Forest Pest Management Cooperative

Report on

Research Accomplishments in 2008

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Forest Pest Management Cooperative
Report on Research Accomplishments in 2008

Executive Summary

The Forest Pest Management Cooperative (FPMC) made significant strides in 2008. A brief summary of FPMC activities is given below. Three primary research projects (systemic injection studies, tip moth impact/hazard/control, and leaf-cutting ant control) were continued from 2007. These projects contained twelve 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 2009 Project Proposals.

Several changes occurred in the membership of the FPMC in 2008. The Campbell Group and Rayonier joined as full members 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. Josh Sherrill (Executive), Ben Cazell (Plantation Contact) and Early McCall (Seed Orchard Contact) will represent Rayonier. In addition, ArborGen acquired International Paper's SuperTree Nurseries and Orchards in November 2007 and joined as an associate member in 2008. Shannon Stewart represents ArborGen on the Executive Committee. **Thank you all for your continued support!**

After two years with the Cooperative, Jason Helvey decided to move on. Billi Kavanagh has taken over the tip moth projects. William Upton, our staff forester, continued to manage the systemic insecticide injection and leaf-cutting ant trials. Staff Assistant Kyle Harrell and seasonal technician Nicolas Battise were hired to provide assistance with field and lab studies. Southern Pine Beetle Prevention Specialists Allen Smith, Mike Murphrey and Aleksandar Dozic 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 is always an important part of the FPMC. To this end, four issues of the *PEST* newsletter were prepared and distributed. Also, 6 presentations, 8 meeting requests, and 54 phone/e-mail requests were addressed relating to the following topics: leaf-cutting ants, pine tip moths, reproduction weevils, bark beetles (*Ips* engravers and mountain pine beetle), fall webworm, redheaded pine sawfly, scales, aphids and pine decline/pitch canker disease.

In 2008, rainfall generally was below normal in most of East Texas. Lufkin, which normally receives 46+ inches per year in rainfall, finished the year a little more than 5 inches below average. However, many locations across the South were within 4 inches of their annual average (Table 1). Several areas had a relatively short period of drought in August and September. Hurricanes Gustav and Ike caused considerable damage

Table 1: Total 2008 rainfall (inches) at locations across the South compared to annual average.

Location	2008	Average	Difference
Lufkin, TX	40.63	46.02	-5.39
Monticello, AR	51.58	55.33	-3.75
Alexandria, LA	57.02	61.44	-4.42
Jackson, MS	54.55	58.64	-4.09
Birmingham, AL	55.64	52.16	3.48
Macon, GA	48.14	45.00	3.14
Raleigh, NC	50.22	46.55	3.67
Columbia, SC	46.38	50.14	-3.76
Tallahassee, FL	60.28	63.21	-2.93

and losses ($92 million and $351 million) to forests in Louisiana and Texas, respectively.

Since the phase out of Volcano in 2003, efforts have been made to evaluate alternative ant baits (Blitz®, Amdro® and Advion®). Unfortunately, the small market for leaf-cutting ant baits and primary focus of insecticide producers 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 and private lands in Texas and Louisiana demands that an effective control option is found. Some progress 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 the FPMC conducted in East Texas showed that bait made from ground corn and of moderate size (3/32" in diameter) was attractive to the ants. Efficacy trials demonstrated that this bait was effective in completely halting ant activity on 80% of the treated colonies after 16 weeks. However, Dupont has again become disinterested because of the small market size and little additional progress was made in 2008.

Populations and damage caused by several defoliators, including red headed pine sawfly, 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 on second-year trees from 26% of shoots infested to 48%; several locations averaged 100% infested shoots by mid-summer. Due to a larger cone crop, coneworm and seed bug pressure declined somewhat in 2008 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 2008 (Table 2). Southern pine beetle populations declined on state and national forests in Alabama, Georgia, Mississippi, Virginia and Florida. On the other hand, SPB infestations increased slightly in North Carolina and South Carolina. The latest overall trend appears to be generally lower SPB activity. With the return of more normal rainfall, *Ips* engraver beetle populations declined in Alabama, Mississippi and Tennessee compared to 2007. In contrast, severe drought conditions in Georgia, North Carolina and South Carolina resulted in a dramatic increase in *Ips* populations during the spring and through late fall and caused considerable tree mortality.

Table 2: Southern pine beetle infestations by state, 2001 - 2008 and latest trend.

State	2000	2001	2002	2003	2004	2005	2006	2007	2008	Latest Trend
OK	0	0	0	0	0	0	0	0	0	Stable
AR	0	0	0	0	0	0	0	0	0	Stable
TX	0	0	0	0	0	0	0	0	0	Stable
LA	0	0	0	0	0	0	0	5	1	Stable
MS	809	143	689	65	158	92	50	208	31	Down
AL	26,407	11,849	4,991	206	1,434	1,791	1,286	765	222	Down
GA	2,682	4,938	9,070	333	73	0	0	2,077	115	Down
TN	9,883	12,746	6,394	1,294	257	5	14	39	1	Down
KY	1,664	3,456	NA	NA	0	0	0	0	0	Stable
VA	1,946	763	274	50	10	0	0	64	33	Down
FL	1,172	2,892	650	2	10	7	3	43	22	Down
SC	13,124	22,270	67,127	9,514	4,324	2,388	2,267	734	990	UP
NC	2,199	3,871	4,028	181	10	24	49	15	131	UP
Total	59,886	62,928	93,223	11,645	6,276	4,307	3,669	3,950	1,546	Down

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 was established in Texas in 2006 to evaluate the effects of treatment timing and dosage rate on chemical efficacy and duration. Other chemicals, including imidacloprid, nemadectin and cyfluthrin, also were tested. The 2006 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 2007 and 2008, particularly at higher rates. Also, we are interested in determining if these chemicals are effective against more aggressive *Dendroctonus* species. Trials established in 2005, 2006 and 2007 in Mississippi and Alabama for southern pine beetle 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 have been completed. Data from Mississippi, California and Alabama trials indicate that emamectin benzoate is highly effective in reducing tree mortality by bark beetles. Fipronil showed some good activity at these sites as well. In contrast, results from Idaho, Utah, and British Columbia 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 Mississippi and Alabama was accepted for publication in the Journal of Economic Entomology. A second manuscript based on results of trials in California, Idaho and Utah is in review.

Trials were established in two seed orchards in 2007 and monitored throughout 2008 to evaluate imidacloprid and dinotefuran alone or combined with emamectin benzoate and fipronil and their effects against pine seed bugs. The 2008 data indicated that both imidacloprid and dinotefuran continued to have some activity against seed bugs, but the addition of emamectin benzoate or fipronil did not enhance their effects. Neither imidacloprid nor dinotefuran appeared to have any appreciable activity against coneworms. Emamectin benzoate provided excellent protection against coneworms at both orchards. Syngenta submitted a registration package to EPA for emamectin benzoate in January 2008. The standard registration process takes 18 months, so we expect to receive a decision from EPA around July 2009.

The pine tip moth project, established in 2001, to evaluate the true impact of this insect pest 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 2008. One hundred and three impact plots on 72 sites are now established in the Western Gulf Region. An additional 15 hazard-rating plots were established in 2007, bringing the total to 135. 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. Bill Stansfield, The Campbell Group, has agreed to conduct a cost/benefit analysis for tip moth control. Unfortunately, little progress was made on the hazard-rating model in 2008. Mr. Andy Burrow, Potlatch Forest Holdings, will be unable to continue with the model's development. Dr. Dean Coble, Stephen F. Austin & State University, has agreed to assist us with model development.

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. Trials were established in 2007 to assess operational applications of fipronil by hand or machine planter, respectively. Hand application after planting is marginally effective, whereas applications of fipronil while machine planting continue to significantly reduce tip moth damage and improve tree growth during the second growing season in 2008. An additional trial was established in 2008 to assess the efficacy of fipronil applied at different depths to one-year old pine. Shallow (4î) fipronil applications provided slightly better protection compared to deeper (8î) applications. The trial established in 2007 on two sites to test the efficacy of fipronil applied to containerized seedlings prior to planting was continued in 2008. The effects were still very good, although not as outstanding as 2007. Because EPA is considering several other fipronil uses, BASF has postponed a request to modify the PTM label to include use on containerized seedlings.

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

TEXAS LEAF-CUTTING ANT

Bait Development and Evaluation - East Texas

Highlights:

- An efficacy trial was conducted in early 2008 to evaluate the efficacy of corn bait containing the highest rate (0.15%) of indoxacarb against the Texas leaf-cutting ant. This bait quickly shut down ant activity after 2 weeks. After 16 weeks >80% of the treated colonies were still inactive.

Justification: Amdro® Ant Block bait is the only product labeled for use against the Texas leaf-cutting ant bait (TLCA). 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 TLCA. DuPont had acquired TLCA bait recipes and a pellet mill from Griffin LLC and was willing to allow the FPMC to use it. The FPMC conducted several trials in 2007 to develop one or more formulations that combine indoxacarb with citrus pulp (orange and grapefruit) or corn and tested them for attractiveness and efficacy for the Texas leaf-cutting ant. Ultimately, corn bait containing 0.15% indoxacarb was found to be most attractive to leaf-cutting ants. In 2008, we evaluated the efficacy of this new bait for halting ant activity with a single application.

Objective: Evaluate the efficacy of new bait using indoxacarb and an attractive carrier (corn) for reducing activity in Texas leaf-cutting ant colonies.

Cooperators:

Dr. Phil Brown	DuPont, Wilmington, DE
Mr. Bob Cassell	Hancock Forest Management, Silsbee, TX
Mr. Bill Stansfield	Campbell Group, Diboll, TX
Mr. Mike Howard	Private landowner, San Augustine Co.
Mr. Rick Gay	Land Manager, Pine Island Club

Study Sites: Active colonies (32) were located in East Texas on lands owned by Campbell Group, Hancock Forest Management and private landowners.

Insecticide:

Indoxacarb – undetectable, slow-acting poison.

Experimental bait - citrus pulp pellets; packing (tight); color (light yellow); size (3 - 7 mm).

Research Approach:

Corn bait formulations were developed based on instructions DuPont provided. The corn and active ingredient were mixed, then bait pellets were formed using a DuPont laboratory pellet mill equipment provided.

The experiment was conducted in East Texas, within 75 miles of Lufkin. In this area, 32 Texas leaf-cutting ant colonies were selected. Those colonies larger than 30 m by 30 m, smaller than 3m by 3 m, adjacent to each other (within 100 m), and/or lacking a distinct central nest area were excluded from this study.

The central nest area (CNA) is defined as the aboveground portion of the nest, characterized by a concentration of entrance/exit mounds, surrounded by loose soil excavated by the ants (Cameron 1989). Scattered, peripheral entrance/exit and foraging mounds were not included in the central nest area. The application rate was based on the area (length X width) of the central nest. The treatments included:

1) Indoxacarb, 0.15% ai - bait was spread uniformly over CNA at 10.0 g/m^2 using a cyclone spreader
2) Check - untreated colonies

The number of active entrance/exit mounds was counted prior to treatment and periodically following treatment at 2, 4, 8 and 16 weeks. Seven 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:

In all, 22 colonies were treated with the indoxacarb/corn bait in February 2008. The bait was found to quickly reduced ant activity (97%) on treated colonies compared to initial activity within 2 weeks after treatment (Table 3). At this time (2 weeks), 82% (18 of 22) of the treatment colonies were completely inactive. Although two additional colonies went inactive after 4 weeks, they renewed activity by the 16-week post-treatment. Of the four colonies that were still active after 16 weeks, all had reduced activity compared to initial activity. This suggests that the bait was effective in killing some, but not all, of the queens in each colony.

Conclusions:

The efficacy trial showed that the 0.15% indoxacarb corn bait was very attractive to the ants and effective in halting ant activity within >80% of the treated colonies. Future work in 2009 should focus on: 1) evaluating the potential for reducing indoxacarb rate while maintaining good efficacy; 2) improving the integrity/strength of bait pellets by adding a “binder”; and 3) evaluating the storage life of the corn bait. However, DuPont has balked at further development, as the market size is insufficient to justify cost of registration and product development. The FPMC is still trying to convince them otherwise.

Acknowledgements: Thanks go to Campbell Group, Hancock Forest Management, and several private landowners who provided access to ant colonies. We appreciate the donation of indoxacarb formulation from DuPont, Wilmington, DE for the trial.

Table 2. Efficacy of indoxacarb baits applied to control the Texas leaf-cutting ant, *Atta texana* , in East Texas (Feb. - May 2008).

Treatment	No. of colonies treated	Mean central nest area (ft^2)	Mean # mounds at Trt	Mean % of initial activity[a] (% of colonies inactive after): 2 weeks	4 weeks	8 weeks	16 weeks
Indoxacarb Corn Pellet 0.15% AI	22	593	185	2.6 **a** (82)	2.0 **a** (91)	3.5 **a** (82)	5.4 **a** (82)
Check (no treatment)	7	572	149	94 **b** (0)	72.5 **b** (0)	92.8 **b** (0)	82.4 **b** (0)

[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 queen ants, 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, communications with several forest industries, TIMOs and private landowners continue to indicate that this bait is rarely effective in completely halting ant activity with a single application, let alone several applications.

Starting in 2007, DuPont Professional Products had provided some support to the FPMC in the form a laboratory pellet mill (acquired from Griffin LLC) and active ingredient (indoxacarb) to develop a new bait formulation specifically designed for leaf-cutting ants. After several trials, an effective bait (0.15% indoxacarb in a corn matrix) was discovered. However, upon evaluating the potential market size, DuPont decided the market was to small and they would not support the registration of the new bait.

The FPMC has been in communication with DuPont since May about different ways to move the development and registration of a bait. Unfortunately, little progress has been made. Possible options include:

1) Purchasing technical active ingredient from DuPont to develop our own bait formulation. The Texas Forest Service (TFS) would pursue a third-party registration for the bait. TFS would also build facilities and hire personnel to produce the bait.
2) A bait developed and produced in Latin America could be registered and imported into the US.
3) Take Dupont's AdvionÆ Fire Ant Bait (also contains indoxacarb), run it through the pellet mill to create a larger pellet that may be more attractive to leaf-cutting ants. The registration of this new bait (if effective) should be fairly simple.

Two other options are also being pursued. One is to modify the Amdro Ant Blockô bait into larger pellets. Ambrands has agreed to provide bait for modification. A trial is planned for early 2009 to test the modified bait. The indication from Ambrands is that registration of the modified bait would be simple since the active and inert ingredients are already registered for other species of ants (fire ants). The other option is to test soil injection of PTMô SC Insecticide (fipronil) solution into underground chambers or entrance holes within the central nest area. If this treatment proved to be effective, it would be a simple matter of adding leaf-cutting ants to the label as PTMô is already registered for soil injection.

SYSTEMIC INSECTICIDE INJECTION TRIALS

Potential Insecticides for Seed Bug Control in Pine Seed Orchards - Arkansas & Texas

Highlights:

- Tree IV injections of imidacloprid alone or combined with emamectin benzoate (EB) continued to significantly reduce seed bug damage on first and second-year cones during the second year after injection, but to a lesser extent compared to first year results.
- Tree IV injections of EB reduced coneworm damage by 88 - 95% at the slash orchard in Texas and by 69 – 92% at the loblolly orchard in Arkansas. Fipronil reduced coneworm damage in the loblolly orchard by 40 – 90%.

Justification: Trials conducted from 1998 – 2006 at Texas, Louisiana, Alabama and Florida 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) Continue evaluating 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:

I.N. Brown	Texas Forest Service, Magnolia Springs, TX
Mr. Steve Smith	Weyerhaeuser Company, Magnolia, AR
Dr. Tom Byram	Western Gulf Tree Improvement Program
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, 0.95 (3/8 in) in diameter and 5-8 cm (2-3 in) deep, were drilled about 30 cm above ground 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 tree 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 $\geq$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.

Results:

In 2007, four trees at the Magnolia orchard began exhibiting yellow needles on some (not all) branches in June, about two months after treatment. Interestingly, all trees were from the same clone and all had received the full rate of imidacloprid (0.4 g AI per inch DBH). None of the study trees exhibited phytotoxic symptoms in 2008.

The study orchard blocks at both orchards had 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, and 21% and 11% damage on check cones (Tables 6 & 7). In 2007, relatively high numbers of both leaffooted and shieldbacked pine seed bugs were observed in the trees at both orchards (Steve Smith and IN Brown, 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 8 & 9). Seed bug populations had declined in 2008, resulting in 29% and 47% damage on check cones in the slash pine and loblolly pine orchards, respectively.

Treatment Effect on Conelet and Cone Survival: Cones and conelets on tagged branches were examined in April and September 2007 and 2008. At both Magnolia Springs and Magnolia, all (or nearly all) treatments containing emamectin benzoate significantly improved survival of conelets compared to check trees in 2007 (Table 4 & 5). In contrast, none of the treatments improved survival of cones. In 2008, all (or nearly all) treatments containing emamectin benzoate significantly improved survival of cones compared to check trees at both Magnolia Springs and Magnolia (Table 4 & 5). In contrast, one treatment containing emamectin benzoate at each site improved survival of conelets.

