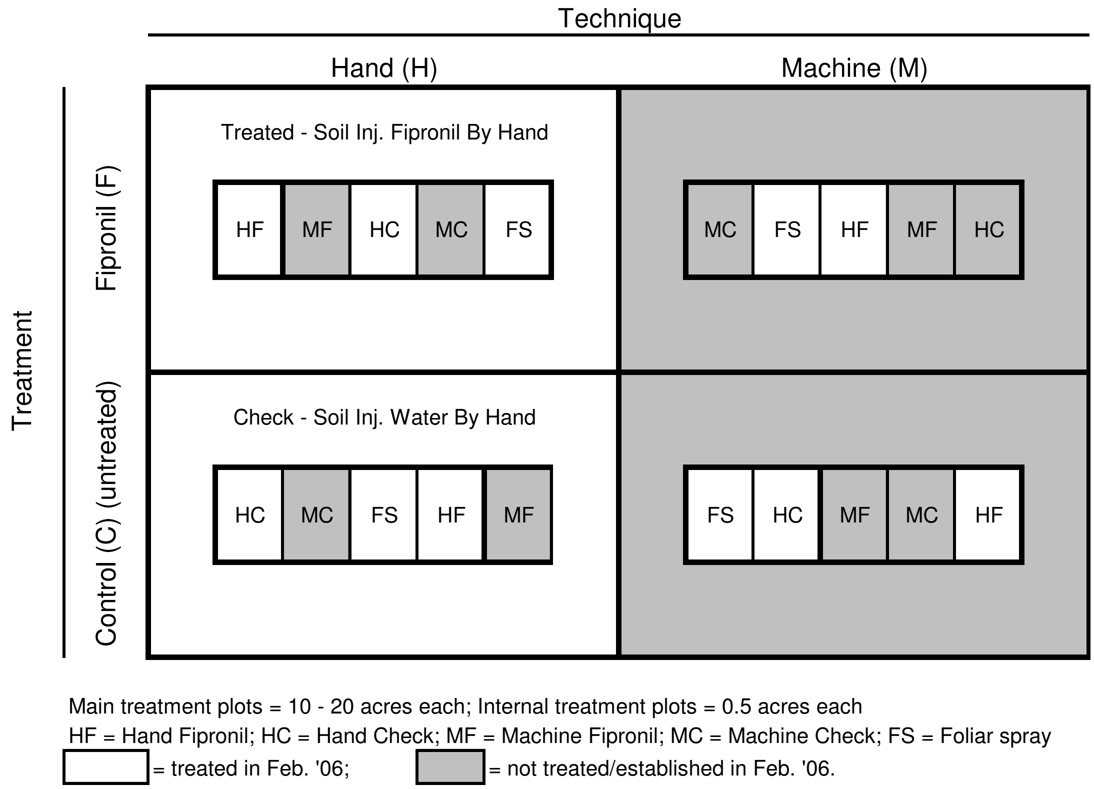
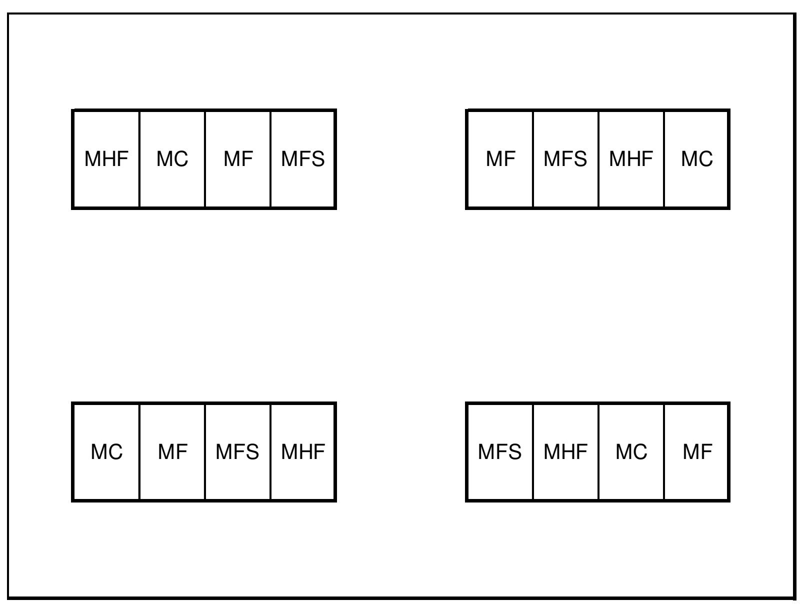


Figure 29. Generalized Plot Design for Arkansas site established in February 2006.



Site = 40 - 50 acres each; Internal treatment plots = 0.5 acres each

MF = Machine Fipronil; MC = Macine Check; MHF = Machine Hand Fipronil; MFS = Machine Foliar spray

Figure 30. Generalized Plot Design for two Texas sites established in December 2006.

Figure 31. Jason Helvey with Kioritz soil injector.

Figure 32. Bill Upton with modified drencher applicator.

Figure 33. Machine planter and injection system on Winston tract, Lufkin, TX

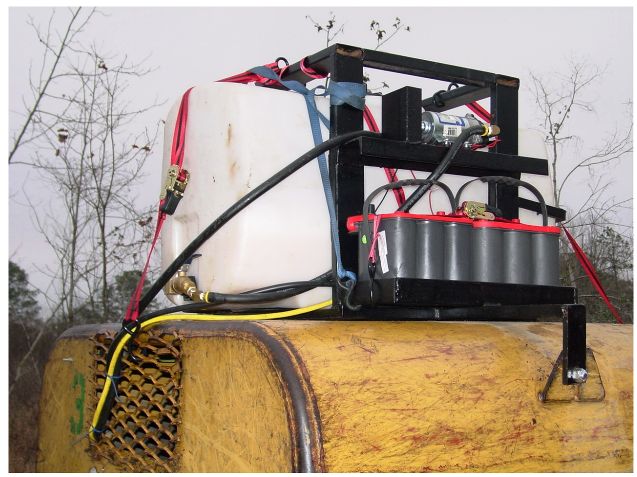


Figure 34. Injection system (tank, pump and battery power) fitted to top of machine planter.

Figure 35. Dispensing fipronil solution from tubing in planter sleeve.

injected fipronil solution (0.3% ai in 37 ml volume) into the soil as each seedling was placed in the planting furrow. In all other plots, seedlings were machine planted at the same spacing. Afterward, in 4 plots each, seedlings were treated with fipronil by hand using a Kioritz soil injector or with a foliar spray (5X / year).

The sites and cooperators included:

1) Crossroads, AR (Weyerhaeuser provided and monitored)
2) Lufkin, TX (Mr. Randy Winston provided and Texas Forest Service monitored)
3) Nacogdoches, TX (Ms. Lou Ann Miller provided and Texas Forest Service monitored)
4) Oak Grove, AR (Weyerhaeuser provided and monitored)

Tip moth damage was evaluated at the AR and TX sites 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 (@ 6") and height in the fall (December) following planting. Data was analyzed by GLM and the Fisher's Protected LSD test using Statview or SAS statistical programs.

Results:

Site 1 - 2006: Tip moth populations were quite low on the AR site during the first generation; none of the shoots were infested on check trees. As a result of the low tip moth pressure, none of the treatments reduced tip moth infestation of top whorl shoots compared to the check during the first generation (Table 42). The fipronil treatment within the subplots had a significantly effect on tip moth damage from the second through the fifth generation, reducing overall damage by 44 – 96% (62% overall). None of the fipronil treatments negatively affected seedling survival after 5 generations. The treatments (fipronil or Mimic) had no apparent effect on height, diameter and volume index compared to check trees (Tables 43).

Site 1 - 2007: Tip moth populations were much higher during the second year with check trees averaging 10% of their shoots infested during the first generation and 32% infested over the whole growing season. The Mimic spray application reduced damage by 75% (range: 16% - 89%) (Table 42). However, the efficacy of the fipronil treatment has faded dramatically in the second season; it reduced damage only by 14% (range: 8% - 21%). The treatments (fipronil or Mimic) had no apparent effect on height, diameter and volume index compared to check trees (Tables 43).