Treatment Effect on Coneworm Damage: At Magnolia Springs in 2007, all injection treatments containing emamectin benzoate significantly reduced late, but not early, coneworm damage compared to the checks (Table 7 & 8). Overall, the emamectin benzoate treatments provided the greatest reductions in total coneworm damage (73 - 85%) compared to the check. 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 was the first time in 9 years of testing emamectin benzoate that this chemical did not reduced coneworm damage.

In 2008, at both sites, all injection treatments containing emamectin benzoate and fipronil (at Magnolia Springs, TX) significantly reduced late, but not early, coneworm damage compared to the checks (Table 7 & 8). Overall, the emamectin benzoate treatments provided the greatest reductions in total coneworm damage (69 - 95%) compared to the check (Figure 3). They also improved the percentage of healthy cones at Magnolia Springs. Fipronil reduced coneworm damage in the loblolly orchard by 40 – 90%. Neither imidacloprid nor dinotefuran alone had any apparent effect on coneworm damage.

Treatment Effect on Seed Bug Damage to First-Year Conelets: In 2007, 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 9). All, except imidacloprid alone, continued to protect conelets to early fall. At Magnolia, AR, 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 2007 (Table 8).

In 2008, evaluation of conelet ovules from Magnolia Springs showed that none of the treatments (injection or spray) improved the percentage of good ovules in conelets early in the year compare to checks (Table 9). Only the spray treatment protected conelets late in the summer. At Magnolia, only the treatment with imidacloprid plus emamectin benzoate reduced seed bug damage early and late in the season (Table 8).

Treatment Effect on Seed Bug Damage to Second-Year Cones: In 2007, 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 8). 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 8). Overall, reductions in seed bug damage for imidacloprid treatments ranged from 43 – 59%.

In 2008, analysis of seed lots from Magnolia Springs showed that none of the treatments (injection or spray) significantly reduced seed bug damage compared to checks (Table 9). However, all but dinotefuran + emamectin benzoate improved the number of filled (healthy) seed. Overall, reductions in seed bug damage ranged from 0 – 15%. Analysis of seed lots from Magnolia also showed that treatments containing full rates of imidacloprid significantly reduced seed damage compared to checks and improved the number of filled (healthy) seed (Table 8). Overall, reductions in seed bug damage for full imidacloprid treatments ranged from 28 – 39%.

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, AR and Magnolia Springs, TX, respectively (Table 10). 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%). In 2008, coneworms and seed bugs combined reduced the potential seed crops of check trees by 44% and 41% at Magnolia and Magnolia Springs, respectively (Table 10). All treatments reduced overall insect damage at Magnolia Springs, but imidacloprid + emamectin benzoate was most effective – reducing damage by 41%. At Magnolia, only treatments containing the full rate of imidacloprid were able to reduce overall insect damage (26 – 39%).

Conclusions: As expected, imidacloprid and dinotefuran were very effective and emamectin benzoate and fipronil were only marginally effective against pine seed bug in 2007. Both imidacloprid and dinotefuran, particularly when combined with emamectin benzoate, improved survival of first year conelets and number of filled seed per cone. Data collected in 2008 indicates that imidacloprid and dinotefuran provide only marginal protection in the second growing season.

As in past trials, the results obtained in 2007 and 2008 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, for reasons that remain unclear, neither emamectin benzoate nor fipronil had any effect against coneworms at the Magnolia orchard in 2007. A review of the procedures used to evaluate cones indicates that many of the “other” cones were inadvertently pooled with coneworm-damaged cones.

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Table 4. Mean percentages (± SE) of surviving conelets and cones on branches of loblolly pine pine protected with systemic injection of emamectin benzoate, fipronil or foliar treatments at Weyerhaeuser's Magnolia Seed Orchard, 2007 & 2008.

		Mean Survival (%)			
		Conelets		Cones	
Treatment	N	2007	2008	2007	2008
Imidacloprid (full)	6	76.9 + 10.3	95.5 + 1.2	62.9 + 12.7	85.7 + 3.6
Imidacloprid (half)	6	79.7 + 7.5	90.2 + 3.2	58.3 + 16.0	79.3 + 4.8
Imidacloprid (full) + Emamectin benzoate (full)	6	95.7 + 1.3 *	89.4 + 3.3	64.2 + 16.7	93.6 + 3.0 *
Imidacloprid (half) + Emamectin benzoate (half)	6	81.8 + 9.8	90.3 + 2.4	77.4 + 9.8	96.8 + 1.3 *
Imidacloprid (full) + Fipronil (full)	6	89.2 + 2.8 *	89.9 + 3.9	64.3 + 12.4	94.2 + 1.9 *
Imidacloprid (half) + Fipronil (half)	6	74.5 + 8.9	87.4 + 6.5	58.5 + 13.1	89.0 + 6.8 *
Emamectin benzoate (full)	6	92.9 + 1.8 *	88.8 + 3.9	76.4 + 8.5	91.2 + 6.1 *
Emamectin benzoate (half)	6	86.0 + 6.9 *	96.1 + 1.5 *	79.4 + 8.1 *	92.0 + 4.1 *
Fipronil (full)	6	74.6 + 5.8	91.4 + 3.2	68.2 + 6.5	89.4 + 4.2
Fipronil (half)	6	80.5 + 5.8	89.1 + 2.3	69.2 + 9.6	88.0 + 4.9
Check	6	70.8 + 6.8	88.6 + 2.5	63.8 + 10.2	77.7 + 6.6

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

Table 5. Mean percentages (± SE) of surviving conelets and cones on branches of slash pine protected with different systemic injection or foliar treatments at Texas Forest Service's Magnolia Springs Seed Orchard, TX, 2007 & 2008.

		Mean Survival (%)			
		Conelets		Cones	
Treatment	N	2007	2008	2007	2008
Imidacloprid	7	85.1 ± 4.0	89.3 ± 3.0	86.6 ± 4.8	88.4 ± 4.8
Imidacloprid + Emamectin benzoate	7	95.6 ± 1.9 *	95.4 ± 2.0	86.7 ± 10.7	95.6 ± 2.2 *
Dinotefuran	7	88.5 ± 4.6	90.4 ± 1.7	87.2 ± 4.4	89.1 ± 3.1
Dinotefuran + Emamectin Benzoate	7	91.7 ± 3.7 *	96.6 ± 1.5 *	89.5 ± 6.1	98.2 ± 0.7 *
Emamectin benzoate	7	95.4 ± 1.0 *	93.8 ± 1.5	90.2 ± 3.9	97.8 ± 0.8 *
Foliar Spray	7	83.4 ± 2.9	90.8 ± 2.7	82.8 ± 4.1	96.1 ± 1.8 *
Check	7	84.6 ± 2.0	91.0 ± 2.4	88.7 ± 2.9	84.7 ± 5.5

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

Table 6. Mean percentages (+ SE) of cones killed early and late by coneworms, other-damaged cones, and healthy cones on loblolly pine protected with systemic injections of imidacloprid (Imid), dinotefuran (Dino), emamectin benzoate (EB) or fipronil (FIP), Magnolia, AR, 2007 & 2008.

Year	Treatment	N	Mean Coneworm Damage (%)			Mean Other Damage (%) *	Mean Healthy (%)
			Early (small dead)	Late (large dead and infested)	Total		
2007	Imid (full)	6	6.7 ± 2.1 †	39.1 ± 7.9	45.8 ± 8.8	0.0 ± 0.0	54.2 ± 8.8
	Imid (half)	6	16.0 ± 7.4	40.2 ± 10.8	56.1 ± 16.4	0.3 ± 0.3	43.6 ± 16.5
	Imid + EB (full)	6	12.0 ± 8.2	37.5 ± 8.3	49.4 ± 12.7	0.1 ± 0.1	50.4 ± 12.8
	Imid + EB (half)	6	13.4 ± 8.1	43.0 ± 9.1	56.4 ± 13.7	0.0 ± 0.0	43.6 ± 13.7
	Imid + FIP (full)	6	6.6 ± 2.3	37.1 ± 8.2	43.5 ± 10.1	0.0 ± 0.0	56.4 ± 10.1
	Imid + FIP (half)	6	12.4 ± 5.3	44.1 ± 10.2	56.4 ± 13.1	0.0 ± 0.0	43.6 ± 13.1
	EB (full)	6	3.7 ± 1.4	47.4 ± 10.8	51.1 ± 12.0	0.0 ± 0.0	48.9 ± 12.0
	EB (half)	6	6.9 ± 3.5	37.9 ± 7.3	44.7 ± 8.6	0.1 ± 0.1	55.2 ± 8.6
	FIP (full)	6	8.7 ± 3.2	42.2 ± 8.5	50.9 ± 10.3	0.0 ± 0.0	49.1 ± 10.3
	FIP (half)	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
2008	Imid (full)	6	3.2 ± 1.2	6.2 ± 2.5	9.5 ± 3.1	18.6 ± 7.0	71.9 ± 5.1
	Imid (half)	6	5.3 ± 1.3	8.9 ± 2.0	14.2 ± 2.1	18.7 ± 7.0	67.1 ± 7.8
	Imid + EB (full)	6	1.4 ± 1.2	1.9 ± 0.9 *	3.3 ± 1.6 *	17.9 ± 6.6	78.8 ± 8.1
	Imid + EB (half)	6	0.1 ± 0.1	0.8 ± 0.4 *	0.9 ± 0.5 *	14.5 ± 8.4	84.6 ± 8.4 *
	Imid + FIP (full)	6	0.2 ± 0.2	1.3 ± 0.5 *	1.5 ± 0.7 *	15.6 ± 7.1	82.9 ± 7.7
	Imid + FIP (half)	6	4.1 ± 3.8	2.3 ± 0.7 *	6.4 ± 4.2	13.4 ± 7.1	80.2 ± 11.2
	EB (full)	6	0.4 ± 0.3	1.4 ± 0.5 *	1.9 ± 0.8 *	20.2 ± 8.7	78.0 ± 8.6
	EB (half)	6	0.1 ± 0.1	1.7 ± 1.1 *	1.8 ± 1.1 *	21.1 ± 8.3	77.2 ± 7.9
	FIP (full)	6	0.1 ± 0.1	0.9 ± 0.5 *	1.1 ± 0.5 *	18.4 ± 4.3	80.6 ± 4.5
	FIP (half)	6	0.6 ± 0.5	1.4 ± 0.8 *	1.9 ± 1.3 *	18.7 ± 4.3	79.3 ± 5.9
	Check	6	1.7 ± 0.7	9.0 ± 3.1	10.7 ± 3.6	15.3 ± 7.2	74.1 ± 6.3

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

Table 7. Mean percentages (+ SE) of cones killed early and late by coneworms, other-damaged cones, and healthy cones on loblolly pine protected with systemic injections of imidacloprid (Imid), dinotefuran (Dino), emamectin benzoate (EB) or fipronil (FIP), Magnolia Springs, TX, 2007 & 2008.

			Mean Coneworm Damage (%)				
Year	Treatment	N	Early (small dead)	Late (large dead and infested)	Total	Mean Other Damage (%) *	Mean Healthy (%)
2007	Imid	7	2.3 ± 1.2	13.7 ± 2.6	16.1 ± 2.6	11.1 ± 3.3	72.8 ± 4.1
	Imid + EB	7	1.8 ± 1.0	2.4 ± 0.7 *	4.2 ± 0.9 *	8.7 ± 1.7	87.1 ± 2.0 *
	Dino	7	2.9 ± 0.9	6.2 ± 0.9 *	9.1 ± 1.5	5.9 ± 1.6	85.0 ± 2.6
	Dino + EB	7	0.9 ± 0.5	3.3 ± 1.1 *	4.2 ± 1.2 *	9.3 ± 1.4	86.5 ± 1.8
	EB	7	0.8 ± 0.5	1.7 ± 0.8 *	2.4 ± 1.2 *	7.1 ± 1.6	90.4 ± 2.0 *
	Spray	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
2008	Imid	7	0.6 ± 0.4	17.0 ± 5.1	17.6 ± 5.2	4.4 ± 1.4	78.0 ± 4.1
	Imid + EB	7	0.6 ± 0.3	1.1 ± 0.4 *	1.7 ± 0.5 *	7.6 ± 3.4	90.7 ± 3.2 *
	Dino	7	0.7 ± 0.4	11.2 ± 3.6	11.9 ± 3.9	6.3 ± 2.1	81.7 ± 5.9
	Dino + EB	7	0.1 ± 0.1	0.6 ± 0.3 *	0.7 ± 0.3 *	10.1 ± 4.6	89.2 ± 4.4 *
	EB	7	0.3 ± 0.2	0.5 ± 0.3 *	0.8 ± 0.3 *	4.1 ± 1.5	95.1 ± 1.4 *
	Spray	7	1.0 ± 0.7	12.9 ± 3.2	14.0 ± 3.4	10.9 ± 3.9	75.1 ± 5.9
	Check	7	1.1 ± 0.4	19.5 ± 4.2	20.5 ± 4.6	7.6 ± 2.0	71.9 ± 6.1

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

Table 8. Seed bug damage, seed extracted, and seed quality (Mean + SE) from first- and second-year cones of loblolly pine protected with systemic injections of full and half rates of Imidacloprid (Imid), emamectin benzoate (EB) and/or fiprinil (FIP), Magnolia, AR, 2007 & 2008.

Year	Treatment	N	Mean Seed Bug Damage (%) to: First-year Conelet Ovules: Early (July)	First-year Conelet Ovules: Late (Sept.)	Second-year Cone Seed: Early (2nd Yr Abort)	Second-year Cone Seed: Late	Second-year Cone Seed: Total	Mean No. Filled Seed per Cone
2007	Imid (full)	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)	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)	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)	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)	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)	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)	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)	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)	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)	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
2008	Imid (full)	5	8.4 ± 2.5	12.6 ± 3.2	7.8 ± 3.1 *	21.1 ± 3.3 *	28.9 ± 3.2 *	72.1 ± 10.3
	Imid (half)	5	8.4 ± 2.8	17.9 ± 6.4	13.3 ± 2.8	29.6 ± 5.6	43.0 ± 5.6	50.7 ± 4.6
	Imid + EB (full)	5	6.6 ± 2.9	4.8 ± 2.2 *	6.8 ± 1.3 *	23.0 ± 3.0	29.8 ± 2.6 *	74.9 ± 10.9 *
	Imid + EB (half)	5	1.3 ± 1.1 *	12.1 ± 5.0	14.8 ± 2.2	26.2 ± 2.9	41.0 ± 4.5	61.1 ± 7.4
	Imid + FIP (full)	5	9.5 ± 4.1	15.0 ± 3.8	13.1 ± 5.5	20.9 ± 3.4 *	33.9 ± 4.5	64.4 ± 10.6
	Imid + FIP (half)	5	6.1 ± 2.9	9.9 ± 4.3	12.9 ± 2.6	24.6 ± 3.6	37.5 ± 4.5	57.9 ± 5.7
	EB (full)	5	1.7 ± 0.9	13.9 ± 5.0	9.4 ± 0.9	35.5 ± 5.0	44.9 ± 4.8	59.5 ± 5.9
	EB (half)	6	1.9 ± 1.2	15.9 ± 2.8	18.1 ± 3.8	23.2 ± 4.3	41.3 ± 6.7	54.4 ± 6.1
	FIP (full)	6	13.5 ± 6.1	18.2 ± 3.4	23.2 ± 5.4	24.2 ± 4.8	47.4 ± 8.4	39.3 ± 9.1
	FIP (half)	6	10.5 ± 4.2	13.7 ± 6.8	18.3 ± 3.0	25.1 ± 3.8	43.4 ± 5.2	48.1 ± 7.6
	Check	5	7.5 ± 2.8	18.0 ± 6.3	18.5 ± 6.1	28.6 ± 4.3	47.1 ± 8.3	44.3 ± 8.6

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

Table 9. 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), Magnolia Springs, TX, 2007 & 2008.

			Mean Good Ovules per Conelet (%)		Mean Seed Bug Damage (%)			Mean No. Filled Seed per Cone
Year	Treatment	N	Early (July)	Late (Sept.)	Early (2nd Yr Abort)	Late	Total	
2007	Imid	7	96.1 ± 1.8 *	86.4 ± 4.7	14.8 ± 8.3	15.5 ± 2.7 *	30.3 ± 8.9 *	41.4 ± 9.6
	Imid + EB	7	97.7 ± 1.6 *	97.9 ± 0.9 *	14.3 ± 7.2	17.7 ± 3.9 *	32.0 ± 8.9 *	45.1 ± 10.0
	Dino	7	95.4 ± 2.1 *	91.1 ± 4.0 *	13.3 ± 6.2	20.0 ± 2.4	33.3 ± 7.2 *	39.2 ± 9.2
	Dino + EB	7	96.4 ± 2.1 *	97.1 ± 0.8 *	9.9 ± 5.9 *	18.2 ± 3.2 *	28.1 ± 7.9 *	48.2 ± 7.4 *
	EB	7	91.5 ± 2.9 *	94.7 ± 2.1 *	16.0 ± 6.7	26.5 ± 2.7	42.5 ± 7.7	40.0 ± 6.6
	Spray	7	92.9 ± 1.9 *	95.3 ± 1.8 *	12.1 ± 3.0	22.8 ± 4.8	34.8 ± 6.1 *	43.8 ± 7.2
	Check	7	82.8 ± 2.5	82.8 ± 4.1	19.8 ± 9.2	25.6 ± 5.3	45.4 ± 9.0	34.2 ± 7.1
2008	Imid	7	91.3 ± 4.1	89.8 ± 3.4	6.5 ± 2.5	18.7 ± 3.0	25.2 ± 4.4	92.1 ± 9.2 *
	Imid + EB	7	98.2 ± 1.4	90.4 ± 1.9	5.7 ± 2.5	18.6 ± 3.3	24.3 ± 4.7	98.5 ± 9.0 *
	Dino	7	96.8 ± 1.4	93.8 ± 3.4	6.7 ± 3.1	21.2 ± 2.9	27.9 ± 5.3	95.9 ± 12.6 *
	Dino + EB	7	99.0 ± 0.6	89.9 ± 2.7	4.9 ± 1.5	25.8 ± 5.1	30.7 ± 6.0	80.1 ± 12.6
	EB	7	97.7 ± 1.5	94.5 ± 2.7 *	7.1 ± 3.4	20.5 ± 2.5	27.6 ± 5.1	88.9 ± 9.6 *
	Spray	7	98.1 ± 1.8	95.2 ± 3.0 *	5.0 ± 2.1	23.4 ± 4.3	28.4 ± 5.2	69.5 ± 8.8
	Check	7	97.7 ± 1.1	83.6 ± 6.1	7.5 ± 3.2	21.2 ± 3.7	28.7 ± 6.1	70.9 ± 9.3

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

Table 10. 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), 2007 & 2008.