Sites 2, 3 and 4 - 2007: A soil injection system was specifically designed by Mr. Lane Day, Precision Machine Services, in cooperation with the WGFPMC, to fit on a C&G planter. This type of planter utilizes a "paddle wheel" system that holds seedlings and lays them uniformly spaced in a furrow. Once installed on a planter, the soil injection system accurately dispenses fipronil solution at each seedling. The treatments were evaluated for efficacy after each generation in 2007. Initially, tip moth damage on check trees was low (2%) but climbed to fairly high levels by the 4^{th} generation (29%) (Table 44). The machine-applied fipronil and Mimic spray were nearly equal in their effectiveness in reducing tip moth damage (74% and 77%, respectively) compared to the check. The fipronil applied by hand also significantly reduced damage (43%) but not nearly as well as the machine-applied treatment. All treatments (both fipronils and Mimic) significantly improved height growth compared to the check, while only Mimic improved volume index (Tables 45).

Conclusions: The initial data (2007) from Sites 2, 3 & 4 indicates that fipronil applied by machine is directed at the roots of the seedling being planted and provides good protection against tip moth for at least one year. However, data from all sites (1-4) indicate that fipronil applied by hand is not as effective. It is possible that because fipronil is largely soil immobile that precise application (right on the roots) is necessary for optimal protection. Further tests are needed to improve effects of hand applications.

Acknowledgments: We greatly appreciate the efforts by Ricky Holeman, private contractor for Weyerhaeuser Company to establish, spray and monitor research plots in AR. Thanks also go to Mr. Randy Winston and Ms. Lou Ann Miller for providing additional research sites in TX. We thank Weyerhaeuser Company for providing the other sites and donating the seedlings. We also thank Dr. Harry Quicke, BASF, for providing the fipronil formulation for the project.

Table 1. Effect of fipronil soil injections applied by hand on pine tip moth infestation of loblolly pine shoots (top whorl) after each of 9 generations, Crossroads, AR - 2006 & 2007.

			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		
2006	Fipronil Hand Appl.	221	0.0	**100**		2.3	**-20**	3.4	**18**		3.3	**39**	*	2.4	**71**	*	2.3	**43**	*
	Mimic Spray Appl.	120	0.6	**-232**		2.5	**-33**	3.4	**17**		2.0	**64**	*	0.6	**93**	*	1.8	**55**	*
	Control	199	0.2			1.9		4.2			5.5			8.5			4.0		
2007	Fipronil Hand Appl.	218	7.8	**21**		15.4	**21**	26.3	**8**		46.9	**16**	*				24.1	**15**	*
	Mimic Spray Appl.	120	2.2	**77**	*	16.4	**16**	3.1	**89**	*	9.6	**83**	*				7.9	**72**	*
	Control	197	9.9			19.5		28.5			55.9						28.3		

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

[shaded box] = treatment reduced damage by >75% compared to check.

Table 43. Effect of fipronil soil injections applied by hand on loblolly pine growth after two season, Crossroads, AR - 2006 & 2007.

	Treatment	N	Mean End of Season Tree Measurements (**Growth Difference (cm or cm^3) Compared to Check**)					
			Height (cm)		Diameter (cm)		Volume (cm^3)	
2006	Fipronil Hand Appl.	220	72.8	**-1.6**	1.20	**0.05**	142.6	**13.9**
	Mimic Spray Appl.	120	71.1	**-3.3**	1.16	**0.01**	136.4	**7.7**
	Control	199	74.4		1.15		128.7	
2007	Fipronil Hand Appl.	220	221.1	**-3.2**	1.99	**-0.14**	1168.7	**-115.8**
	Mimic Spray Appl.	120	229.5	**5.2**	2.09	**-0.04**	1280.4	**-4.1**
	Control	199	224.3		2.13		1284.5	

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

Table 44. Effect of fipronil application technique on pine tip moth infestation of loblolly pine top whorl shoots after each of 5 generations on three sites in East Texas and Southwest Arkansas - 2007.

Treatment §	N	Mean Percent of Loblolly Pine Shoots Infested (**Pct. Reduction Compared to Check**) Gen 1			Gen 2			Gen 3			Gen 4			Gen 5			Mean		
Machine FIP	550	0.1	**96**	*	3.5	**55**	*	4.0	**73**	*	5.0	**83**	*	5.5	**64**	*	3.6	**74**	*
Machine + Hand FIP SI	550	1.5	**37**		4.2	**46**	*	8.7	**42**	*	15.1	**49**	*	9.9	**34**	*	7.9	**43**	*
Machine + Mimic Spray	550	1.8	**25**		2.2	**71**	*	2.6	**83**	*	5.8	**80**	*	3.6	**76**	*	3.2	**77**	*
Machine Only (Check)	550	2.4			7.7			15.0			29.4			15.1			13.8		

§ SI = Kioritz Soil Injector method [shaded box] = 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 45. Effect of fipronil application technique on loblolly pine growth parameters after the first year on three sites in East Texas and Southwest Arkansas - 2007

Year	Treatment §	N	Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm^3) Compared to Check**) Height (cm)			Diameter (cm)			Volume (cm^3)		
2007	Machine + Fip	550	53.4	*	**6.2**	0.85		**0.03**	50.8		**5.8**
	Machine + Hand Fip Soil Inj	550	55.7	*	**8.5**	0.86	*	**0.04**	53.5		**8.4**
	Machine + Mimic Spray	550	59.4	*	**12.2**	0.95	*	**0.13**	81.8	*	**36.7**
	Machine + Check	550	47.2			0.82			45.1		

§ Fip = Fipronil; Fip Inj = Kioritz Soil Injection Method
* 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 Containerized Pine Seedlings

Highlights: Both fipronil treatments (1X and 5X) provided exceptional protection against tip moth throughout the first growing season; 99% and 100% reduction in damage compared to check.

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

Cooperators:

Mr. James Tule	formerly with Temple Inland Forest Products, Jasper, TX
Dr. Harry Quicke	BASF Co., Auburn, AL

Study Sites: Two first-year Temple Inland plantations were selected in Polk Co. and Angelina Co., Texas in February 2007.

Insecticides:

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

Design: Randomized complete block design at each site with site areas 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.

Treatments:

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 Single Pounce® Foliar - Pounce® applied in nursery (2qts/100K) 1X/ seedling
4) Containerized Check (untreated)
5) Bare Root Fipronil (12 ml/seedling) - Soil injection next to transplant in March
6) Bare Root Single Mimic® Foliar - Mimic® applied 5X /year
7) Bare Root Check (untreated)

Research Approach:

Two families of loblolly pine containerized and bare-root seedlings were selected at the Temple Inland Nursery, 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 7 plot areas. One hundred seedlings were planted per plot at 8’ X 11’ spacing (500 TPA).

Treatment Evaluation: Tip moth damage were evaluated on 50 internal trees within 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, coneworm, etc. The trees were measured for diameter and height (at 6") in the December following planting. Data were analyzed by GLM and the Tukey's Compromise test using Statview or SAS statistical programs.

Results: Tip moth populations were quite low on the 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 46). The fipronil treatments on the containerized seedlings had a significant effect on tip moth damage from the second through the fifth generation, reducing overall damage by 97 – 100%. The soil injection treatment of the bareroot 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 47). However, the Mimic spray treatment had no apparent effect on any of the growth parameters compared to check trees.

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

Table 46. 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

[shaded box] = 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 47. Effect of fipronil application technique and rate on pine tip moth infestation of loblolly pine shoots after after the first year on two sites in East Texas - 2007.