					2007		2008	
Tree Spp.	Site	Treatment	Application Technique, Treatment Date(s)	N	Mean Combined Losses (%)	Mean Reduction (%)	Mean Combined Losses (%)	Mean Reduction (%)
Loblolly pine	AR	Imid (full)	Tree IV - Apr., '07	6	63.2 + 4.5 *	21.7	29.8 + 3.6 *	32.9
		Imid (half)	Tree IV - Apr., '07	6	75.0 + 8.0	7.1	42.2 + 4.0	5.0
		Imid + EB (full)	Tree IV - Apr., '07	6	64.8 + 8.9 *	19.7	26.9 + 2.5 *	39.4
		Imid + EB (half)	Tree IV - Apr., '07	6	67.9 + 5.3	15.9	35.2 + 4.7	20.7
		Imid + FIP (full)	Tree IV - Apr., '07	6	58.3 + 7.6 *	27.8	30.5 + 5.2 *	31.3
		Imid + FIP (half)	Tree IV - Apr., '07	6	75.1 + 6.4	6.9	35.8 + 3.9	19.4
		EB (full)	Tree IV - Apr., '07	6	74.5 + 5.9	7.7	37.1 + 6.0	16.1
		EB (half)	Tree IV - Apr., '07	6	71.2 + 5.9	11.8	33.0 + 5.2 *	25.7
		FIP (full)	Tree IV - Apr., '07	6	76.9 + 6.3	4.7	38.0 + 4.9	14.4
		FIP (half)	Tree IV - Apr., '07	6	78.4 + 4.7	2.9	36.5 + 4.4	17.8
		Check		6	80.7 + 5.2		44.4 + 5.4	
Slash pine	TX	Imid	Tree IV - Apr., '07	7	39.0 + 7.1 *	21.5	38.6 + 2.5	6.8
		Imid + EB	Tree IV - Apr., '07	7	32.6 + 7.4 *	34.4	24.2 + 4.9 *	41.6
		Dino	Tree IV - Apr., '07	7	37.0 + 6.2 *	25.6	35.0 + 4.8	15.5
		Dino + EB	Tree IV - Apr., '07	7	28.7 + 6.1 *	42.3	28.8 + 6.4 *	30.4
		EB	Tree IV - Apr., '07	7	40.3 + 6.4 *	18.9	26.9 + 5.0 *	35.0
		Spray	Hydraulic - 2X	7	40.6 + 4.3 *	18.3	35.4 + 5.6	14.5
		Check		7	49.7 + 7.2		41.4 + 5.4	

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

SYSTEMIC INSECTICIDE INJECTION TRIALS

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

Highlights:

- The FPMC continued to evaluate the efficacy of formulations of fipronil, emamectin benzoate, and nemadectin and a new chemical, abamectin, 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 34 months after injections. The efficacy of lower concentrations (>0.4 g AI/inch DBH) began to fade after 20 months.
- Fipronil continued to fade and provided very limited protection at high rate against *Ips* engraver beetles and wood borers 34 months after injections.
- High rates (0.4 g AI/inch DBH) of nemadectin were still highly effective against *Ips* engraver beetles 28 months after injection.
- Both rates (0.4 and 0.8 g AI/inch DBH) of abamectin applied in the spring were highly effective against *Ips* engraver beetles and wood borers 5 months after injection.

Justification: In 2004 and 2005, the FPMC conducted injection trials in East Texas to evaluate the potential efficacy of the systemic insecticides emamectin benzoate 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 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 treatments. Additional chemical products, including nemadectin (Fort Dodge Animal Health) and abamectin (Mauget) are 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, nemadectin, and abamectin in reducing colonization success of pine engraver beetles and wood borers on loblolly pine; 2) evaluate the chemicals applied at different timings and dosage rates using Arborjet's Tree IV™ pressurized injection system; and 3) determine the duration of treatment efficacy.

Cooperators:

Mr. 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
Ms. Marianne Waindle	Mauget, Arcadia, CA
Mr. Joseph Doccola	Arborjet, Inc., Worchester, MA

Study Sites: Two 20-year-old, recently thinned loblolly pine plantations were selected on land owned by Rayonier about 10 miles east of Lufkin, 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 (Ava-jet™, Arborjet Inc.) – 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*

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

Treatments:

Trial 1: 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 2: Established April 2008

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

Treatment Methods and Evaluation:

Trial 1: 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 to the laboratory. Phloem tissue (50 g) was collected from each emamectin benzoate- and fipronil-treated bolt. Xylem tissue (50 g) was also collected from the emamectin benzoate-treated bolts. All samples were temporarily placed in a freezer before being sent in dry ice to either the Syngenta or BASF laboratory. In 2007 and 2008, a second and third series, respectively, of plant tissues (phloem and xylem from 5m and 1st and 2nd year foliage) were collected from each emamectin benzoate tree. All samples were sent to Syngenta's laboratory in Greensboro, NC, for analysis of chemical concentrations.

Trial 2: Loblolly pine trees (240), 15 – 20 cm DBH, were selected in April 2008. Thirty - forty trees were each injected with one of two treatments: abamectin (April and October 2008), or fipronil (October 2008) at two different rates (0.4g or 0.8g per 1 inch of tree diameter). Each injection treatment (1 - 6) consisted of a single insecticide formulation injected into four cardinal points about 0.3 m above the ground on each tree using the Arborjet Tree IV™.

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

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

Each series of bolts was retrieved about 3 weeks after deployment, after 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.

In 2008, data was also collected for:
6) Number of bark beetle emergence holes on the bark surface.
7) Percent of bark sample with bark beetle activity, estimated by overlaying a 100 cm^2 grid on the underside of each bark strip and counting the number of squares where bark beetle adult and larvae had fed.
8) Number ambrosia beetle entrance hole in the xylem.

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: Timing, Rate & Concentration in Tissue:

Ips Attack Success – In 2007, 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 11). Most (90%) 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 treatments had significantly fewer nuptial chambers with egg galleries (Tables 11, 15 & 19). Nearly all treatments reduced the total number and length of egg galleries compared to check trees (Tables 12, 13, 16, 17, 20 & 21). However, emamectin benzoate continued to provide the best overall protection against bark beetles compared to the other treatments.

In 2008, after more than two years (28 – 34 months), the total number of attacks (nuptial chambers constructed) by male *Ips* engraver beetles did not differ among the treatments (Table 11). In this third series, less than half (47%) of the nuptial chambers were successfully constructed on untreated bolts - with at least one egg gallery radiating from each nuptial chamber. As a result, none of the treatments had significantly fewer nuptial chambers with egg galleries (Tables 11, 15 & 19). All emamectin benzoate treatments and the high rate fipronil and nemadectin reduced the total number and length of egg galleries compared to check trees (Tables 12, 13, 16, 17, 20 & 21). Emamectin benzoate continued to provide the best overall protection against bark beetles compared to the other treatments.

Cerambycid Larval Feeding – In 2007, the attack level of wood borers (egg niches) on logs from injected trees was often significantly greater than that on check logs (Table 14, 18 & 22). Relatively little cerambycid feeding (20%) occurred on untreated bolts during the 3 weeks period between tree felling and bolt evaluation (Table 14, 18 & 22). All emamectin benzoate treatments and the high rate nemadectin treatment 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.

In 2008, the attack level of wood borers (egg niches) on logs from injected trees did not differ from that on check logs (Table 17, 21 & 25). Relatively little cerambycid feeding (14%) occurred on untreated bolts during the 3-week period between tree felling and bolt evaluation (Table 14, 18 & 22). All emamectin benzoate treatments and the high rate nemadectin treatment 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: - Plant tissue samples were collected from emamectin benzoate trees in 2006, 2007 & 2008. The 2006 & 2007 have been analyzed, but Syngenta has been reluctant to release the data. The 2008 emamectin benzoate samples are to be analyzed in the near future.

Trial 2: Abamectin formulation:
Ips Attack Success – The total number of attacks (nuptial chambers constructed) by male *Ips* engraver beetles did not differ among the treatments (Table 23). Most (87%) of the nuptial chambers were successfully constructed on untreated bolts - with at least one egg gallery radiating from each nuptial chamber. In contrast, both abamectin treatments had significantly fewer nuptial chambers with egg galleries (Tables 23). Both treatments completely prevented brood development compared to check trees (Tables 24 & 25).

Cerambycid Larval Feeding – The attack level of wood borers (egg niches) on logs from injected trees did not differ from that on check logs (Table 26). Relatively little cerambycid feeding (10%) occurred on untreated bolts during the 3 weeks period between tree felling and bolt evaluation (Table 17, 21 & 25). Both abamectin treatments reduced the amount of larval feeding and development compared to the check.

Conclusions:

Trial 1 continues to show that emamectin benzoate is highly effective in preventing successful attacks by *Ips* bark beetles and cerambycids 28 and 34 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 12 & 13).

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 2 revealed that abamectin was highly effective against bark beetles and wood borers. No significant difference in the efficacy of abamectin at the two rates was observed 5 months after injection.

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Table 11: Attack success and gallery construction of *Ips* engravers beetles on loblolly pine bolts cut 2 - 30 months after Fall (Oct.) and Spring (May) trunk injections with different rates of emamectin benzoate; Lufkin, TX, 2006, 2007 & 2008.

Evaluation period	Season/Yr. Injected	Treatment	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
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
28 Months Post-Injection (Sept. '08)	Spring 2006	EB 0.016g	7.4 *	78.7	2.0	21.3	9.4
		EB 0.08g	4.2	92.7	0.3	7.3	4.6
		EB 0.4g	6.0	98.4	0.1 *	1.6	6.1
34 Months Post-Injection (Sept. '08)	Fall 2005	EB 0.016g	7.6	81.0	1.8	19.1	9.3
		EB 0.08g	7.9 *	94.0	0.5	6.0	8.4
		EB 0.4g	9.0 *	67.7	4.3	32.3	13.3
		Check	2.0	53.3	1.8	46.7	3.8

* 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 12: Mean number of egg galleries constructed by *Ips* engravers beetles in loblolly pine bolts cut 2 - 30 months after Fall (Oct.) and Spring (May) trunk injections with different rates of emamectin benzoate; Lufkin, TX, 2006, 2007 & 2008.

			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
28 Months Post-Injection (Sept. '08)	Spring 2006	EB 0.016g	2.5	95.2	0.1 *	4.8	2.6
		EB 0.08g	0.3	100.0	0.0 *	0.0	0.3
		EB 0.4g	0.1	100.0	0.0 *	0.0	0.1 *
34 Months Post-Injection (Sept. '08)	Fall 2005	EB 0.016g	3.2	96.7	0.1 *	3.3	3.3
		EB 0.08g	0.8	72.7	0.3 *	27.3	1.1
		EB 0.4g	4.7	97.9	0.1 *	2.1	4.8
		Check	0.5	16.7	2.5	83.3	3.0

* 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 13: Mean length of egg galleries constructed by *Ips* engravers beetles in loblolly pine bolts cut 2 - 30 months after Fall (Oct.) and Spring (May) trunk injections with different rates of emamectin benzoate; Lufkin, TX, 2006, 2007 & 2008.

			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
28 Months Post-Injection (Sept. '08)	Spring 2006	EB 0.016g	7.9	95.5	0.4 *	4.5	8.3 *
		EB 0.08g	1.3	100.2	0.0 *	0.0	1.3 *
		EB 0.4g	0.4	100.0	0.0 *	0.0	0.4 *
34 Months Post-Injection (Sept. '08)	Fall 2005	EB 0.016g	7.4	93.1	0.6 *	7.0	8.0 *
		EB 0.08g	4.3	81.1	1.0 *	18.9	5.3 *
		EB 0.4g	11.8	95.9	0.5 *	4.1	12.3 *
		Check	6.5	23.6	21.0	76.4	27.5

* 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: Extent of feeding by cerambycid larvae in loblolly pine bolts cut 2 - 30 months after Fall (Oct.) and Spring (May) trunk injections with different rates of emamectin benzoate; Lufkin, TX, 2006, 2007 & 2008.

Evaluation period	Season/Yr. Injected	Treatment	No. of egg niches on bark	% phloem area consumed by larvae	No. of bark beetle emergence holes on bark	% phloem area colonized by bark beetles	No. of ambrosia beetle entrance holes in xylem
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			
28 Months Post-Injection (Sept. '08)	Spring 2006	EB 0.016g	6.1	1.6 *	9.7 *	9.5 *	2.0
		EB 0.08g	6.9	0.0 *	0.0 *	0.1 *	0.6
		EB 0.4g	7.1	0.4 *	0.0 *	0.1 *	0.6
34 Months Post-Injection (Sept. '08)	Fall 2005	EB 0.016g	5.9	1.0 *	2.3 *	8.0 *	3.2
		EB 0.08g	6.7	1.6 *	0.1 *	0.1 *	1.6
		EB 0.4g	6.4	1.1 *	1.2 *	3.2 *	3.6
		Check	5.7	14.1	65.9	30.1	1.7

* 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 15: Attack success and gallery construction of *Ips* engravers beetles on loblolly pine bolts cut 8, 20 & 30 months after Fall (Oct. 2005) trunk injection, with different rates fipronil; Lufkin, TX, 2006, 2007 & 2008.

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 2006)	BAS 350UB 0.02g	3.6	69.2	1.6	30.8	5.2
	BAS 350UB 0.1g	3.3	49.3	3.4	50.7	6.7
	BAS 350UB 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 2007)	BAS 350UB 0.02g	1.2	23.1	4.0 *	76.9	5.2
	BAS 350UB 0.1g	3.4 *	40.5	5.0	59.5	8.4
	BAS 350UB 0.4g	3.3 *	44.0	4.2 *	56.0	7.5
	Check	0.9	10.3	7.8	89.7	8.7
Fall (Oct) / 34 Months Post-Injection (Sept. 2008)	BAS 350UB 0.02g	5.3 *	57.1	4.0	42.9	9.3
	BAS 350UB 0.1g	3.0	44.7	3.7	55.3	6.7
	BAS 350UB 0.4g	2.7	70.4	1.1	29.6	3.9
	Check	2.0	53.3	1.8	46.7	3.8

* 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: Mean number of egg galleries constructed by *Ips* engravers beetles in loblolly pine bolts cut 8, 20 & 34 months after Fall (Oct. 2005) trunk injection with different rates fipronil; Lufkin, TX, 2006, 2007 & 2008.

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)	BAS 350UB 0.02g	1.0 *	50.0	1.0 *	50.0	2.0 *
	BAS 350UB 0.1g	4.1	62.1	2.5 *	37.9	6.6
	BAS 350UB 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)	BAS 350UB 0.02g	8.8	64.7	4.8 *	35.3	13.6
	BAS 350UB 0.1g	7.8	69.0	3.5 *	31.0	11.3
	BAS 350UB 0.4g	6.1	81.3	1.4 *	18.7	7.5 *
	Check	5.7	24.4	17.7	75.6	23.4
Fall (Oct) / 34 Months Post-Injection (Sept. 2008)	BAS 350UB 0.02g	2.3	30.4	5.3	69.6	7.7
	BAS 350UB 0.1g	2.3	28.6	5.7	71.4	8.0
	BAS 350UB 0.4g	2.0	82.3	0.4	17.7	2.4
	Check	0.5	16.7	2.5	83.3	3.0

* 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: Mean length of egg galleries constructed by *Ips* engravers beetles in loblolly pine bolts cut 8, 20 & 34 months after Fall (Oct. 2005) trunk injection with different rates fipronil; Lufkin, TX, 2006, 2007 & 2008.

Injection season / Evaluation period	Treatment	Length of egg galleries: Without larvae cm	Without larvae % of Total	With larvae cm	With larvae % of Total	Total length
Fall (Oct) / 8 Months Post-Injection (July 2006)	BAS 350UB 0.02g	4.3 *	32.3	9.0 *	67.7	13.3 *
	BAS 350UB 0.1g	9.1	53.8	7.8 *	46.2	16.9 *
	BAS 350UB 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)	BAS 350UB 0.02g	38.7	53.7	33.4 *	46.3	72.1 *
	BAS 350UB 0.1g	31.2	61.2	19.9 *	39.0	51.0 *
	BAS 350UB 0.4g	28.6	82.4	6.1 *	17.6	34.7 *
	Check	39.9	22.6	136.7	77.4	176.6
Fall (Oct) / 34 Months Post-Injection (Sept. 2008)	BAS 350UB 0.02g	5.7	29.8	13.3	70.2	19.0
	BAS 350UB 0.1g	11.9	47.7	13.0 *	52.3	24.9
	BAS 350UB 0.4g	5.0	81.4	1.1 *	18.6	6.1
	Check	6.5	23.6	21.0	76.4	27.5

* 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: Extent of feeding by cerambycid larvae in loblolly pine bolts cut 8, 20 and 34 months after Fall (Oct. 2005) trunk injection with different rates fipronil; Lufkin, TX, 2006, 2007 & 2008.

Injection season / Evaluation period	Treatment	No. of egg niches on bark	% phloem area consumed by larvae	No. of bark beetle emergence holes on bark	% phloem area colonized by bark beetles	No. of ambrosia beetle entrance holes in xylem
Fall (Oct) / 8 Months Post-Injection (July 2006)	BAS 350UB 0.02g	4.0	4.6			
	BAS 350UB 0.1g	6.4	3.3 *			
	BAS 350UB 0.4g	9.9	0.9 *			
	Check	6.6	8.1			
Fall (Oct) / 20 Months Post-Injection (July 2007)	BAS 350UB 0.02g	12.8 *	26.5			
	BAS 350UB 0.1g	17.7 *	28.4			
	BAS 350UB 0.4g	13.6 *	15.7			
	Check	7.1	19.6			
Fall (Oct) / 34 Months Post-Injection (Sept. 2008)	BAS 350UB 0.02g	5.2	12.1	62.0	38.0	2.0
	BAS 350UB 0.1g	4.1	3.6	5.4 *	9.3	1.5
	BAS 350UB 0.4g	5.8	6.0	29.6	14.0	2.6
	Check	5.7	14.1	65.9	30.1	1.7

* 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 19: Attack success and gallery construction of *Ips* engravers beetles on loblolly pine bolts cut 2, 14 & 28 months after Spring (May 2006) trunk injection with different rates of nemadectin; Lufkin, TX, 2006, 2007 & 2008.

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 2006)	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 2007)	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
Spring (May) / 28 Months Post-Injection (Sept. 2008)	Nemadectin 0.02g	2.5	45.5	3.0	54.5	5.5
	Nemadectin 0.1g	4.0	78.3	1.1	21.7	5.1
	Nemadectin 0.4g	3.7	82.2	0.8	17.8	4.5
	Check	2.0	53.3	1.8	46.7	3.8

* 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: Mean number of egg galleries constructed by *Ips* engravers beetles in loblolly pine bolts cut 2, 14 & 28 months after Spring (May 2006) trunk injection with different rates of nemadectin; Lufkin, TX, 2006, 2007 & 2008.

		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 2006)	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 2007)	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
Spring (May) / 28 Months Post-Injection (Sept. 2008)	Nemadectin 0.02g	1.0	20.0	4.0	80.0	5.0
	Nemadectin 0.1g	1.4	92.5	0.1 *	7.1	1.6
	Nemadectin 0.4g	0.9 *	64.3	0.5 *	35.7	1.4
	Check	0.5	16.7	2.5	83.3	3.0

* 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: Mean length of egg galleries constructed by *Ips* engravers beetles in loblolly pine bolts cut 2, 14 or 28 months after Spring (May 2006) trunk injection with different rates of nemadectin; Lufkin, TX, 2006, 2007 & 2008.

		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 2006)	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 2007)	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
Spring (May) / 28 Months Post-Injection (Sept. 2008)	Nemadectin 0.02g	6.0	18.2	27.0	81.8	33.0
	Nemadectin 0.1g	3.9	85.4	0.7 *	14.6	4.6 *
	Nemadectin 0.4g	2.6	52.0	2.4 *	48.0	5.0 *
	Check	6.5	23.6	21.0	76.4	27.5

* 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 22: Extent of feeding by cerambycid larvae in loblolly pine bolts cut 2, 14 & 28 months after Spring (May 2006) trunk injection with different rates of nemadectin; Lufkin, TX, 2006, 2007 & 2008.

Injection season / Evaluation period	Treatment	No. of Borer egg niches on bark	% phloem area consumed by borer larvae	No. of bark beetle emergence holes on bark	% phloem area colonized by bark beetles	No. of ambrosia beetle entrance holes in xylem
Spring (May) / 2 Months Post-Injection (July 2006)	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 2007)	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			
Spring (May) / 28 Months Post-Injection (Sept. 2008)	Nemadectin 0.02g	7.8	15.9	99.2	41.2	3.9
	Nemadectin 0.1g	7.8	7.7	10.8 *	4.5 *	0.4
	Nemadectin 0.4g	5.2	3.8 *	0.6 *	0.5 *	0.5
	Check	5.7	14.1	65.9	30.1	1.7

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

				Mean # of nuptial chambers without egg galleries		Mean # of nuptial chambers with egg galleries		
Evaluation period	Chemical	Rate	N	No.	% of total	No.	% of total	Mean total # of nuptial chambers
5 month Post-Injection (Sept)	Abamectin	High (0.8 g AI = 40ml / "dbh)	11	4.2 *	94	0.3 *	6	4.5
	Abamectin	Low (0.4 g AI = 20ml / "dbh)	9	3.3 *	79	0.9 *	21	4.2
		Check	11	0.6	13	4.2	87	4.8

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

Table 24: Mean number of egg galleries constructed by *Ips* engravers beetles (per 1000 cm^2) in loblolly pine bolts cut 5 months after trunk injection with abamectin using the Tree IV injection system; Lufkin, Texas - 2008.

				Number of egg galleries				
				Without larvae		With larvae		
Evaluation period	Chemical	Rate	N	No.	% of total	No.	% of Total	Total #
5 Month Post-Injection (Sept. 2008)	Abamectin	High (0.8 g AI = 40ml / "dbh)	11	0.2 *	100	0.0 *	0	0.2 *
	Abamectin	Low (0.4 g AI = 20ml / "dbh)	9	1.2	100	0.0 *	0	1.2 *
		Check	11	1.5	18	6.6	82	8.1

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

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

				Length of egg galleries				
				Without larvae		With larvae		
Evaluation period	Chemical	Rate	N	cm	% of Total	cm	% of Total	Total length
5 Month Post-Injection (Sept. 2008)	Abamectin	High (0.8 g AI = 40ml / "dbh)	11	0.5 *	100	0.0 *	0	0.5 *
	Abamectin	Low (0.4 g AI = 20ml / "dbh)	9	3.9	100	0.0 *	0	3.9 *
		Check	11	8.5	10	74.0	90	82.5

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

Table 26: Extent of feeding by cerambycid larvae (per 1000 cm^2) in loblolly pine bolts cut 5 months after trunk injection with abamectin using the Tree IV injection systems; Lufkin, Texas - 2008.

Evaluation Period	System	Rate	N	No of cerambycid egg niches on bark	Percent phloem area consumed by larvae
5 Month Post-Injection (Sept.)	Abamectin	High (0.8 g AI = 40ml / "dbh)	11	4.3	0.1 *
	Abamectin	Low (0.4 g AI = 20ml / "dbh)	9	6.3	1.3 *
		Check	11	7.9	10.1

* 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

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

Highlights:

- The FPMC continued to evaluate 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 establish new trials in Alabama, California and Idaho.
- Final results indicate that fipronil and emamectin benzoate were effective in reducing/preventing tree mortality by southern pine beetle (Alabama) for 2 years, western pine beetle (California) for 3 years, mountain pine beetle (Idaho) in the second year after treatment.
- Results indicate that fipronil and emamectin benzoate were ineffective in reducing/preventing tree mortality by mountain pine beetle (British Columbia) or spruce beetle (Utah). Treatment failure is likely due to cold climates and insufficient time between treatment application and beetle attack.
- Emamectin benzoate treatment applied in the fall (9 months prior to beetle attack) was effective in preventing mountain pine beetle from successfully attacking lodgepole pine trees in Colorado.
- New fipronil formulations (PW and UK) were effective in reducing tree mortality in Alabama and California, but not in Idaho. Higher rates did not improve efficacy.

Justification: Bark beetles (Coleoptera: 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 FPMC conducted an injection trial in East Texas to evaluate the potential efficacy of several reported systemic insecticides, including emamectin benzoate, fipronil, imidacloprid and dinotefuran, for protection of loblolly pine against *Ips* engraver beetles. Emamectin benzoate injections had been found to be highly effective (4+ years) against both 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 has/is being conducted at 13 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;
11) Talladega National Forest, Oakmulgee Ranger District in Bibbs and Perry Co., Alabama with SPB attacking loblolly pine,
12) Private timberland near Brownsville, California, with western pine beetle (WPB) attacking ponderosa pine;
13) Challis National Forest, Cape Horn Area near Stanley. Idaho, with mountain pine beetle (MPB) attacking lodgepole pine.

Treatments:

Trials 1-10

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.

Trial 11

1) Fipronil (PW) injection at 0.16 g AI per cm (0.4 g AI per in) DBH,
2) Fipronil (PW) injection at 0.32 g AI per cm (0.8 g AI per in) DBH,
3) Untreated (control) - used to assess beetle pressure during each summer (2008)

Trials 12-13

4) Fipronil (PW) injection at 0.08 – 0.16 g AI per cm (0.2 – 0.4 g AI per in) DBH,
5) Fipronil (UK) injection at 0.08 – 0.16 g AI per cm (0.2 – 0.4 g AI per in) DBH,
6) Untreated (control) - used to assess beetle pressure during each summer (2008, 2009)

Treatment Methods and Evaluation:

Each insecticide (injection or spray) treatment was applied to 12-35 randomly assigned trees. A similar number of trees were used for each set of untreated checks (3 sets (by year) total). Test trees were 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 1-2 months (depending on water availability) to translocate chemicals prior to being challenged by the application of synthetic pheromone baits. Due to the short season because elevation, the trees in Utah were not baited until 2006 (Table 27). 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 were required per tree. All treatments were applied between 0600 and 1100 hours 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 was/will be assessed in August for multiple, consecutive years until efficacy is diminished. The period between pheromone removal and mortality assessment was/will be sufficient for trees to "fade," an irreversible symptom of pending mortality. Presence of species-specific 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 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) – Trial 1</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 1). 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 1). 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 blue stain 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 28).

Southern pine beetle on loblolly pine (AL) – Trials 6, 10 & 11

2006 at Oakmulgee NF (Trial 6) - 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 2). 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 28). 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 29).

2007 – 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 2). 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 (Trial 10)– 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 3). 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.

2008 – The results showed nearly 65% (11 of 17) the check trees exhibited fading crowns by December 2008 (Figure 3). In contrast, 10% and 44% of the fipronil- and emamectin benzoate-treated trees had faded, respectively. As in 2007, mortality of check trees was caused by a combination of SPB activity and blue-stain fungi infection. In contrast, mortality of injected trees was due to blue stain fungi alone.

2008 at Oakmulgee NF (Trial 11) - The study trees were baited with the three-component bait (frontalin, turpentine and endo-brevicomin) from the start (May). The results showed nearly 90% (27 of 30) the check trees exhibited fading crowns by December 2008 (Figure 4). In contrast, 50% and 43% of the fipronil (low)- and fipronil (high)-treated trees had faded, respectively. All dead trees were cut down to determine the cause of tree mortality. As in the past, mortality of check trees was caused by a combination of SPB activity and blue-stain fungi infection. Similarly, 4 of 28 (14%) fipronil trees had died due to the same causes. On the other hand, SPB were unsuccessful in 24 of 28 (86%), but all were infected with blue stain fungi.

<u>Western pine beetle on ponderosa pine (CA) – Trial 2 & 12</u>

2005 in Calavaras Co (Trial 2) - 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 5).

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 5). 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 5). 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.

2008 – The final assessment for the 2007 season revealed that 60% (21 of 35) of the check trees had died (Figure 5). In contrast, 29% (6 of 21), 28% (8 of 29) and 0% of the fipronil-, bifenthrin-, and emamectin benzoate-treated trees had died. This indicates that only 52% of the checks survived WPB attack and fungal infections. In contrast, 54% of the fipronil-injected, 70% of the bifenthrin-sprayed and 97% of the EB-injected trees survived.

2008 in Brownsville (Trial 12) – Nearly all baited trees were heavily attacked by WPB within 3 weeks. A preliminary assessment of potential tree mortality was conducted in October 2008 At that time, better than 36% (10 of 28) the check trees exhibited fading crown or were so heavily attacked by bark beetles it was presumed that the trees would die. In contrast, no more than 18%, of any of the fipronil-treated trees had faded or were expected to die. A final assessment is planned for summer 2009 (Figure 6).

<u>Mountain pine beetle on lodgepole pine (ID) – Trials 3 & 13</u>

2005 in Yankee RD (Trial 3) - 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 7). 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 7). In contrast, only 0%, 23% 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.

2008 in Cape Horn RD (Trial 13) – Nearly all baited trees were heavily attacked by MPB within 3 weeks. A preliminary assessment of potential tree mortality was conducted in August. At that time, better than 50% (6 of 12) of the check trees exhibited fading crown or were so heavily attacked by bark beetles it was presumed that the trees would die. In contrast, 50-80 % of the fipronil-treated trees had faded or were expected to die. A final assessment is planned for summer 2009 (Figure 8).

Mountain pine beetle on lodgepole pine (BC) – Trial 5

One set of trees was treated in fall 2005. A second set was treated in May 2006. In anticipation of epidemic beetle 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. Several trees were ìlostî (unable to relocate). Of those found, all study trees were killed regardless of treatment. No assessment was made as to the extent of adult or larval success.

Mountain pine beetle on lodgepole pine (CO) – Trial 8 & 9

2007 in Summit Co. (Trial 8) – One set of trees was treated in fall 2006. No trees were attacked during the summer of 2007, so no assessment of treatment efficacy could be made. No report has been received yet as to the extent of beetle attack on study trees in 2008.

2007 in State Forest (Trial 9) - One set of trees was treated in fall 2006. A second set was treated in May 2007. Most trees were heavily attacked during the 2007 flight period (June – August). The final assessment was made in June 2008. Beetle pressure was sufficient to kill 70% (21 of 30) of the untreated trees (Figure 9). In contrast, all EB treatments significantly reduced tree mortality. The fall treatment proved most effective with only 20% (6 of 30%) mortality.

Spruce beetle on Engelmann spruce (UT) – Trial 4

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 10). 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.

Conclusions:

The results of trials presented above indicate that emamectin benzoate and fipronil injection treatments can provide very good protection against *Dendroctonus* bark beetles. However, the level of treatment efficacy is affected by several factors:

1) Temperature – in warmer climes (MS, AL and CA) trees are actively translocating chemicals for a longer period of time during the year.
2) Moisture availability – good moisture levels allow quicker movement from point of injection to sites where insects attack. Under drought conditions, trees will close stomates to conserve water thus halting translocation.
3) Treatment timing – sufficient time needs to be allowed for the tree to transport chemical to target sites. In colder and drier climes, treatments should be made in the fall, 9+ months prior to the next beetle attack.
4) Bark beetle populations – the treatments are effective under low populations by killing pioneer beetles and preventing the initiation of mass attack. However, at moderate to high populations, the many attacks (although unsuccessful) can still result in tree mortality due to inoculated blue stain fungi.

Additional trials are planned in 2009 in AL and CA to evaluate the potential efficacy of combination treatments of emamectin benzoate and fungicide.

Acknowledgements: Many thanks go to our cooperators: Chris Fettig, Steve Clarke, Steve Munson, Carl Jorgensen, Leo Rankin, Gary Severson, Meg Halford, Cindy Ragland, Jim Meeker and Tim Haley 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 Robert Borys, Vladimir Cizek, Chris Dabney, Griffin Guess, Jason Helvey, Wood Johnson, Teresa Krause, Roger Menard, Genie Michiel, Doris Oberlander, Blake Smith and Abbie Drake-Spier. These trials were supported by funds from the FPMC, Western Bark Beetle Initiative, Southern Pine Beetle Initiative, BASF and Syngenta.