Treatment	N	Height (cm)					Diameter (cm)					Volume (cm^3)				
		Mean End of Season Tree Measurements (**Growth Difference (cm or cm3) Compared to Check**)														
		Ang.	Polk	Mean			Ang.	Polk	Mean			Ang.	Polk	Mean		
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		

* 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 (Spike & Tablet) Trials – Western Gulf

Highlights:

- The effects of imidacloprid plus fertilizer and disulfoton plus fertilizer spikes, applied in 2003, on tip moth damage had disappeared completely by the third growing season. However, differences between treated and untreated trees for height, diameter and volume continued to expand even through the fifth year.
- Imidacloprid tablet treatments (≥10%), with and without fertilizer, applied in 2004, continued to provide moderate protection against tip moths through the second year; reducing damage levels by 32 – 49%. There was a rate effect with higher rates providing better protection. However, none of the tablet treatments significantly improved height or diameter growth even after 4 years.
- All imidacloprid tablet treatments, with and without fertilizer, applied in 2005, provided good protection against tip moths during the first year; reducing overall damage levels by 88 – 100%. However, very low populations in the second year resulted in little or no differences among treatments. Only the 20% imidacloprid + fertilizer + Merit spray treatment continued to significantly improved height or diameter growth through the third year.
- All imidacloprid treatments (tablet, gel & granular), applied in 2006, continued to provide good to excellent protection through the second year; reducing overall damage levels by 60 – 93%. Three of four tablet treatments provided the greatest gains in height and diameter growth compared to the check.
- All imidacloprid tablet treatments, applied in 2007, significantly reduced tip moth damage levels on all sites through the first year. The tablets significantly improved growth parameters on four of six sites.

Objectives: 1) Determine the efficacy of imidacloprid (spikes or tablets) in reducing pine tip moth infestation levels on loblolly pine seedlings; 2) evaluate this product applied at different rates to transplanted seedlings; 3) determine the effect of imidacloprid alone or combined with fertilizer on seedling growth; and 4) determine the duration of chemical activity.

Cooperators:

Ms. Emily Goodwin	formerly with Temple Inland Forest Products, Diboll, TX
Mr. Conner Fristoe	Plum Creek Timber Co., Crossett, AR
Dr. Nick Chappell	Potlatch Forest Holdings, Warren, AR
Ms. Valerie Sawyer & Mr. Peter Birks	Weyerhaeuser Co., Columbus, MS
Dr. Eric Taylor	Texas A&M Cooperative Extension Service, Overton, TX
Dr. Nate Royalty and Ann Thurston	Bayer Crop Science, Research Triangle Park, NC

Study Sites: In 2003, one second-year plantation was selected near Huntington, TX as part of the Fipronil Technique and Rate Trial (see Fig. 36). In 2004, two second-year plantations were selected at Groveton and Overton, Texas. In 2005, a second year site was selected near Zavalla, TX. In 2006, a second year site was selected near Winnfield, LA. In 2007, 6 second-year sites were selected in TX (2 near Colmesneil), MS (near Millard) and AR (1 each near Crossroads, Warren and Crossett). Second-year 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.

Insecticides:

Imidacloprid – highly systemic neonictinoid with activity against Lepidoptera.
Disufoton – systemic organophosphate with activity against Lepidoptera.
Fipronil – a phenyl pyrazole with some systemic activity against Lepidoptera.

Design: Randomized complete block design 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.

Year & Treatments:

2003	1)	2.5% imidacloprid spike + Fertilizer -	3 spikes in soil next to transplant
	2)	1% disulfoton spike + Fertilizer-	3 spikes in soil next to transplant
	3)	Bare root Check -	Treat w/ Terrasorb™ and plant bare root
2004	1)	5% imidacloprid tablet -	1 tablet in soil next to transplant
	2)	5% imidacloprid tablet + Fertilizer-	1 tablet in soil next to transplant
	3)	10% imidacloprid tablet -	1 tablet in soil next to transplant
	4)	10% imidacloprid tablet + Fertilizer-	1 tablet in soil next to transplant
	5)	15% imidacloprid tablet -	1 tablet in soil next to transplant
	6)	15% imidacloprid tablet + Fertilizer-	1 tablet in soil next to transplant
	7)	20% imidacloprid tablet -	1 tablet in soil next to transplant
	8)	20% imidacloprid tablet + Fertilizer-	1 tablet in soil next to transplant
	9)	Fertilizer only-	1 tablet in soil next to transplant
	10)	Mimic® Foliar -	Apply Mimic® (0.6 ml/L water) 5X / season
	11)	Bare root Check -	Treat w/ Terrasorb™ and plant bare root
2005	1)	10% imidacloprid tablet -	1 tablet in plant hole
	2)	20% imidacloprid tablet -	1 tablet in plant hole
	3)	20% imidacloprid tablet + Fertilizer-	1 tablet in plant hole
	4)	20% imidacloprid tablet + Fertilizer + single Merit® spray	1 tablet in plant hole
	5)	Pounce® Foliar -	Apply Pounce® (0.6 ml/L water) 1X / season
	6)	Merit® Foliar -	Apply Merit® (0.6 ml/L water) 1X / season
	7)	Bare root Check -	Treat w/ Terrasorb™ and plant bare root
2006	1)	20% Merit (Imid.) FXT Std. tablet -	1 tablet in soil next to transplant
	2)	20% Merit FXT Std. tablet -	2 tablets in plant hole
	3)	20% Merit FXT Std. tablet -	1 tablet in plant hole
	4)	20% Merit FXT 'Burst' tablet -	1 tablet in plant hole
	5)	Fertilizer -	On soil surface next to transplant
	6)	Gel (5% Imid.) -	In plant hole
	7)	Combo gel (5% Imid.+ 1% Fipronil) -	In plant hole
	8)	Merit (Imid.)70 WG -	In plant hole
	9)	Mimic® or Pounce® Foliar -	Apply Mimic® (0.6 ml/L water) 5X / season
	10)	Bare-root Check -	Treat w/ Terrasorb™ and plant bare-root

2007 All 6 study sites had:

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

Two sites also had:

5)	10% Merit (Imid.) FXT Std. tablet -	1 tablet in plant hole
6)	15% Merit FXT Std. tablet -	1 tablet in plant hole

Research Approach:

In all research years (2003 – 2007), a single family of loblolly pine bare root seedlings was selected at the TFS Indian Mounds Nursery, Alto, TX. All seedlings were operationally lifted by machine in January or February, culled of small and large caliper seedlings, treated with Terrasorb™ root coating, bagged and stored briefly in cold storage.

Fifty seedlings for each treatment were planted (1.8 X 3 m (= 6 X 10 ft) spacing) on one year old (entering 2nd growing season) plantation sites – to ensure a high level of tip moth pressure on the treatment trees. At each site, resident trees were removed and replaced with treatment trees. 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, three plant spikes (2003) or one treatment tablet (2004, 2005, 2006 or 2007) was pushed into the soil 6 cm deep and 4 cm from each assigned seedling. In 2005, 2006 or 2007, one or two tablets were dropped into the plant hole just prior to placement of the seedling in the plant hole.

Treatment Evaluation: 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:

Insecticide/fertilizer spikes

In 2003, fertilizer spikes containing imidacloprid or disulfoton were effective in significantly reducing tip moth damage for three and two generations, respectively (Table 48). By the fifth generation, the damage level of neither treatment differed from the check. Overall, imidacloprid and disulfoton reduced damage levels by 52 and 15%, respectively. Disulfoton and imidacloprid plus fertilizer spike treatments both resulted in marked improvements in all growth parameters compared to check trees (Table 49). Both insecticide/fertilizer spike treatments significantly improved survival compared to check trees.

In 2004, the imidacloprid plus fertilizer treatment continued to reduce tip moth damage levels, particularly in the second, third and fourth generations. Overall, this treatment reduced damage by

18% compared to check trees (Table 48). Seedlings receiving insecticide/fertilizer treatments again had significantly greater height, diameter and volume growth compared to check trees. Percent gains in these parameters were larger in 2004 compared to 2003; indicating that the treatment effects on growth had not declined.