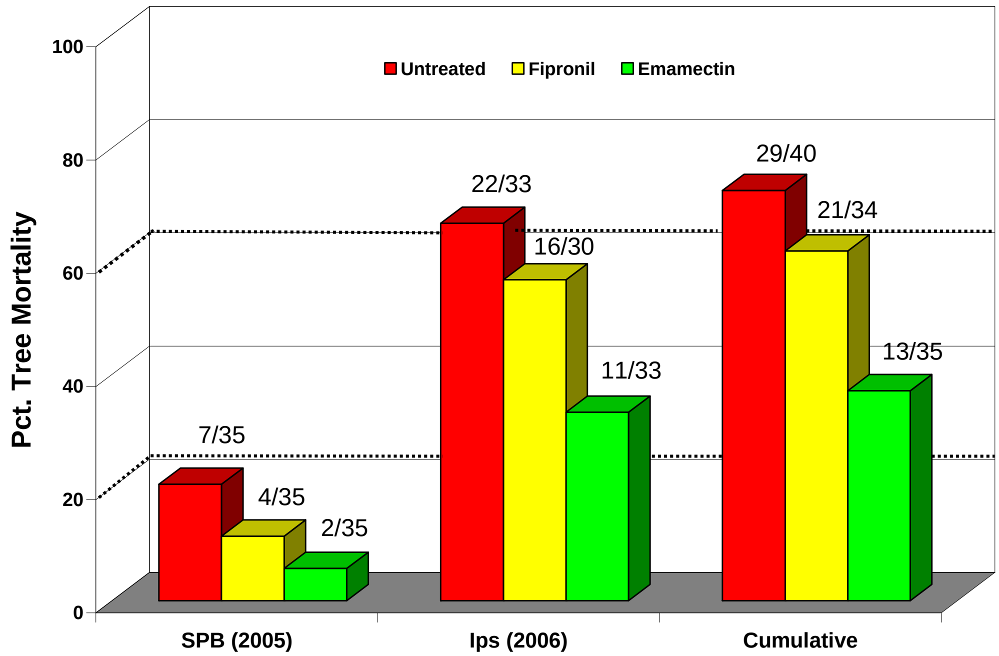

Figure 1. Yearly and cumulative effects of injection treatments on loblolly pine mortality caused by southern pine beetle (2005) and Ips engraver beetle (2006), Chickasawhay, Ranger District, DeSoto National Forest, MS. The dashed line at 60% cumulative mortality is the level of control tree mortality necessary for a valid test; the dashed line at 20% cumulative mortality is the maximum allowable mortality of treatments to be considered efficacious.

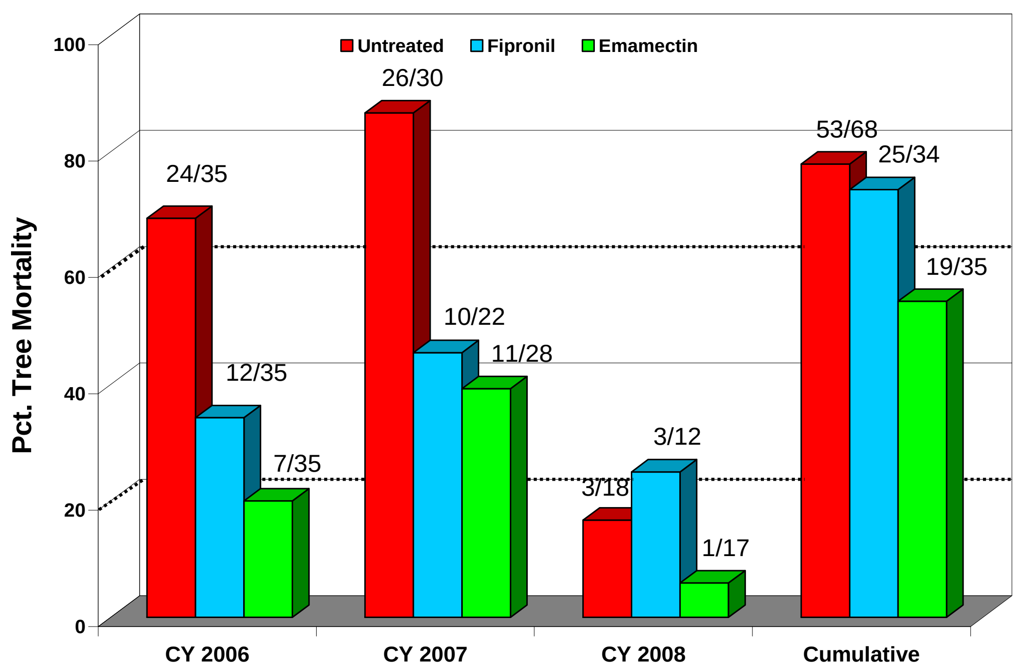

Figure 2. Effects of injection treatments on loblolly pine mortality caused by southern pine beetle (2006 - 2008), Oakmulgee Ranger District, Talladega National Forest, AL. The dashed line at 60% cumulative mortality is the level of control tree mortality necessary for a valid test; the dashed line at 20% cumulative mortality is the maximum allowable mortality of treatments to be considered efficacious.

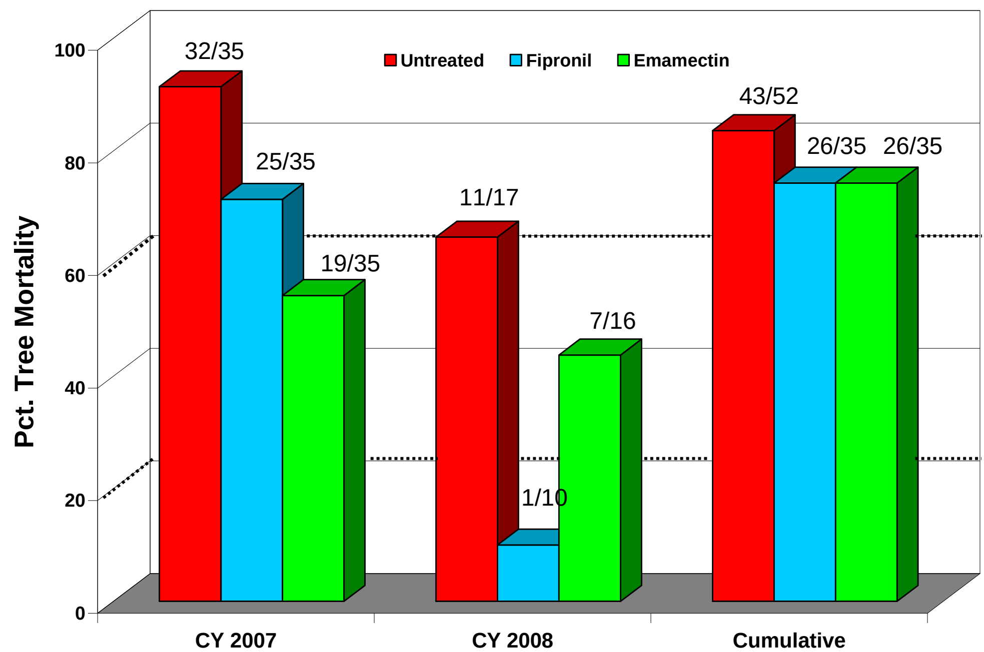

Figure 3. Effects of injection treatments on loblolly pine mortality caused by southern pine beetle (2007 & 2008), Bankhead Ranger District, Bankhead National Forest, AL. The dashed line at 60% cumulative mortality is the level of control tree mortality necessary for a valid test; the dashed line at 20% cumulative mortality is the maximum allowable mortality of treatments to be considered efficacious.

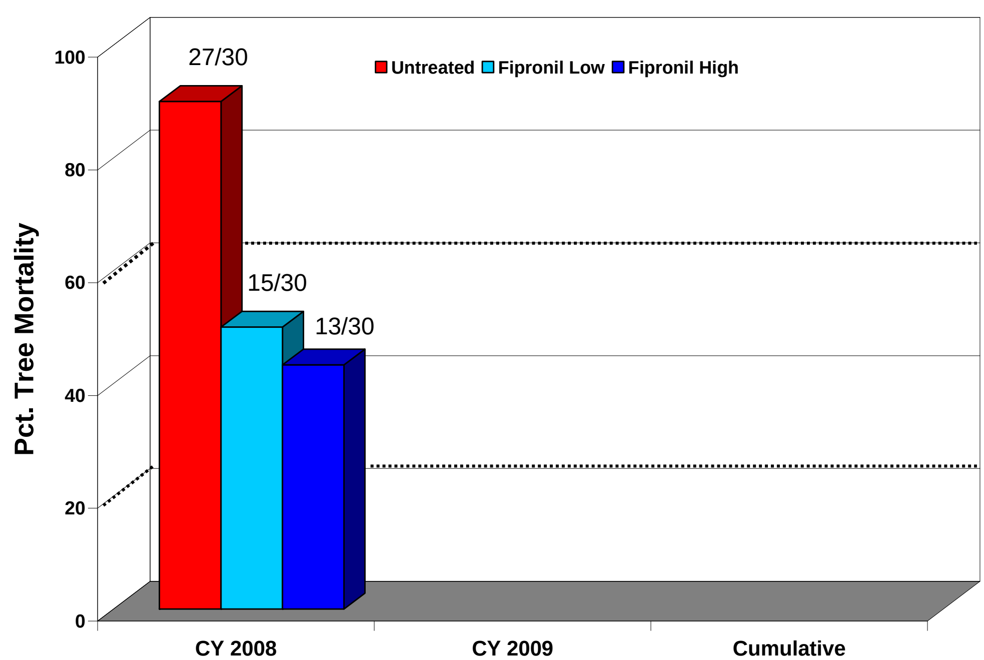

Figure 4. Effects of fipronil injection treatments on loblolly pine mortality caused by southern pine beetle in 2008), Oakmulgee Ranger District, Talladega National Forest, AL. The dashed line at 60% cumulative mortality is the level of control tree mortality necessary for a valid test; the dashed line at 20% cumulative mortality is the maximum allowable mortality of treatments to be considered efficacious.

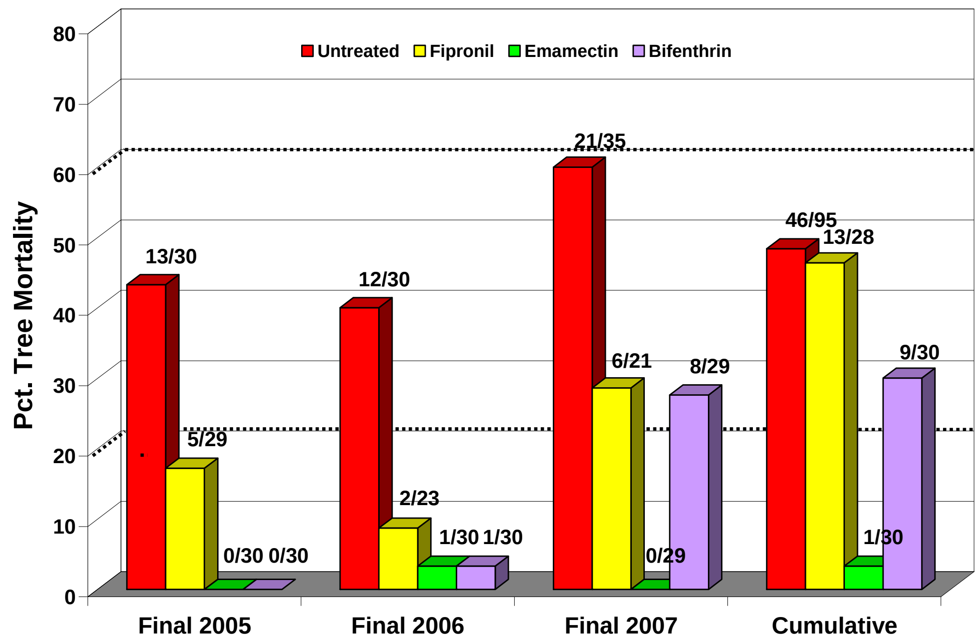

Figure 5. Yearly and cumulative effects of injection treatments on ponderosa pine mortality caused by western pine beetle (2005-2007), Sierra Pacific Industries (SPI) land in Calaveras Co., California. The dashed line at 60% cumulative mortality is the level of control tree mortality necessary for a valid test; the dashed line at 20% cumulative mortality is the maximum allowable mortality of treatments to be considered efficacious.

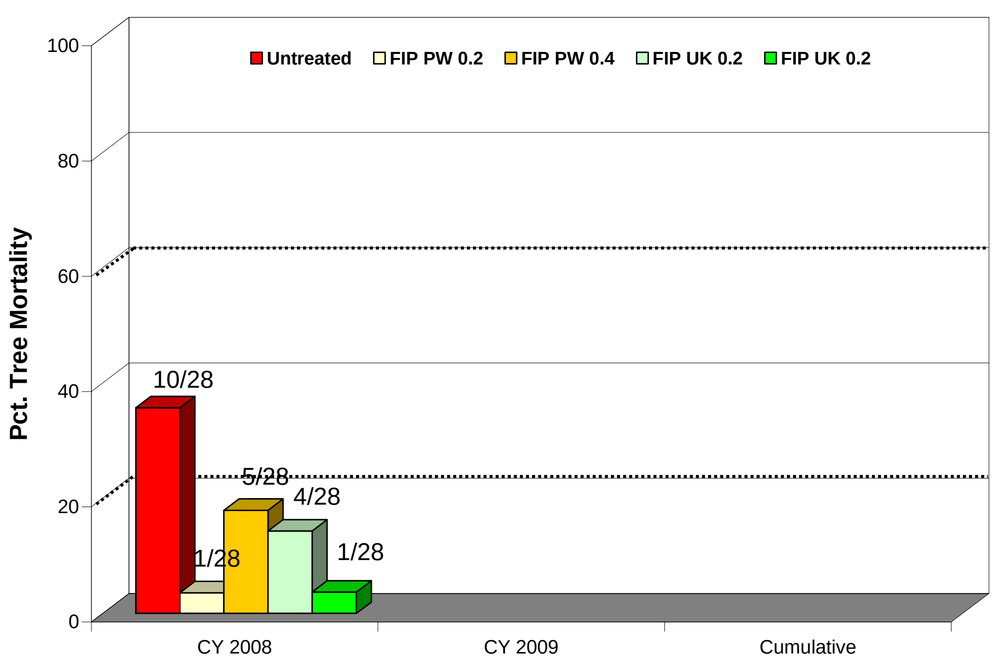

Figure 6. Effects of fipronil injection treatments on ponderosa pine mortality caused by western pine beetle (so far in 2008), near Brownsville, CA. The dashed line at 60% cumulative mortality is the level of control tree mortality necessary for a valid test; the dashed line at 20% cumulative mortality is the maximum allowable mortality of treatments to be considered efficacious.

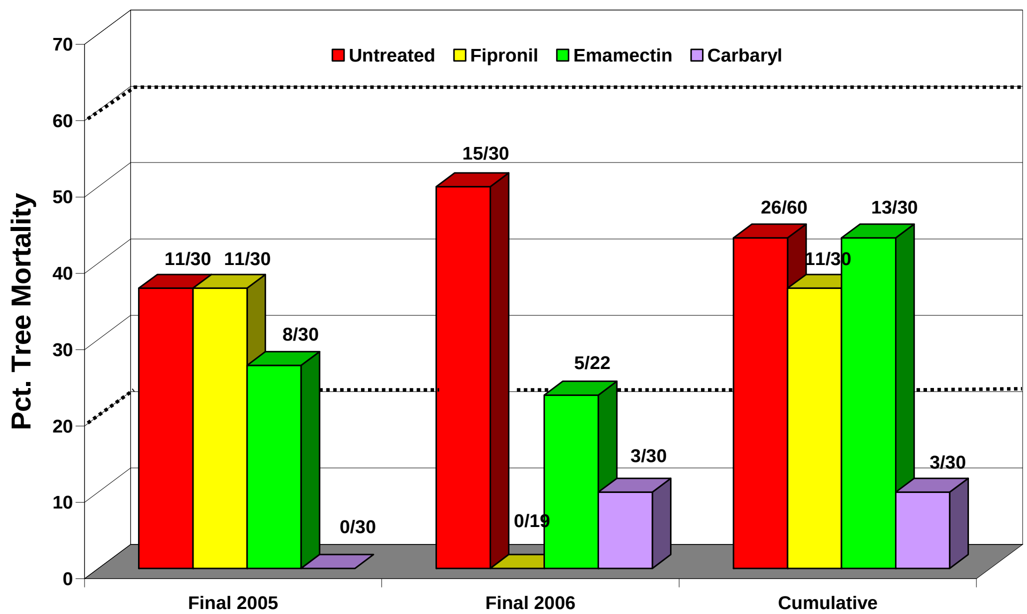

Figure 7. Yearly and cumulative effects of injection treatments on lodgepole pine mortality caused by mountain pine beetle as of September 2007, Challis National Forest, Yankee Ranger District in Custer Co., Idaho. The dashed line at 60% cumulative mortality is the level of control tree mortality necessary for a valid test; the dashed line at 20% cumulative mortality is the maximum allowable mortality of treatments to be considered efficacious.