In 2005, the effects of both treatments on tip moth damage have faded completely in the third growing season (Table 48). Seedlings receiving insecticide/fertilizer treatments again had significantly greater height, diameter and volume growth compared to check trees. The differences between treated trees and checks in height, diameter and volume continued to expand, indicating that the treatment effects on growth had not declined (Table 49).

In 2007, insecticide/fertilizer treatments again had significantly greater height, diameter and volume growth compared to check trees. The differences between treated trees and checks in height, diameter and volume continued to expand, indicating that the treatment effects on growth had not declined (Table 49).

Imidacloprid Tablets (2004)

In 2004, tip moth populations were quite low on both sites during the first generation with an average of only 5% of the shoots infested on check trees. 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 (Table 50). In contrast, nearly all treatments containing imidacloprid or fertilizer alone or combined provided moderate to excellent protection during the second through the fifth generations, reducing damaged by 30 – 100% (39 – 84% overall). An increase in imidacloprid concentration in the tablets had no apparent effect on tip moth damage levels. Seedling survival was generally poor for most treatments with averages for the two sites ranging from 55 – 72% compared to 69% survival for check trees. Only trees treated with the 15% imidacloprid only tablets had significantly lower survival than the check. None of the treatments, including the Mimic® spray, significantly improved height and diameter growth compared to the checks (Tables 51-53). Only seedlings receiving a 5% imidacloprid + fertilizer tablet had significantly greater volume index compared to check trees.

In 2005, tip moth populations were again low on both sites during the first generation with an average of only 6% of the shoots infested on check trees. 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 (Table 50). Treatments containing imidacloprid or fertilizer alone or combined provide low to moderate protection during the second through the fifth generations, reducing overall damage by 3 – 49%. Increasing imidacloprid concentration in the tablets tended to improve protection against tip moth damage. None of the treatments, including the Mimic® spray, significantly improved height, diameter or volume growth compared to the checks (Tables 51-53).

By 2007 (four years after planting), none of the treatments, including the Mimic® spray, had significantly improved height, diameter or volume growth compared to the checks (Tables 51-53).

Imidacloprid Tablets (2005)

In 2005, tip moth populations were very low on the single site during the first, second and fourth generations with averages of 0.8%, 1.7% and 0% of the shoots infested on check trees, respectively. As a result of the low tip moth pressure, none of treatments significantly reduced tip moth infestation levels compared to the check during these generations (Table 54). In contrast, all treatments containing imidacloprid or fertilizer alone or combined provided excellent protection during the third and fifth generations, reducing damaged by 91 – 100% (88 – 100% overall). The addition of fertilizer or increase in imidacloprid concentration in the tablets had no apparent effect on tip moth damage levels. Only seedlings receiving a 20% imidacloprid + fertilizer tablet + Merit spray had significantly greater diameter and volume index compared to check trees (Table 55).

In 2006, tip moth population levels were very low through all five generations with averages of 0.7 – 3.9% of the shoots infested on check trees (Table 54). As a result of the low tip moth pressure, none of treatments significantly reduced tip moth infestation levels compared to the check during these generations. Only seedlings receiving a 20% imidacloprid + fertilizer tablet + Merit spray continued to have significantly greater diameter and volume index compared to check trees (Table 55).

In 2007, only seedlings receiving a 20% imidacloprid + fertilizer tablet + Merit spray continued to have significantly greater diameter and volume index compared to check trees (Table 55). The differences between treated trees and checks in height, diameter and volume continued to expand, indicating that the treatment effects on growth had not declined.

<u>Imidacloprid tablets, gels and granular (2006)</u>

In 2006, tip moth populations were very low on the single site during the first and second generations with averages of 0.8% and 0% of the shoots infested on check trees, respectively. As a result of the low tip moth pressure, none of treatments significantly reduced tip moth infestation levels compared to the check during these generations (Table 56). In contrast, all treatments containing imidacloprid or fertilizer alone or combined provided excellent protection during the third through fifth generations, reducing damaged by 70 – 100% (77 – 100% overall). Imidacloprid tablet and granular formulations had similar effects on tip moth damage levels. In contrast, the gel formulations (imidacloprid alone or combined with fipronil) had short term effects against tip moth and/or significantly reduced survival of seedlings (Table 57). None of the study treatments significantly improved any of the growth parameters compared to check trees.

In 2007, tip moth populations were much higher throughout the year compared to 2006. As a result of the higher tip moth pressure, all treatments significantly reduced tip moth infestation levels compared to the check during the first three generations (Table 56). Most treatments containing imidacloprid alone or combined with fertilizer provided good protection through fifth generation, reducing damaged by 44 – 90% (60 – 93% overall). Imidacloprid tablet and granular formulations had similar effects on tip moth damage levels. In contrast, the gel formulations (imidacloprid alone or combined with fipronil) had short term effects against tip moth and/or significantly reduced survival of seedlings (Table 57). None of the study treatments significantly improved any of the growth parameters compared to check trees.

<u>Imidacloprid Tablets (2007)</u>

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 TX site to 45% and 55% at the end of the year on two AR sites (Table 58 & 59). All tablet treatments placed in the plant hole were highly effective in reducing tip moth damage throughout the year. Overall, damage was reduced by 77-81%. Tablets pushed into the soil after the seedlings were planted and foliar sprays were less effective; reducing damage by 55-68%. Tablet treatments significantly improved growth parameters compared to checks on four of six sites (Table 60).

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Table 48. Effect of imidacloprid + fertilizer or disolfoton + fertilizer plant spikes on pine tip moth infestation of loblolly pine shoots (top whorl) on one site in east Texas, 2003 - 2005.

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		
2003	Imidacloprid + Fert.	50	1.0	**74**		1.2	**90**	*	0.0	**100**	*	21.9	**53**	*	41.7	**22**		13.2	**52**	*
	Disulfoton + Fert.	50	3.1	**19**		5.0	**59**	*	4.2	**81**	*	45.3	**2**		60.0	**-12**		23.4	**15**	
	Check	100	3.9			12.3			22.6			46.1			53.4			27.5		
2004	Imidacloprid + Fert.	50	17.3	**-37**		4.7	**57**	*	10.3	**53**	*	22.9	**50**	*	67.7	**-15**		24.4	**18**	*
	Disulfoton + Fert.	50	21.6	**-71**		12.4	**-14**		15.9	**27**		22.2	**51**	*	66.0	**-12**		27.8	**7**	
	Check	100	12.6			10.9			21.9			45.5			59.2			29.8		
2005	Imidacloprid + Fert.	50	21.6	**-69**		6.5	**-67**		1.2	**14**		34.9	**-13**		25.7	**-31**		18.0	**-30**	
	Disulfoton + Fert.	50	17.9	**-41**		2.1	**46**		1.4	**1**		51.8	**-68**	*	34.8	**-77**	*	21.6	**-56**	*
	Check	100	12.8			3.9			1.4			30.8			19.7			13.8		

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

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

Table 49. Effect of imidacloprid + fertilizer or disolfoton + fertilizer plant spikes on loblolly pine growth on one site in east Texas, 2003 - 2007.

			Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm3) Compared to Check)**						
Year	Treatment	N	Height (cm)		Diameter (cm) [a]		Volume (cm^3)		Mean Percent Tree Survival
2003	Imidacloprid + Fert.	50	58.8 *	**9.0**	1.21 *	**0.15**	101.4 *	**29.3**	98 *
	Disulfoton + Fert.	50	54.5 *	**4.7**	1.21 *	**0.16**	95.4 *	**23.3**	96 *
	Check	100	49.8		1.06		72.1		90
2004	Imidacloprid + Fert.	50	161 *	**31**	3.6 *	**0.5**	2223 *	**698**	94
	Disulfoton + Fert.	50	152 *	**22**	3.6 *	**0.6**	2314 *	**790**	94
	Check	100	129		3.0		1525		87
2005	Imidacloprid + Fert.	46	282 *	**44**	3.4 *	**0.9**	3566 *	**1542**	92
	Disulfoton + Fert.	47	271	**33**	3.2 *	**0.7**	3267 *	**1243**	94
	Check	87	238		2.5		2024		87
2007	Imidacloprid + Fert.	46	600 *	**53**	9.0 *	**1.6**	49309 *	**17112**	92
	Disulfoton + Fert.	47	606 *	**59**	8.5 *	**1.1**	46026 *	**13829**	94
	Check	86	547		7.4		32197		86

[a] Diameter taken at 6" above ground in 2003 and 2004; at breast height in 2005 and 2007.