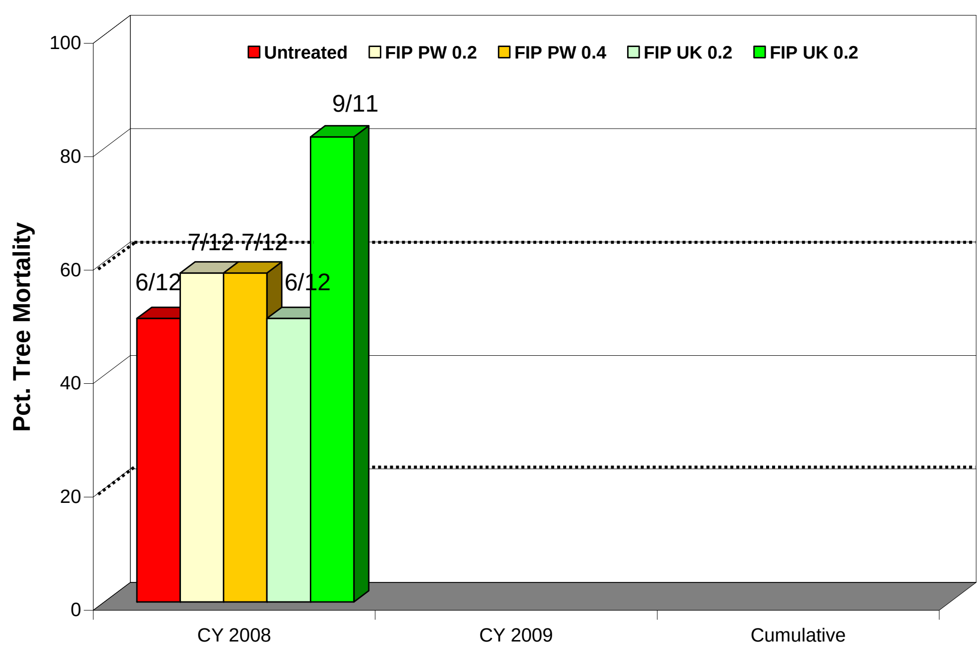

Figure 8. Effects of fipronil injection treatments on lodgepole pine mortality caused by mountain pine beetle (so far in 2008), Cape Town area near Stanley, ID. The dashed line at 60% cumulative mortality is the level of control tree mortality necessary for a valid test; the dashed line at 20% cumulative mortality is the maximum allowable mortality of treatments to be considered efficacious.

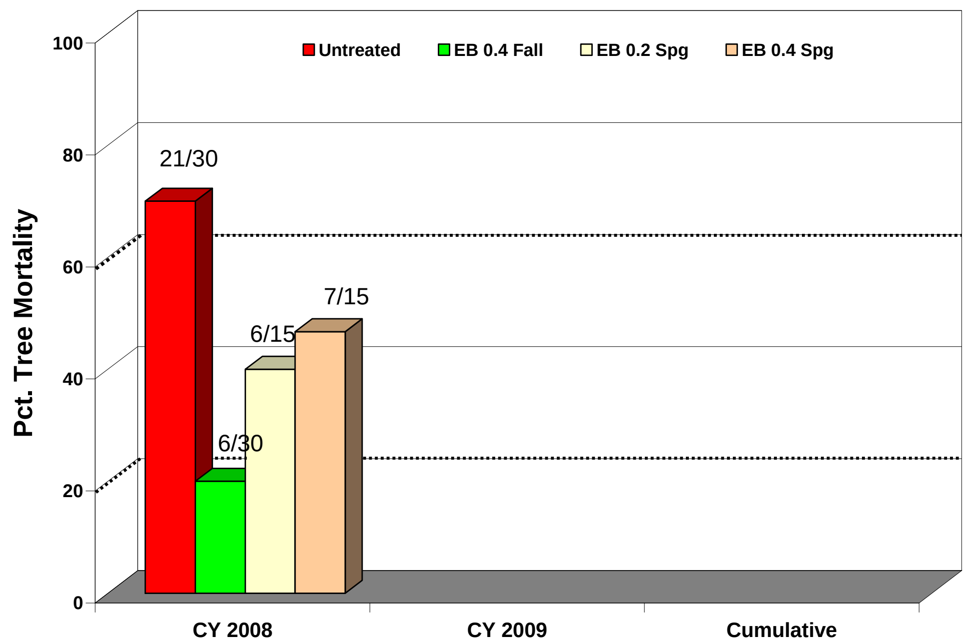

Figure 9. Effects of emamectin benzoate injection treatments on lodgepole pine mortality caused by mountain pine beetle (so far in 2008), The State Forest, CO. The dashed line at 60% cumulative mortality is the level of control tree mortality necessary for a valid test; the dashed line at 20% cumulative mortality is the maximum allowable mortality of treatments to be considered efficacious.

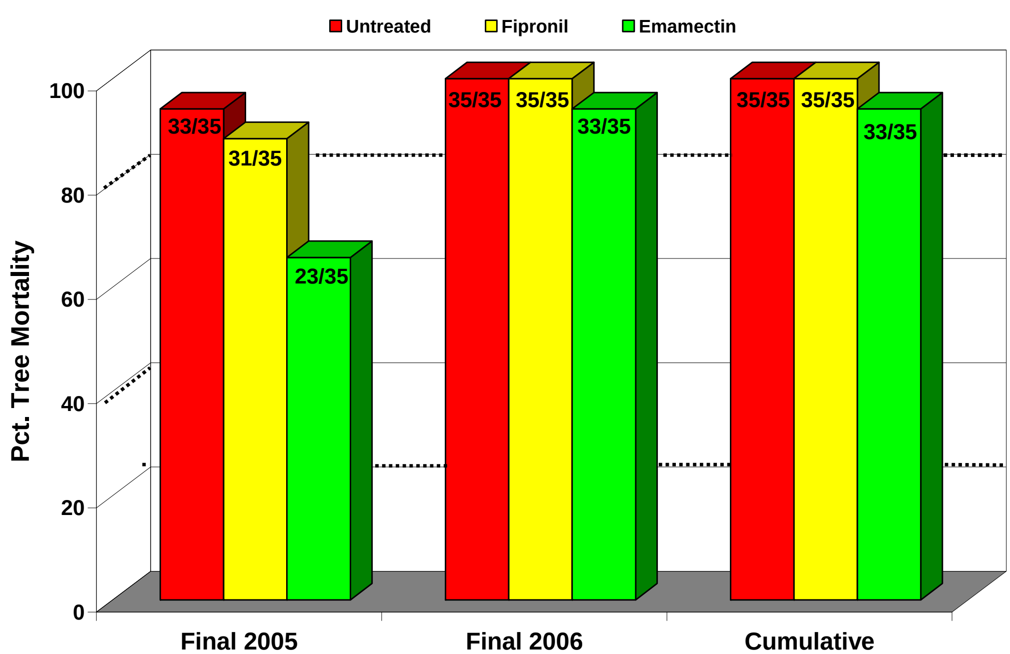

Figure 10. Preliminary and final effects of injection treatments on Engelmann spruce mortality caused by spruce beetle, Manti-LaSal National Forest in Emery and Carbon Co., Utah. The dashed line at 60% cumulative mortality is the level of control tree mortality necessary for a valid test; the dashed line at 20% cumulative mortality is the maximum allowable mortality of treatments to be considered efficacious.

Table 27. Scheduled Injection, Baiting and Evaluation Dates for Twelve *Dendroctonus* Bark Beetle Trials

	SPB, Ips & BTB (MS)	SPB & BTB (AL)	WPB (CA)	MPB (ID)	SB (UT)	MPB (BC)	MPB (CO)	WPB (CA)	MPB (ID)
Project Leader(s)	Grosman & Clarke	Grosman & Clarke	Fettig	Jorgenson	Munson	Rankin	Doccola	Fettig	Jorgenson
Injection Dates	Apr-05	Apr-06	May-05	Jun-05	Aug-05	Sep-05 May-06	Sep-06 May-07	Apr-08	Jun-08
Baiting Period	May - Jul 2005 May - Jun 2006	May - Jun 2006 May - Jun 2007	Jul. - Aug 2005 Jul - Aug 2006 Jul - Aug. 2007	July, 2005 July, 2006	Apr - Jul 2006	---------	---------	Jul - Aug 2008	July, 2008
Prelim Evaluation	Aug. 2005 Aug. 2006	Jun - Jul 2006 Jun - Jul 2007	Oct 2005 Oct 2006 Oct 2207	Aug 2005 Aug 2006	Feb 2007	Nov 2006	Nov 2007	Oct2008	Aug 2008
Final Evaluation	Dec. 2005 Dec. 2006	Dec. 2006 Dec. 2007	June 2006 June 2007 June 2008	Jun 2006 Jun 2007	Jun 2007	Apr 2007	Aug 2008	Jun 2009	Jun 2009

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

Table 28 - 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 29. 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	BTB Brood Present	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 potential to effectively and efficiently inject emamectin benzoate (EB) into pine trees; 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* engraver beetles and wood borers 1 and 13 months after injection. Treatments made using the Tree IV, Quick-jet and Sidewinder were highly and equally effective against both insect groups. In contrast, the effects of the Portle treatment declined markedly by 13 months.

Justification: Injection trials conducted by the 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 manufacturer of EB, is interested in knowing if the EB formulation can be applied to pine trees using other available injection/infusion systems and whether these applications are effective in preventing/reducing insect damage.

Objectives: 1) Evaluate the ability of various available injection systems to 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:

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

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

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

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

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

<u>Tree IV</u> 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 product be injected 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 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 30). 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/will be transported to a nearby plantation that had been recently thinned and contained fresh slash material. Bolts were/will be 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/will be 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 was 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 31). 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 less than that required by the other systems.

Table 32 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). Each criterion had a value ranging from 2 to 10 points.

The Tree IV system (Arborjet) garnered 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-like tubing, the need to mix product with water prior to injection, and the need to measure product and fill the system for each tree

The Quick-jet system (Arborjet) performed nearly as well 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 plugs need to be installed in each tree.

The Portle System (ArborSystem) ranked third with 71 points. Its attractive features are that the system 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 additional 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 equipment cost is high, there is a need to change and recharge batteries, the model tested had a tendency to leak around injections points and there is a tendency for chemical to get on the surfaces of the drill and pump handle. Thus, the potential for chemical exposure is fairly high and cleaning the system takes longer than other systems.

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 33 – 36)

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).

Further assessments of treatment duration showed that EB treatments applied with the Tree IV, Quick-jet and Sidewinder were still highly effective 13 months after application. The treatment applied by the Portle was noticeably less effective.

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 its Tree IV system and has just released the new 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 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 based on Dr. Blair Helson's STIT concept.

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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.

Characteristics (Potential Points)	System: 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 33: Attack success and gallery construction of *Ips* engravers beetles on loblolly pine bolts cut 1 & 12 months after trunk injection with emamectic benzoate using different injection systems; Lufkin, Texas - 2007 & 2008.

Injection season / Evaluation period	System	Rate	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
Spring (May) / 1 month Post-Injection (June 2007)	Tree IV	Low (5ml / "dbh)	5	5.8	81	1.4	19	7.2
	AJ Micro	Low (5ml / "dbh)	5	2.6	100	0.0 *	0	2.6 *
	Portal	Low (5ml / "dbh)	5	6.6 *	100	0.0 *	0	6.6
	Sidewinder	Low (5ml / "dbh)	5	4.8	96	0.2 *	4	5.0
	Tree IV	High (10ml / "dbh)	5	9.4 *	96	0.4 *	4	9.8
	AJ Micro	High (10ml / "dbh)	5	5.0	100	0.0 *	0	5.0
	Portal	High (10ml / "dbh)	5	4.4	100	0.0 *	0	4.4
	Sidewinder	High (10ml / "dbh)	5	5.6	93	0.4 *	7	6.0
	Check		5	3.4	44	4.4	56	7.8
Spring (May)/ 13 months Post-Injection (June 2008)	Tree IV	High (10ml / "dbh)	5	3.4 *	100	0.0 *	0	3.4
	AJ Micro	Low (5ml / "dbh)	5	2.4 *	100	0.0 *	0	2.4
	Portal	Low (5ml / "dbh)	5	1.0	36	1.8	64	2.8
	Sidewinder	High (10ml / "dbh)	5	2.6 *	100	0.0 *	0	2.6
	Check		5	1.0	26	2.8	74	3.8

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

Table 34: 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 & 2008.

Injection season / Evaluation period	System	Rate	N	Number of egg galleries: Without larvae No.	Without larvae % of total	With larvae No.	With larvae % of Total	Total #
Spring (May) / 1 month Post-Injection (June 2007)	Tree IV	Low (5ml / "dbh)	5	2.0	77	0.6 *	23	2.6 *
	AJ Micro	Low (5ml / "dbh)	5	0.0 *	####	0.0 *	####	0.0 *
	Portal	Low (5ml / "dbh)	5	0.0 *	####	0.0 *	####	0.0 *
	Sidewinder	Low (5ml / "dbh)	5	0.2 *	100	0.0 *	0	0.2 *
	Tree IV	High (10ml / "dbh)	5	0.8	80	0.2 *	20	1.0 *
	AJ Micro	High (10ml / "dbh)	5	0.0 *	####	0.0 *	####	0.0 *
	Portal	High (10ml / "dbh)	5	0.0 *	####	0.0 *	####	0.0 *
	Sidewinder	High (10ml / "dbh)	5	0.4 *	100	0.0 *	0	0.4 *
	Check		5	4.2	27	11.2	73	15.4
Spring (May)/ 13 months Post-Injection (June 2008)	Tree IV	High (10ml / "dbh)	5	0.0	####	0.0 *	####	0.0 *
	AJ Micro	Low (5ml / "dbh)	5	0.0	####	0.0 *	####	0.0 *
	Portal	Low (5ml / "dbh)	5	1.4	35	2.6 *	65	4.0 *
	Sidewinder	High (10ml / "dbh)	5	0.0	####	0.0 *	####	0.0 *
	Check		5	0.4	5	7.4	95	7.8

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

Table 35: Mean 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 & 2008.

Injection season / Evaluation period	System	Rate	N	Length of egg galleries: Without larvae cm	Without larvae % of Total	With larvae cm	With larvae % of Total	Total length
Spring (May) / 1 month Post-Injection (June 2007)	Tree IV	Low (5ml / "dbh)	5	7.6	56	6.0 *	44	13.6 *
	AJ Micro	Low (5ml / "dbh)	5	0.0 *	####	0.0 *	####	0.0 *
	Portal	Low (5ml / "dbh)	5	0.0 *	####	0.0 *	####	0.0 *
	Sidewinder	Low (5ml / "dbh)	5	1.0 *	100	0.0 *	0	1.0 *
	Tree IV	High (10ml / "dbh)	5	4.6	70	2.0 *	30	6.6 *
	AJ Micro	High (10ml / "dbh)	5	0.0 *	####	0.0 *	####	0.0 *
	Portal	High (10ml / "dbh)	5	0.0 *	####	0.0 *	####	0.0 *
	Sidewinder	High (10ml / "dbh)	5	1.8	100	0.0 *	0	1.8 *
	Check		5	15.2	13	98.8	87	114.0
Spring (May)/ 13 months Post-Injection (June 2008)	Tree IV	High (10ml / "dbh)	5	0.0	####	0.0 *	####	0.0 *
	AJ Micro	Low (5ml / "dbh)	5	0.0	####	0.0 *	####	0.0 *
	Portal	Low (5ml / "dbh)	5	3.8	3	123.6 *	97	127.4 *
	Sidewinder	High (10ml / "dbh)	5	0.0	####	0.0 *	####	0.0 *
	Check		5	2.0	2	81.4	98	83.4

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

Table 36: Extent of feeding by cerambycid larvae (per 1000 cm^2) in loblolly pine bolts cut 1 and 13 month after trunk injection with emamectin benzoate using different injection

Injection season / Evaluation period	System	Rate	N	No of cerambycid egg niches on bark	Percent phloem area consumed by larvae
Spring (May) / 1 month Post-Injection (Jun. 2007)	Tree IV	Low (5ml / "dbh)	5	11.6	0.0 *
	AJ Micro		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 *
	AJ Micro		5	11.4	0.0 *
	Portal		5	16.2	0.0 *
	Sidewinder		5	13.4	0.0 *
	Check		5	11.4	6.8
Spring (May) / 13 months Post-Injection (Jun. 2008)	Tree IV	High (10ml / "dbh)	5	15.8	1.2 *
	AJ Micro	Low (5ml / "dbh)	5	12.8	0.0 *
	Portal	Low (5ml / "dbh)	5	11.2	9.4 *
	Sidewinder	High (10ml / "dbh)	5	16.6	0.4 *
	Check		5	17.4	63.4

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

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

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

Since 2002, an attempt had being made to expand the potential forestry market for emamectin benzoate through trials with other tree and pest species. 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).

Several FPMC trials were established in 2005 - 2007 with some ongoing in 2008, 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 the 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. The product will be called "**Tree-äge**." A decision by EPA on this request is expected by July 2009. Requests were made and approved in 2008 for 24C (Special Local Need) registration for use against emerald ash borer in IL, IN, MD, MI, MN, MO, OH, PA, VA, WI & WV. Additional requests for 24C registration for use in seed orchards were made in GA and FL but they have yet to be approved.

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 formulation of fipronil was injected into trees as part of a seed orchard trial (2003) and a bark beetle trial (2004). The EC formulation reduced overall coneworm damage by 80% and was highly effective in preventing the colonization and mortality of stressed loblolly pine by southern pine engraver beetles (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 FPMC trials mentioned above. Although fipronil tends to require more time to move throughout the tree, it proved 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. Unfortunately, the results were less effective than expected. Again timing and temperatures appear to play a role in reduced activity. At this time, BASF has not submitted an application to EPA for registration of fipronil and its use for injection is not expected before 2010.

Imidacloprid – Imidacloprid is another neonictinoid chemical tested by the FPMC 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 were 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 significant effect against coneworm and efficacy was not enhanced by emamectin benzoate. The effects declined markedly 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/inch DBH) was not found to be active against bark beetles in our 2004 trial, it was found by Arborjet (at 0.4g/inch DBH) to be as effective as imidacloprid against emerald ash borer (Joe Doccola, Arborjet, personnel communication). One advantage dinotefuran has over imidacloprid is that it is 100X more water soluble (40g/L vs 0.4g/L). Thus, higher concentrations can be developed that translocate more quickly compared to imidacloprid. Arborjet, working in cooperation with Valent, developed a formulation of dinotefuran that may be combined with emamectin benzoate for seed orchard use. The trial in 2007 and 2008 showed that this chemical can reduce seed bug damage but had little effect against coneworms.