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

Table 50. Effect of tablets containing imidacloprid alone or combined with fertilizer at different rates on pine tip moth infestation of loblolly pine shoots (top whorl) after each of 5 generations on two sites in the Western Gulf Region - 2004 & 2005.

			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		
2004	5% Imid.	100	6.2	**-22**	4.6	**76**	*	7.1	**72**	*	6.1	**77**	*	9.2	**67**	*	6.6	**68**	*
	10% Imid.	100	7.9	**-56**	0.9	**95**	*	0.0	**100**	*	4.3	**84**	*	8.2	**70**	*	4.3	**79**	*
	15% Imid.	100	5.2	**-2**	2.7	**86**	*	5.9	**77**	*	8.6	**68**	*	8.0	**71**	*	6.1	**71**	*
	20% Imid.	100	6.2	**-22**	2.2	**88**	*	5.5	**79**	*	4.8	**82**	*	14.9	**47**	*	6.7	**68**	*
	5% Imid. + Fert.	100	6.1	**-20**	8.7	**54**	*	12.0	**53**	*	13.5	**49**	*	23.6	**15**		12.8	**39**	*
	10% Imid. + Fert.	100	7.0	**-39**	6.5	**66**	*	5.8	**77**	*	6.9	**74**	*	11.9	**57**	*	7.6	**63**	*
	15% Imid. + Fert.	100	4.6	**10**	3.2	**83**	*	0.7	**97**	*	1.7	**94**	*	6.4	**77**	*	3.3	**84**	*
	20% Imid. + Fert.	100	3.4	**34**	2.6	**86**	*	1.4	**94**	*	8.2	**69**	*	14.1	**49**	*	5.9	**72**	*
	Fert. only	100	9.7	**-92**	7.5	**60**	*	13.1	**49**	*	17.0	**36**	*	15.4	**45**	*	12.6	**40**	*
	Mimic spray	100	8.2	**-62**	2.8	**85**	*	0.5	**98**	*	6.9	**74**	*	3.1	**89**	*	4.3	**79**	*
	Check	100	5.1		18.9			25.6			26.5			27.8			20.8		
2005	5% Imid.	100	9.3	**-51**	11.0	**48**	*	21.0	**5**		31.5	**-31**		29.5	**9**		21.0	**3**	
	10% Imid.	100	6.3	**-2**	13.5	**36**		17.4	**21**		25.0	**-4**		9.3	**71**	*	14.8	**32**	*
	15% Imid.	100	5.2	**16**	9.1	**57**	*	10.9	**50**	*	18.5	**23**		24.9	**23**		13.5	**37**	*
	20% Imid.	100	5.5	**12**	11.7	**44**	*	10.1	**54**	*	13.2	**45**	*	13.7	**58**	*	11.0	**49**	*
	5% Imid. + Fert.	100	12.5	**-102**	10.2	**52**	*	14.3	**35**	*	25.2	**-5**		26.0	**20**		17.9	**17**	
	10% Imid. + Fert.	100	6.7	**-9**	16.5	**22**		11.7	**47**	*	14.9	**38**		20.7	**36**	*	14.3	**34**	*
	15% Imid. + Fert.	100	5.8	**7**	15.3	**27**		8.4	**62**	*	18.3	**24**		18.2	**44**	*	13.3	**39**	*
	20% Imid. + Fert.	100	9.2	**-48**	17.8	**16**		7.2	**67**	*	15.7	**35**		14.3	**56**	*	13.3	**38**	*
	Fert. only	100	4.4	**29**	20.6	**3**		10.3	**53**	*	16.9	**30**		19.3	**40**	*	14.9	**31**	*
	Mimic spray	100	6.1	**1**	4.9	**77**	*	3.6	**84**	*	2.2	**91**	*	3.0	**91**	*	4.0	**82**	*
	Check	100	6.2		21.1			22.0			24.1			32.5			21.6		

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

[shaded box] = treatment reduced damage by >75% compared to check.

Table 51. Effect of tablets containing imidacloprid alone or combined with fertilizer at different rates on loblolly pine height growth after one, two and four seasons on two sites in east Texas, 2004, 2005 & 2007.

Treatment	N	Height (cm) (**Growth Difference (cm or cm3) Compared to Check**)														
		2004			2005			2007								
								Groveton			Overton		Combined			
5% Imid.	100	48.8		**-2.1**	125.7		**-8.1**	438.0		**-25.6**	327.6	**10.3**	383.7		**-13.6**	
10% Imid.	100	48.3		**-2.5**	115.6	*	**-18.1**	382.5	*	**-81.1**	335.2	**17.9**	355.3	*	**-42.0**	
15% Imid.	100	43.8	*	**-7.1**	117.2	*	**-16.6**	374.6	*	**-89.0**	334.2	**16.9**	349.5	*	**-47.8**	
20% Imid.	100	50.0		**-0.9**	130.8		**-3.0**	392.6	*	**-71.0**	306.0	**-11.2**	344.7	*	**-52.6**	
5% Imid. + Fert.	100	54.8		**3.9**	141.7		**8.0**	437.4		**-26.2**	349.0	**31.7**	401.2		**3.9**	
10% Imid. + Fert.	100	45.0		**-5.8**	121.0		**-12.7**	417.1		**-46.5**	324.8	**7.5**	361.4		**-35.9**	
15% Imid. + Fert.	100	39.4	*	**-11.4**	105.7	*	**-28.0**	420.1		**-43.5**	305.2	**-12.0**	365.8		**-31.5**	
20% Imid. + Fert.	100	50.5		**-0.4**	138.7		**5.0**	479.0		**15.4**	325.3	**8.0**	393.0		**-4.3**	
Fert. only	100	42.9	*	**-8.0**	117.9		**-15.8**	412.2	*	**-51.4**	289.3	**-28.0**	361.6		**-35.7**	
Mimic spray	100	47.8		**-3.1**	135.7		**2.0**	460.1		**-3.5**	337.4	**20.1**	401.4		**4.1**	
Check	100	50.9			133.7			463.6			317.3		397.3			

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

Table 52. Effect of tablets containing imidacloprid alone or combined with fertilizer at different rates on loblolly pine diameter growth after one, two and four seasons on two sites in East Texas, 2004, 2005 & 2007.

Treatment	N	Diameter (cm) (**Growth Difference (cm or cm3) Compared to Check**)												
		2004			2005		2007							
							Groveton			Overton		Combined		
5% Imid.	100	0.75	*	**-0.18**	1.77	**0.12**	6.26		**-0.40**	3.80	**0.00**	5.05		**-0.32**
10% Imid.	100	0.80		**-0.13**	1.53	**-0.12**	5.27	*	**-1.40**	4.20	**0.40**	4.65	*	**-0.71**
15% Imid.	100	0.68	*	**-0.24**	1.81	**0.16**	5.04	*	**-1.63**	3.79	**-0.01**	4.26	*	**-1.10**
20% Imid.	100	0.89		**-0.04**	1.57	**-0.08**	5.48	*	**-1.19**	3.42	**-0.38**	4.34	*	**-1.03**
5% Imid. + Fert.	100	1.03		**0.10**	1.90	**0.25**	6.41		**-0.26**	4.60	**0.80**	5.67		**0.30**
10% Imid. + Fert.	100	0.72	*	**-0.21**	1.65	**0.00**	5.87		**-0.79**	4.16	**0.36**	4.84		**-0.53**
15% Imid. + Fert.	100	0.60	*	**-0.32**	1.45	**-0.20**	5.95		**-0.72**	3.51	**-0.29**	4.79		**-0.57**
20% Imid. + Fert.	100	0.88		**-0.05**	1.62	**-0.03**	6.74		**0.07**	4.08	**0.28**	5.25		**-0.12**
Fert. only	100	0.75	*	**-0.18**	1.72	**0.08**	5.56	*	**-1.10**	3.19	**-0.61**	4.58		**-0.78**
Mimic spray	100	0.85		**-0.08**	1.75	**0.10**	6.31		**-0.35**	4.23	**0.43**	5.32		**-0.05**
Check	100	0.93			1.65		6.66			3.80		5.37		

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

Table 53. Effect of tablets containing imidacloprid alone or combined with fertilizer at different rates on loblolly pine volume growth and tree survival after one, two and four seasons on two sites in east Texas, 2004, 2005 & 2007.

Treatment	N	Volume Index (cm^3) (**Growth Difference (cm or cm3) Compared to Check**) 2004		2005		2007 Groveton		2007 Overton		2007 Combined		Mean % Tree Survival (**Pct. Gain compared to Checks**)	
5% Imid.	100	49.9	**-18.9**	503.6	**74**	19984	**-3956**	6041	**329**	13131	**-2550**	59	**-8**
10% Imid.	100	60.6	**-8.1**	363.7	**-66**	14113 *	**-9827**	7966	**2254**	10584 *	**-5097**	54	**-16**
15% Imid.	100	31.9 *	**-36.8**	534.3 *	**104**	12411 *	**-11529**	6703	**991**	8872 *	**-6809**	50	**-22**
20% Imid.	100	89.1	**20.3**	399.4	**-31**	15077 *	**-8863**	5328	**-384**	9680 *	**-6001**	56	**-13**
5% Imid. + Fert.	100	104.6 *	**35.9**	671.7 *	**242**	20822	**-3118**	10734	**5022**	16687	**1006**	61	**-5**
10% Imid. + Fert.	100	40.7	**-28.0**	432.2	**2**	18171	**-5769**	8203	**2491**	12153	**-3528**	53	**-17**
15% Imid. + Fert.	100	34.2	**-34.5**	312.0	**-118**	19576	**-4364**	4953	**-759**	12663	**-3018**	55	**-14**
20% Imid. + Fert.	100	81.7	**13.0**	455.4	**25**	26252	**2312**	6938	**1226**	15449	**-232**	59	**-8**
Fert. only	100	43.3	**-25.4**	504.4	**74**	15202 *	**-8738**	3919	**-1793**	10556 *	**-5125**	51	**-20**
Mimic spray	100	58.7	**-10.1**	523.7	**94**	22343	**-1597**	7464	**1752**	15227	**-454**	69	**8**
Check	100	68.8		430.1		23940		5712		15681		64	

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

Table 54. Effect of tablets containing imidacloprid alone or combined with fertilizer at different rates on pine tip moth infestation of loblolly pine shoots (top whorl) after each of 5 generations on one site in the Western Gulf Region: 2005 - 2006.

			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		
2005	10% Imid.	50	0.0	**100**		0.6	**66**		0.0	**100**	*	0.0	**#####**		0.0	**100**	*	0.0	**100**	*
	20% Imid.	50	0.7	**18**		0.8	**53**		0.0	**100**	*	0.0	**#####**		0.0	**100**	*	0.2	**96**	*
	20% Imid. + Fert.	50	0.0	**100**		0.0	**100**		0.0	**100**	*	0.0	**#####**		0.0	**100**	*	0.0	**100**	*
	20% Imid. + Fert. + Merit spray	50	0.4	**52**		1.4	**17**		1.0	**91**	*	0.0	**#####**		0.0	**100**	*	0.7	**88**	*
	Merit® spray	50	0.5	**40**		0.4	**74**		0.4	**96**	*	6.6	**#####**	*	5.4	**62**	*	2.8	**53**	
	Pounce® spray	50	6.0	**-619**	*	2.4	**-40**		4.1	**64**	*	2.9	**#####**		6.5	**54**		4.2	**29**	
	Check	50	0.8			1.7			11.2			0.0			14.0			5.9		
2006	10% Imid.	50	0.0	**100**		0.0	**100**		1.5	**56**		4.6	**-531**		9.1	**-131**		3.0	**-21**	
	20% Imid.	50	3.7	**-95**		0.5	**80**		0.9	**74**		6.2	**-740**		5.6	**-42**		3.4	**-37**	
	20% Imid. + Fert.	50	4.0	**-111**		0.0	**100**		1.7	**50**		10.9	**-1381**		5.8	**-47**		4.5	**-79**	
	20% Imid. + Fert. + Merit spray	50	0.0	**100**		0.0	**100**		4.7	**-38**		6.0	**-716**		4.0	**-3**		3.0	**-18**	
	Merit® spray	50	4.7	**-147**		0.0	**100**		6.1	**-79**		16.5	**-2149**		9.0	**-130**		7.3	**-192**	
	Pounce® spray	50	0.5	**73**		11.0	**-340**		7.3	**-115**		2.1	**-183**		4.0	**-3**		4.9	**-95**	
	Check	50	1.9			2.5			3.4			0.7			3.9			2.5		

* Means followed by an asterik are significantly different from checks at the 5% level based on Fisher's Protected LSD.
[shaded box] = treatment reduced damage by >75% compared to check.

Table 55. Effect of tablets containing imidacloprid alone or combined with fertilizer at different rates on loblolly pine growth and tree survival after two seasons on one site in east Texas: 2005 - 2007.

Year	Treatment	N	Height (cm)			Diameter (cm)			Volume (cm^3)			Survival (**Pct. Gain compared to Checks**)	
			Mean End of Season Tree Measurements (**Growth Difference (cm or cm^3) Compared to Check**)										
2005	10% Imid.	50	32.5		**1.4**	0.52		**0.04**	10.8		**0.8**	68	**-3**
	20% Imid.	50	32.1		**1.0**	0.50		**0.02**	10.1		**0.1**	54	**-23**
	20% Imid. + Fert.	50	31.0		**-0.1**	0.44		**-0.04**	6.9		**-3.1**	58	**-17**
	20% Imid. + Fert. + Merit spray	50	33.1		**2.0**	0.56	*	**0.08**	12.8	*	**2.8**	74	**6**
	Fert. only	50	30.7		**-0.5**	0.50		**0.02**	9.3		**-0.7**	74	**6**
	Mimic spray	50	30.6		**-0.5**	0.47		**-0.01**	8.1		**-1.9**	62	**-11**
	Check	50	31.1			0.48			10.0			70	
2006	10% Imid.	50	96		**2**	1.2		**0.0**	150		**-10**	66	**-3**
	20% Imid.	50	87		**-7**	1.2		**-0.1**	123		**-37**	54	**-21**
	20% Imid. + Fert.	50	87		**-7**	1.3		**0.1**	171		**11**	60	**-12**
	20% Imid. + Fert. + Merit spray	50	101		**7**	1.4	*	**0.2**	215	*	**56**	72	**6**
	Merit® spray	50	96		**2**	1.4		**0.1**	192		**32**	74	**9**
	Pounce® spray	50	86		**-8**	1.4		**0.1**	195		**35**	64	**-6**
	Check	50	94			1.2			160			68	
2007	10% Imid.	50	237		**8**	1.7		**0.1**	914		**64**	68	**3**
	20% Imid.	50	215		**-14**	1.6		**-0.1**	862		**12**	54	**-18**
	20% Imid. + Fert.	50	233		**4**	1.7		**0.0**	798		**-52**	60	**-9**
	20% Imid. + Fert. + Merit spray	50	255	*	**26**	2.1	*	**0.4**	1441	*	**591**	72	**9**
	Merit® spray	50	230		**1**	1.7		**0.0**	769		**-81**	76	**15**
	Pounce® spray	50	223		**-7**	1.6		**0.0**	676		**-174**	64	**-3**
	Check	50	229			1.7			850			66	

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

Table 56. Effect of imidacloprid application technique and rate on pine tip moth infestation of loblolly pine shoots (top whorl) during each generation (5) of the first two growing seasons, Winnfield, LA, 2006 & 2007.