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 beetles. The results suggest some activity, but treatment and evaluation earlier in the year should provide more conclusive evidence. Additional tests initiated in 2006 confirmed that nemadectin has moderate activity against *Ips* engraver beetles. The trial was continued through 2008 and showed that nemadectin at the highest rate (0.4 g AI / inch DBH.) has very good efficacy against *Ips* engravers and wood borers 28 months after injection. Fort Dodge Animal Health is planning to sell the use rights to another company who would then submit for EPA registration.

Abamectin – Abamectin (Syngenta) is an avermectin derivative and closely related to emamectin benzoate. A preliminary trial was conducted in 2008 in cooperation with Mauget Co. to determine if abamectin has similar efficacy against bark beetles. The results indicate that abamectin is very active against *Ips* engraver beetles and wood borers. The trial was expanded in the fall and will extend to 2011. An additional trial was initiated in the fall 2008 at the Rayonier seed orchard near Fernandino Beach, FL (see 2009 Proposals).

PINE TIP MOTH TRIALS

Impact Study – Western Gulf Region

Highlights:

- Fifteen new Nantucket pine tip moth impact plots were established in 2008, bringing the total to 103 plots established since 2001.
- Tip moth damage levels on first-year check trees remained stable at 24% in 2008. Damage levels on second-year check trees, established in 2006, increased markedly from 2007 and had the highest average (48%) over the eight years of the study.
- Periodic applications of MimicÆ to first- and second-year trees in 2007 provided good protection against tip moth on most sites. This resulted in overall damage reductions of 82 and 64 percent, respectively, compared to untreated checks.
- Protected trees experienced significantly improved tree growth compared to check trees at all tip moth damage levels. Growth improvements of protected trees increased as damage levels on check trees increased; trees protected from high damage levels (>20% shoots infested) had 63% greater volume than unprotected trees.
- 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 MimicÆ, were on average 29 cm (1 ft) taller, had 0.42 cm greater diameter and 6,293 cm^3 (0.22 ft^3) greater volume compared to check trees.

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

Cooperators:

Mr. Conner Fristoe	Plum Creek Timber Co., Crossett, AR
Dr. Nick Chappell	Potlatch Forest Holdings, Warren, AR
Mr. Peter Birks	Weyerhaeuser Co., Columbus, MS
Mr. Bill Stansfield	The Campbell Group, Diboll, TX
Mr. Jeff Hall	Forest Investment Associates, Jackson, MS
Mr. Andy Burrow	Potlatch Forest Holdings, Moscow, ID

Study Sites: Several FPMC members have established 10 or more impact study sites by 2008. In most plantation sites, one to two areas were selected and divided into 2 plots each – with each plot containing 126 trees (9 rows X 14 trees). Tip moth populations were monitored on TFS sites in East Texas.

Insecticide:
Mimic® 2F (tebufenozide) - molting stimulant specific to Lepidoptera.

Design: 72 sites X 1-2 plots X 2 treatments X 50 trees = 9,600 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 within the designated Mimic® plot (treatment area) on first- and second-year sites. Application dates were based on optimal spray period predictions for locations near each study site (Fettig et al. 2003), generally every 7-8 weeks starting in late February and ending in late September.

Tip Moth Damage Survey: Tip moth infestation levels were determined by surveying the internal 50 trees within each plot during the pupal stage of each tip moth generation for the first two years after establishment. Each tree was ranked 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 11 shows the mean number of pine tip moths captured in traps per day at several one- to three-year-old sites surrounding Lufkin, TX from 2001- 2007. The optimal spray periods in East Texas (near Lufkin) for the first four generations were predicted to be March 22-26, May 21-25, July 10-14, and Aug 19-23 (Fettig et al. 2003). Based on previous years trap data (Figure 11), a fifth spray period was calculated to be September 29 to October 3. In contrast, optimal spray periods for southern Arkansas sites (near Crossett) should be April 6-10, June 5-9, July 30-August 3, and Sept. 13-17. The distribution of new Confirm® (Mimic®) product and use of a surfactant resulted in much improved protection on both first- and second-year sites in 2008 (Table 35).

Fifteen new impact plots were established in 2008, bringing the total number of plots established since 2001 to 103. Figure 12 shows the distribution of the 103 first- thru eight-year impact study sites in the Western Gulf Region.

<u>Group 1 - Eighth-year sites (12)</u>:
Trees on these sites were not measured in 2008.

<u>Group 2 - Seventh-year sites (4 new)</u>:
Trees on these sites were not measured in 2008.

<u>Group 3 - Sixth-year sites (8 new; 24 total)</u>:
Trees on these sites were not measured in 2008.

<u>Group 4 - Fifth-year sites (2 new; 26 total)</u>:
Three years after the last Mimic® spray the difference in growth (height, diameter and volume) between Group 4 Mimic-treated and untreated trees has expanded considerably . When combined with Group 1, 2 & 3 sites, five-year old Mimic-treated trees are on average 29 cm (1 ft) taller, had 0.42 cm greater diameter at breast height and 6,293 cm^3 (0.22 ft^3) greater volume compared to check trees (Table 38 and Figures 13 15 & 17). This is a decline compared to the 33 cm (1.1 ft) greater height, 0.5 cm greater diameter at breast height and 8,292 cm^3 (0.29 ft^3) greater volume compared to check trees calculated for the Group 1, 2 & 3 sites alone.

Group 5 - Fourth-year sites (6 new; 40 total):
Trees on these sites were not measured in 2008. Their next measurements are scheduled for 2009.

Group 6 - Third-year sites (22 new; 64 total):
As with fifth-year sites, the difference in growth (height, diameter and volume) between Mimic-treated and untreated trees continued to expand even after Mimic sprays were halted. On this group of sites, Mimic-treated trees averaging 21 cm (0.7 ft) taller, had 0.49 cm greater diameter at breast height, and 1,220 cm^3 (0.04 ft^3) greater volume compared to check trees. These ìmoderateî 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 37). Overall (64 sites), Mimic-treated trees were on average 24 cm (0.8 ft) taller, had 0.5 cm greater diameter at breast height and 1,251 cm^3 (0.037 ft^3) greater volume compared to check trees (Table 38, Figures 13-16).

Group 7 - Second-year sites (13 new; 88 total):
Tip moth infestation levels on untreated second-year trees were considerably higher (48% of shoots infested) in 2008 compared to similar aged trees in 2007 (26% of shoots infested) (Table 37). Overall protection of second-year trees was better, but not great, with MimicÆ reducing damage to shoots by only 64%. Combined, these factors have resulted in smaller than expected gains in the height (11%), diameter (8%) and volume (27%) of MimicÆ-treated trees compared to check trees (Table 38, Figures 13-15).

Group 8 - First-year sites (15 new; 103 total):
Overall, tip moth infestation levels on untreated first-year seedlings was the same (24% of shoots infested) in 2008 compared to the 2006 levels (24% of shoots infested) (Table 37). Mimic® protection was considerably better in 2008 after the purchase of new product and the use of a crop oil surfactant. Overall the sprays reduced damage by 82%; reductions in damage were above 75% on 13 of 15 sites. Mimic®-treated trees on only 5 of 15 sites showed 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 7%, 6% and 20%, respectively compared to check trees (Table 38, Figures 13-15). This is in stark contrast to the 20%, 35% and 116% gains in height, diameter and volume growth, respectively, obtained in 2005.

To determine if there is a threshold of tip moth damage that significantly impacts tree growth, the 64 sites were divide into three groups based on level of mean shoots infested over the first two year (i.e., $\leq$ 10%, 11 – 20%, and > 20%). By the end of year 3, the Mimic treatment significantly improved 3rd year growth at all tip moth pressures; by 17% at low ($\leq$ 10%) levels, by 40% at moderate (11 – 20% shoots infested) levels, and by 63% at high (>20%) levels (Figure 16, Table 39). If analysis is restricted to crop tree (top 30% or 15 trees by volume, there is a similar trend in growth gains from low to high tip moth pressures. By the end of year 5, the Mimic treatment significantly improved growth at moderate pressures by 26% and at high pressures by 9% (Figure 17, Table 40).

Conclusions: Overall, tip moth populations and damage levels increased markedly in 2007 and 2008 compared to 2005 and 2006. Although close to average rainfall was received in 2007, the extensive drought conditions that occurred in the Western Gulf Region through 2005, most of

2006, and periodically since then may have allowed populations to build. Multiple applications of Mimic® were able to significantly reduce tip moth infestation levels on most one- and two-year-old sites in 2008. 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 64 sites 3 years of age or older showed that two year mean tip moth damage levels (percent shoots infested) of less than 10% can still significantly impact tree growth in a given year.

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 is supported by the fact that first year trees in 2002 had good protection (85% reduction in damage) from MimicÆ 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 MimicÆ 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. Bill Stansfield, biometrician with The Campbell Group, 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 2009. If additional impact sites are to be installed, we recommend that PTM SC Insecticide be used and applied at planting to protect trees for 2+ years. Also, it is important to continue Mimic treatments on second-year sites and monitor tip moth damage and impact on third- and fifth-year sites in 2009.

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

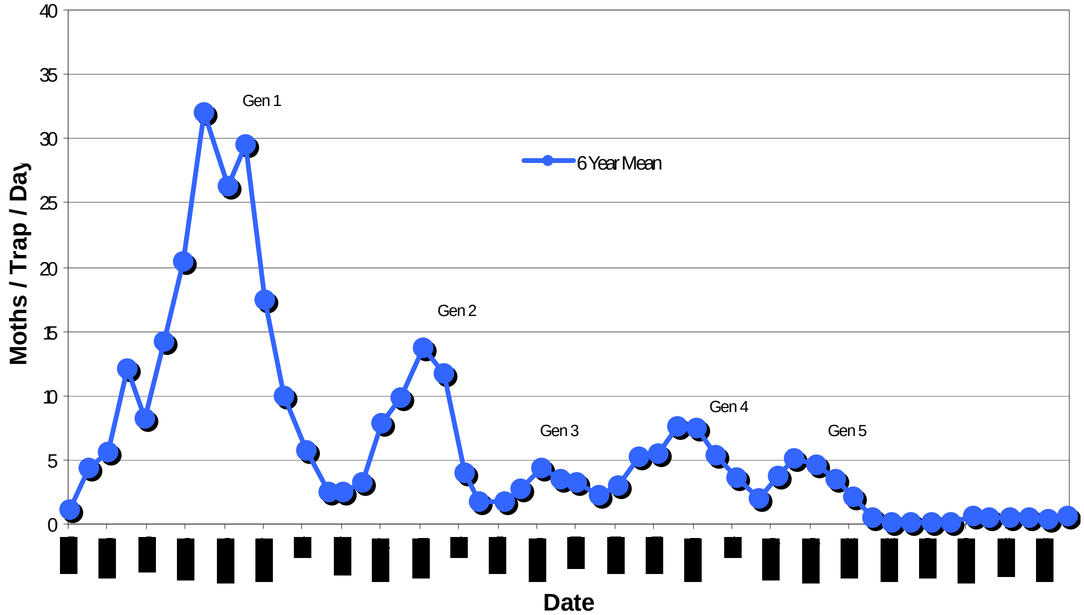


Figure 11. Mean number of pine tip moth adults captured per trap per day in the Lufkin, TX area (2001 - 2007).

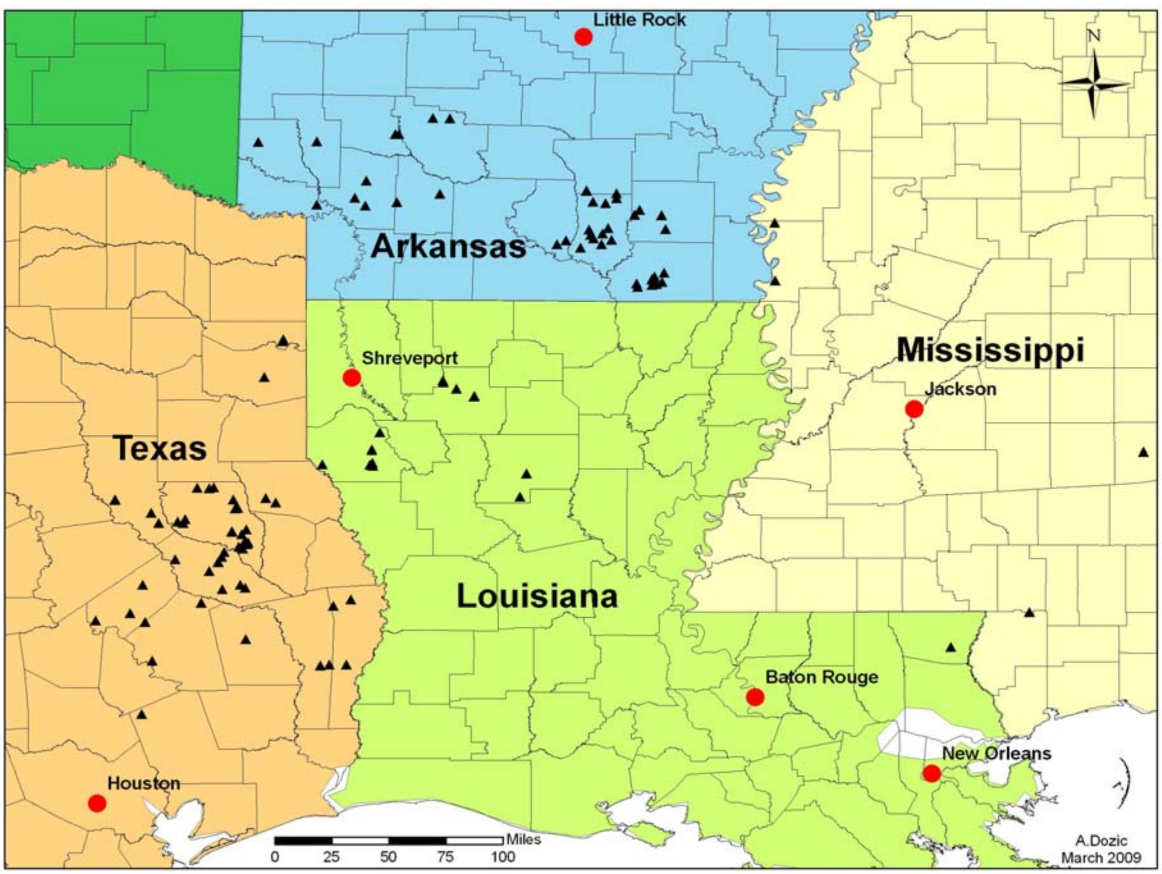


Figure 12. Distribution of 103 one- to five-year old impact sites (▲) from 2001 – 2008 in the Western Gulf Region.

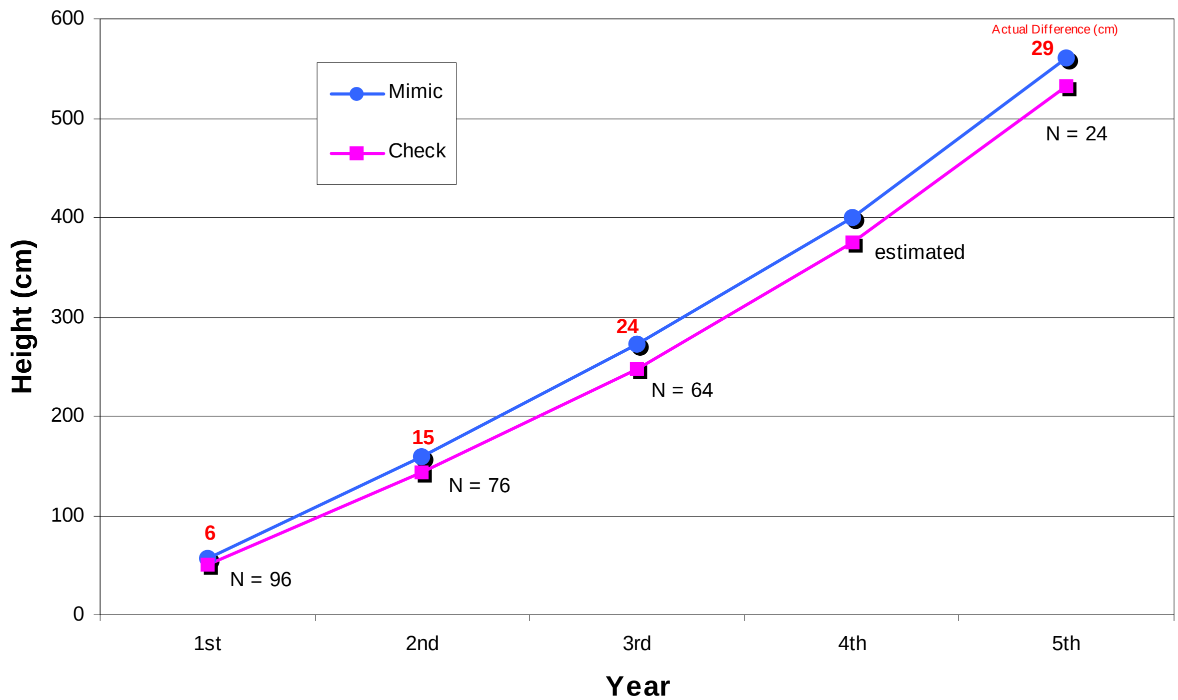


Figure 13. Mean height (cm) of one- to five-year old loblolly pine treated with Mimic® compared to untreated trees on all Western Gulf sites: 2001 – 2008.