Year	Treatment §	N	Gen 1		Gen 2		Gen 3		Gen 4		Gen 5		Overall Mean	
2006	20% Merit Ball 2X	50	3.0 *	**-275**	2.1 *	**##**	0.0 *	**100**	0.0 *	**100**	3.8 *	**75**	1.9 *	**77**
	20% Merit Ball 1X	50	0.0	**100**	0.0	**##**	0.0 *	**100**	4.8 *	**70**	3.4 *	**77**	1.6 *	**79**
	20% Merit Burst 1X	50	0.0	**100**	0.0	**##**	0.0 *	**100**	0.0 *	**100**	2.6 *	**83**	0.5 *	**94**
	Imid 5% gel 10g	50	0.0	**100**	0.0	**##**	1.4 *	**87**	0.0 *	**100**	0.0 *	**100**	0.3 *	**96**
	ImidFip Comb 10g	50	0.0	**100**	0.0	**##**	0.0 *	**100**	3.8 *	**76**	9.2	**39**	2.6 *	**67**
	Confidor 70 WG	50	0.0	**100**	0.0	**##**	0.0 *	**100**	0.0 *	**100**	0.0 *	**100**	0.0 *	**100**
	Merit 20% Ball Soil	50	0.8	**2**	0.8	**##**	0.0 *	**100**	0.0 *	**100**	0.6 *	**96**	0.0 *	**100**
	Fertilizer	50	0.0	**100**	0.0	**##**	1.2 *	**89**	1.6 *	**90**	0.0 *	**100**	0.6 *	**93**
	Mimic spray	50	0.0	**100**	0.0	**##**	0.0 *	**100**	0.0 *	**100**	0.0 *	**100**	0.0 *	**100**
	Check	50	0.8		0.0		10.4		15.9		15.0		7.9	
2007	20% Merit Ball 2X	34	0.7 *	**85**	4.9 *	**65**	2.3 *	**94**	6.2 *	**87**	17.0 *	**77**	5.6 *	**85**
	20% Merit Ball 1X	35	0.0	**100**	4.4	**68**	3.8 *	**90**	24.4 *	**50**	39.8 *	**47**	14.5 *	**60**
	20% Merit Burst 1X	40	0.0	**100**	3.6	**74**	2.3 *	**94**	9.2 *	**81**	18.7 *	**75**	6.2 *	**83**
	Imid 5% gel 10g	18	0.0	**100**	2.4	**83**	4.6 *	**88**	8.1 *	**84**	15.8 *	**79**	7.0 *	**81**
	ImidFip Comb 10g	20	0.0	**100**	1.3	**91**	0.0 *	**100**	7.4 *	**85**	41.9	**44**	10.8 *	**70**
	Confidor 70 WG	37	0.0	**100**	0.0	**100**	2.4 *	**94**	2.9 *	**94**	7.8 *	**90**	2.7 *	**93**
	Merit 20% Ball Soil	39	0.0	**100**	2.4	**82**	9.7 *	**75**	18.0 *	**63**	25.6 *	**66**	10.9 *	**70**
	Fertilizer	40	0.6	**87**	6.4	**54**	16.7 *	**56**	35.9 *	**27**	55.6 *	**26**	22.8 *	**37**
	Mimic spray	38	0.0	**100**	0.0	**100**	5.3 *	**86**	3.2 *	**93**	2.7 *	**96**	2.3 *	**94**
	Check	31	4.8		13.8		38.3		49.1		74.9		36.2	

§ All treatments placed in plant hole except Ball Soil and Fertilizer, placed adjacent to seedling.

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

[shaded box] = treatment reduced damage by >75% compared to check.

Table 57. Effect of fipronil application technique and rate on loblolly pine growth parameters and tree survival after the first year on one site in the Western Gulf region - 2006 & 2007

Year	Treatment §	N	Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm^3) Compared to Check**) Height (cm)			Diameter (cm)			Volume (cm^3)			Mean % Tree Survival (**Pct. Gain Compared to Check**)		
2006	20% Merit Ball 2X	50	39.8	**2.2**		0.58	**0.03**		15.4	**-0.1**		70	**13**	
	20% Merit Ball 1X	50	39.5	**1.8**		0.54	**-0.01**		19.1	**3.6**		70	**13**	
	20% Merit Burst 1X	50	32.3	**-5.3**	*	0.42	**-0.13**	*	9.9	**-5.5**	*	82	**32**	*
	Imid 5% gel 10g	50	28.3	**-9.3**	*	0.40	**-0.15**	*	6.0	**-9.4**	*	36	**-42**	*
	ImidFip Comb 10g	50	38.9	**1.3**		0.47	**-0.08**		12.9	**-2.5**		40	**-35**	*
	Confidor 70 WG	50	36.1	**-1.5**		0.52	**-0.02**		14.3	**-1.2**		74	**19**	
	Merit 20% Ball Soil	50	38.5	**0.8**		0.53	**-0.02**		16.2	**0.8**		78	**26**	
	Fertilizer	50	35.2	**-2.4**		0.49	**-0.06**		10.7	**-4.7**		84	**35**	*
	Mimic spray	50	36.4	**-1.2**		0.53	**-0.02**		13.5	**-2.0**		76	**23**	
	Check	50	37.6			0.55			15.4			62		
2007	20% Merit Ball 2X	50	148.0	**24.6**	*	2.14	**0.23**		874	**312**	*	70	**13**	
	20% Merit Ball 1X	50	141.8	**18.4**	*	2.16	**0.25**		757	**195**		70	**13**	
	20% Merit Burst 1X	50	136.5	**13.1**		1.84	**-0.07**		618	**56**		82	**32**	*
	Imid 5% gel 10g	50	115.1	**-8.2**		1.62	**-0.29**		372	**-190**		36	**-42**	*
	ImidFip Comb 10g	50	141.5	**18.1**		1.95	**0.04**		701	**139**		38	**-39**	*
	Confidor 70 WG	50	129.3	**5.9**		1.85	**-0.06**		599	**37**		74	**19**	
	Merit 20% Ball Soil	50	140.7	**17.3**		2.11	**0.20**		785	**223**		78	**26**	
	Fertilizer	50	127.8	**4.4**		1.93	**0.02**		549	**-13**		84	**35**	*
	Mimic spray	50	126.4	**3.0**		1.93	**0.02**		662	**100**		74	**19**	
	Check	50	123.4			1.91			562			62		

§ All treatments placed in plant hole except Ball Soil and Fertilizer, placed adjacent 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 Bayer tablets on percent shoots infested by pine tip moth after each of five generations on six Western Gulf 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

[shaded box] = 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 59. Effect of Bayer tablets on percent shoots infested by pine tip moth after each of five generations on two Western Gulf sites - 2007.

		Mean Percent Shoots Infested (Pct. Reduction Compared to Check)							
		Generation 1				Generation 2			
Treatment §	N	TX1	AR1	Mean		TX1	AR1	Mean	
10% FXT Ball PH	50	0.5	0.4	0.4	**4**	5.4	0.6 *	3.0	**78**
15% FXT Ball PH	50	1.5	0.0	0.7	**-63**	0.0 *	5.1	2.6	**81**
20% FXT Ball PH	50	0.0	0.9	0.5	**0**	0.0 *	3.1	1.6	**88**
20% FXT Ball Adjacent	50	0.0	0.4	0.2	**56**	2.5 *	10.8	6.7	**50**
Mimic foliar spray	50	2.1	0.5	1.3	**-192**	3.2 *	2.8	3.0	**78**
Check	50	0.0	0.9	0.5		13.3	9.4	11.3	
		Generation 3				Generation 4			
Treatment §	N	TX1	AR1	Mean		TX1	AR1	Mean	
10% FXT Ball PH	50	0.6 *	3.8 *	2.2	**80**	1.0 *		1.0	**96**
15% FXT Ball PH	50	0.0 *	5.6 *	2.8	**74**	3.0 *		3.0	**88**
20% FXT Ball PH	50	0.0 *	6.5 *	3.2	**70**	1.8 *		1.8	**93**
20% FXT Ball Adjacent	50	0.0 *	6.8 *	3.4	**69**	0.0 *		0.0	**100**
Mimic foliar spray	50	2.2	8.2	5.2	**52**	2.4 *		2.4	**90**
Check	50	5.4	16.4	10.9		24.6		24.6	
		Generation 5 (Last)				Mean			
Treatment §	N	TX1	AR1	Mean		TX1	AR1	Mean	
10% FXT Ball PH	50	0.0 *	12.6	6.3	**73**	1.2 *	3.4 *	2.3	**81**
15% FXT Ball PH	50	6.3 *	5.2 *	5.7	**75**	1.4 *	3.4 *	2.4	**79**
20% FXT Ball PH	50	2.1 *	8.3 *	5.2	**77**	0.6 *	4.8 *	2.7	**77**
20% FXT Ball Adjacent	50	0.0 *	12.1	6.1	**74**	0.4 *	7.2 *	3.8	**68**
Mimic foliar spray	50	2.4 *	8.9 *	5.6	**75**	2.1 *	5.5 *	3.8	**68**
Check	50	24.5	21.5	23.0		11.0	12.7	11.8	

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

(shaded box) = 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 60. Effect of Bayer tablets on height, diameter and volume index after the first growing season on six Western Gulf sites - 2007.

Mean Parameter Growth (**Growth Difference (cm or cm^3) Compared to Check**)

		Height (cm)		6 Trt Site		Height (cm)				4 Trt Site	
Treatment §	N	TX1	AR1	Mean		TX2	AR2	AR3	MS1	Mean	
10% FXT Ball PH	50	48.8 *	63.3 *	54.9 *	**10.3**						
15% FXT Ball PH	50	48.2 *	61.5 *	55.0 *	**10.3**						
20% FXT Ball PH	50	53.5 *	57.7	55.6 *	**11.0**	46.9 *	56.4 *	42.2	91.4	69.6 *	**10.3**
20% FXT Ball Adjacent	50	54.6 *	58.0	56.3 *	**11.7**	40.7 *	53.9 *	39.6	97.2	68.8 *	**9.5**
Mimic foliar spray	50	45.8	48.3	47.0	**2.3**	42.9 *	56.1 *	37.9	83.6	62.9	**3.6**
Check	50	39.1	50.3	44.6		33.5	47.3	35.6	90.7	59.3	

		Diameter (cm)		6 Trt Site		Diameter (cm)				4 Trt Site	
Treatment §	N	TX1	AR1	Mean		TX2	AR2	AR3	MS1	Mean	
10% FXT Ball PH	50	0.83 *	0.80	0.81	**0.12**						
15% FXT Ball PH	50	0.85 *	0.74	0.79	**0.10**						
20% FXT Ball PH	50	0.91 *	0.77	0.84	**0.15**	0.68 *	1.05	0.53	1.82	1.15	**0.10**
20% FXT Ball Adjacent	50	0.87 *	0.73	0.80	**0.11**	0.56	0.99	0.47	2.01	1.12	**0.07**
Mimic foliar spray	50	0.74	0.73	0.74	**0.05**	0.66 *	1.06 *	0.47	1.85	1.10	**0.05**
Check	50	0.68	0.70	0.69		0.54	0.93	0.47	1.94	1.05	

		Volume Index (cm^3)		6 Trt Site		Volume Index (cm^3)				4 Trt Site	
Treatment §	N	TX1	AR1	Mean		TX2	AR2	AR3	MS1	Mean	
10% FXT Ball PH	50	42.9 *	63.6 *	51.7 *	**25.3**						
15% FXT Ball PH	50	44.6 *	42.0	43.3 *	**16.9**						
20% FXT Ball PH	50	59.0 *	48.8	53.8 *	**27.4**	24.6 *	75.1 *	15.3	355.0	115.5 *	**15.0**
20% FXT Ball Adjacent	50	51.3 *	39.1	45.0 *	**18.6**	15.6	65.6	11.7	355.0	107.7 *	**7.1**
Mimic foliar spray	50	32.5	31.7	32.1	**5.8**	21.8 *	73.7 *	10.7	346.8	103.4	**2.9**
Check	50	22.9	30.0	26.4		11.2	50.7	11.6	376.2	100.5	

§ 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.

PINE TIP MOTH TRIALS

Summary and Registration Status of Tested Systemic Insecticides

Over the past 9 years (1998 – 2007), the WGFPMC 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 seven years we have established 88 impact plots and 120 hazard-rating plots in the Western Gulf Region and accumulated a large pool of data from which to address these two questions. Data analyses have determined the damage threshold for impact to be about 10% 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 that has 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 based on data from numerous sites now indicates that sites with deep, excessively or poorly drained soils are more prone to tip moth damage. This needs to be validated with data from additional sites. It is important that evaluations and data collections continue on already established impact and hazard-rating sites in 2008 and beyond and that new sites be established.

Fipronil: Over the past six years (2002 – 2007), 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, would 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 pushing the envelop in the 2004 and 2005 trials by applying fipronil 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, there is concern 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 applicators, the Kioritz ($350 - $460) and a modified cattle drencher, were successfully used to apply fipronil solution by hand in 2005 and 2006. Soil injection trials established in 2005 again showed that this application technique is consistently effective in reducing pine tip moth damage. At least one forest industry had experimented with a ‘puddle planter”, developed by Mr. Kevin Darrow (formerly with Pelton Reforestation Inc.), that ‘injects’ water into plant furrows while machine planting seedlings. This would seem to be a safe and efficient way of treating bare root or containerized seedlings with fipronil where operational use of machine planters is possible. Mr. Lane Day and Jim Rogers, contracted by the WGFPMC, were able to develop and successfully tested a new soil injection system in late 2006. The treatment applied by machine was consistently effective in protecting first year seedling on three sites through 2007. Additional machine planter trials are planned in 2008 that evaluate the area-wide effects of fipronil treatments.

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 also showed excellent first year results. 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.

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. Although product registration normally takes about 18 months, a request by Weyerhaeuser for an Emergency Use Permit (Section 18) in NC caused EPA to review the registration sooner. **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 61 provides information about the PTM product (distributors, cost, etc.).**

Additional trials are planned for 2008 to refine treatment rates and timing and determine effects on second year trees.

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). Recently, 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 a single trial replicates (Technique and Rate Trial, 2003-2004), again the cost of treatment per seedling for operational forestry use would be prohibitive.

Bayer Environmental Science also is interested in the potential for using tablets containing imidacloprid + fertilizer to protect seedlings against tip moth. Trials in 2004 and 2005 indicated that 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. Bayer was encouraged by the results of these trials as well as other trials on the East Coast. They submitted a request to EPA for a full Section 3 registration in 2006**. EPA approved the registration of "SilvaShield Forestry Tablet" (20% imidacloprid + fertilizer) in December 2006. The tablets can be applied for protection of pine against tip moth, aphids and soft scales and hybrid poplar against leaf beetles. Table 61 provides information about the PTM product (distributors, cost, etc.)**

Additional trials are planned for 2008 to refine treatment rates and timing, application depth and determine effects on second year trees.

Table 61: 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: ~$240 per bag (contains 1200 tablets); cost depends on quantity purchased.	RRS quote: ~$300 per gallon; 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	$90.00	$49.22
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; under development by Mr. Lane Day.
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: **Kioritz Soil Injector** (0.8 gallon capacity) $354.99 thru Amazon.com $365.00 thru treestuff.com $374.95 thru treecaresupplies.com $462.93 + shipping thru Rittenhouse.com **PTM Spot Gun** (1.2 gallon capacity) $88.00 thru feltonmedical.com
Recommended Quantity per Seedling	1 tablet	1.3 ml PTM + 13.7 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.

PTM & SilvaShield Labels and MSDS sheets

PTM Spot Gun