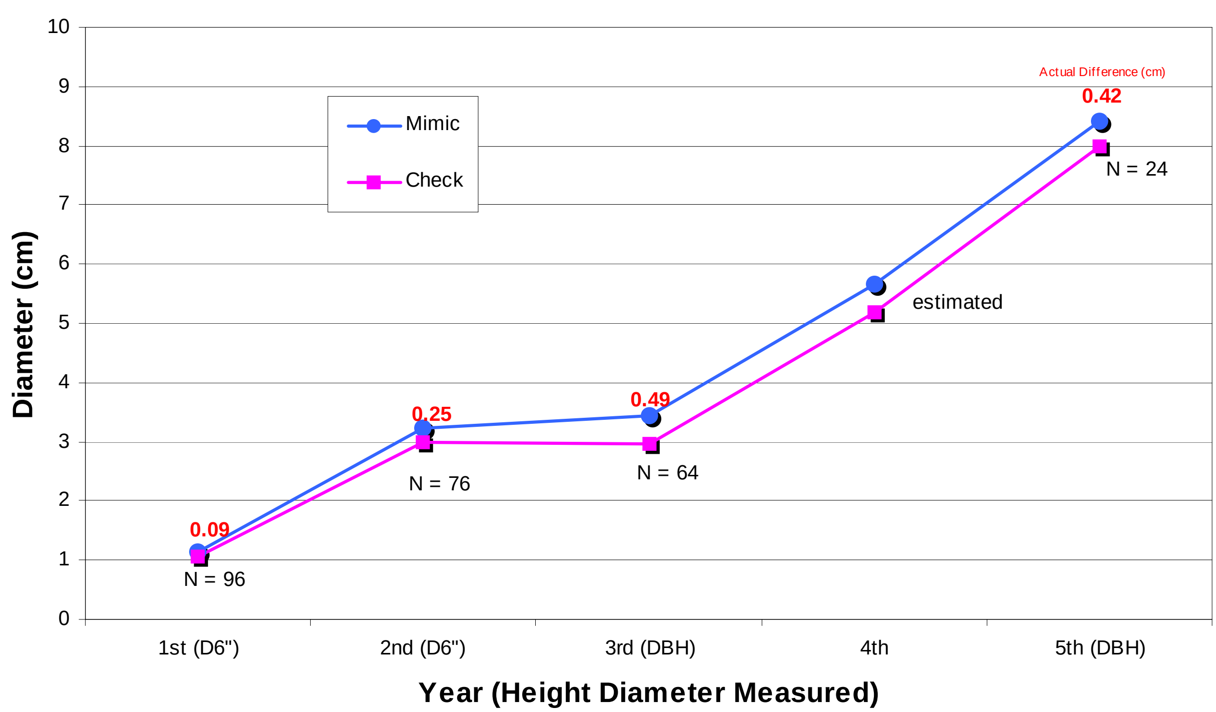


Figure 14. Mean diameter (cm) of one- to five-year old loblolly pine treated with Mimic® compared to untreated trees on all Western Gulf sites: 2001 – 2008.

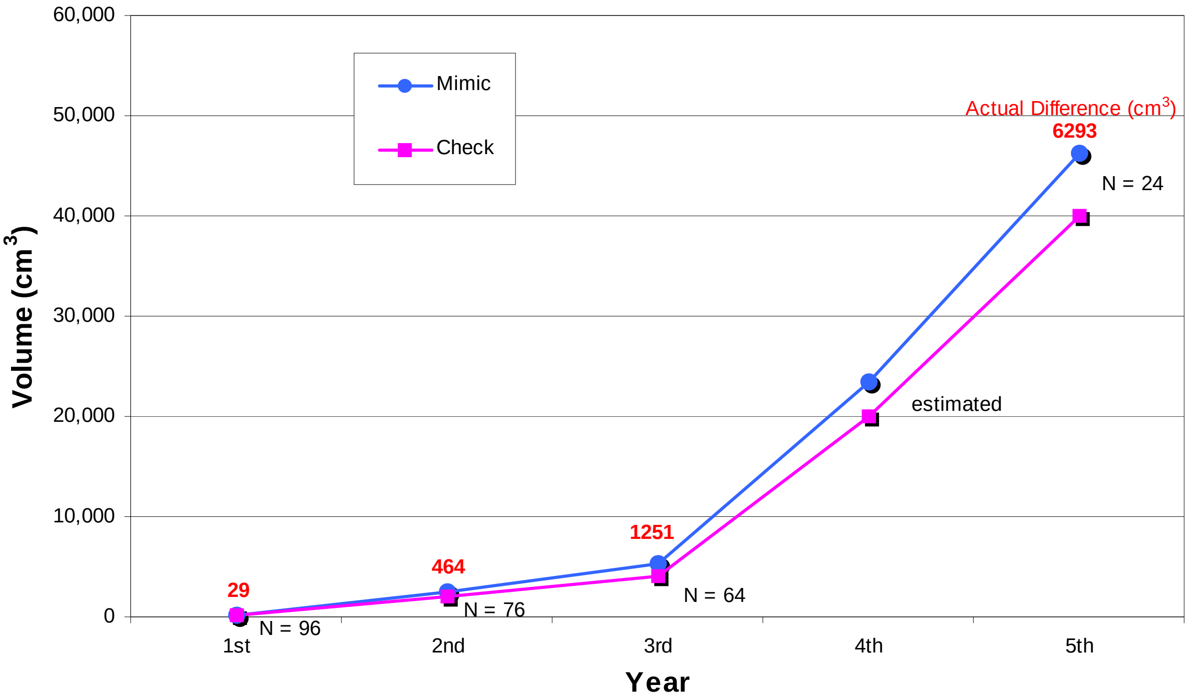


Figure 15. Mean volume index (cm^3) of one- to five-year old loblolly pine treated with Mimic compared to untreated trees on all Western Gulf sites: 2001 – 2008.

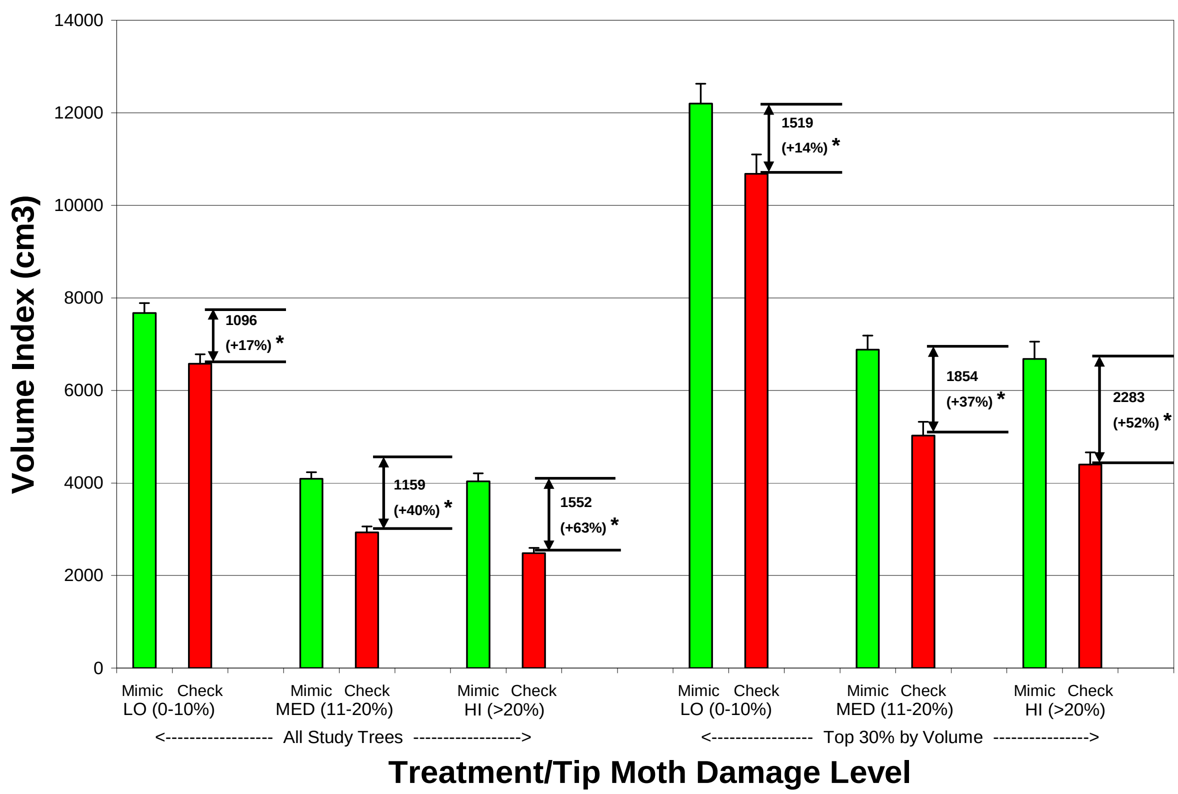


Figure 16. Differences in 3rd-year volume index (cm^3) of protected and unprotected loblolly pine exposed to different tip moth pressures.

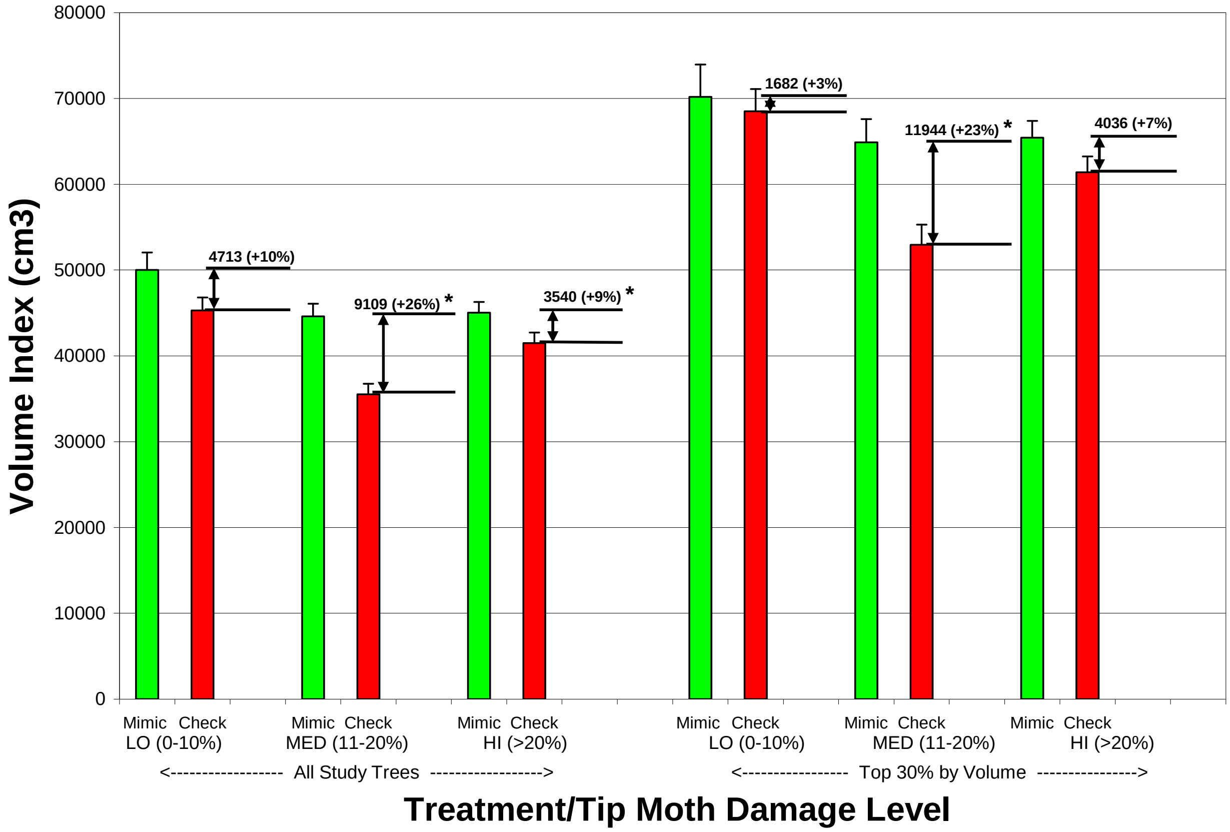


Figure 17. Differences in 5th-year volume index (cm^3) of protected and unprotected loblolly pine exposed to different tip moth pressures

Table 37: 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 each generation in Year 1 and 2; Arkansas, Lousiana, Mississippi and Texas sites, 2001 - 2008.

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

	Planted 2006 (N=29) (N=22)		Planted 2007 (N= 13)		Planted 2008 (N=15) (N=?)		Planted 2009 (N= ?)		Mean Year 1	Mean Year 2
Treatment	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	(N=104)	(N=76)
Mimic®	5.0	13.2	15.5	17.1	4.4				5.2	8.5
Check	14.0	26.0	24.0	47.9	24.0				17.7	25.0
% Reduction	65	49	35	64	82				**70**	**66**

Table 38. 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 - 2008.

Treatment	Mean: Year 1 (N= 9024 trees on 96 sites)	Year 2 (N= 7227 trees on 76 sites)	Year 3 (N= 6124 trees on 64 sites)	Year 5 (N= 2294 trees on 24 sites)
	Height (cm)			
Mimic®	56.1	159	272	561
Check	50.6	144	248	533
Actual Diff. In Growth (cm)	6	15	24	28
Pct. Gain Compared to Check	**11**	**10**	**10**	**5**
	Diameter (cm)			
	at 6"	at 6"	at DBH	at DBH
Mimic®	1.14	3.24	3.45	8.41
Check	1.05	2.99	2.96	7.99
Actual Diff. In Growth (cm)	0.09	0.25	0.49	0.42
Pct. Gain Compared to Check	**9**	**8**	**17**	**5**
	Volume Index (cm^3)			
Mimic®	129	2551	5266	46268
Check	101	2088	4015	39975
Actual Diff. In Growth (cm)	28	464	1251	6293
Pct. Gain Compared to Check	**28**	**22**	**31**	**16**

Volume Index = Height X Diameter^2

Table 39. Differences in fifth-year height, diameter and volume of protected (Mimic-sprayed) and unprotected loblolly pine exposed to different tip moth pressures.

Tip Moth Pressure on Checks	Treatment §	# Sites at Year 3	N Trees	Mean End of Year 5 Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm/tree, cm^3/tree or ft^3/acre) Compared to Check**)								
				Height (cm)			Diameter (cm)			Volume (cm^3/tree)		
Low	Mimic	7	328	567.1	**13.0**		8.53	**0.11**		50006.7	**4712.9**	
(0-10%)	Check		343	554.1			8.42			45293.8		
Med	Mimic	11	524	543.8	**40.7**	*	8.32	**0.76**	*	44621.9	**9109.2**	*
(11-20%)	Check		509	503.1			7.56			35512.7		
3 High	Mimic	6	295	586.3	**27.5**	*	8.43	**0.21**		45033.8	**3540.3**	*
(>20%)	Check		294	558.8			8.23			41493.5		

§ Tip Moth Pressure = average percent of shoots infested during the first two years. Mimic was applied to seedlings before each generation (5X/year) during the first two years.
***** Means followed by an asterik are significantly different from checks at the 5% level based on Fisher's Protected LSD.

Table 40. Differences in third-year height, diameter and volume of protected (Mimic-sprayed) and unprotected loblolly pine exposed to different tip moth pressures.

				Mean End of Year 3 Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm/tree, cm^3/tree or ft^3/acre) Compared to Check**)								
Tip Moth Pressure on Checks	Treatment §	# Sites at Year 3	N Trees	Height (cm)			Diameter (cm)			Volume (cm^3/tree)		
Low	Mimic	21	1014	304.3	**15.4**	*	4.25	**0.28**	*	7673.2	**1095.6**	*
(0-10%)	Check		1011	288.9			3.97			6577.6		
Med	Mimic	26	1209	266.6	**26.5**	*	2.96	**0.52**	*	4092.2	**1158.9**	*
(11-20%)	Check		1227	240.1			2.44			2933.3		
3 High	Mimic	17	801	243.6	**27.5**	*	3.18	**0.68**	*	4037.3	**1552.5**	*
(>20%)	Check		805	216.1			2.50			2484.8		

§ Tip Moth Pressure = average percent of shoots infested during the first two years. Mimic was applied to seedlings before each generation (5X/year) during the first two years.
***** Means followed by an asterik are significantly different from checks at the 5% level based on Fisher's Protected LSD.

PINE TIP MOTH TRIALS

Hazard Rating Study – Western Gulf Region

Highlights:

- Data on site characteristics were collected from 28 plots (15 - first-year and 13 - second-year) in the Western Gulf Region in 2008. In total, 135 hazard-rating plots have been established since 2001.
- Little additional progress was made in 2008 on the development of the hazard-rating model. However, Dr. Dean Coble has agreed to provide assistance in the further development of the model.
- Consolidation of 2001 – 2008 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
Mr. Peter Birks	Weyerhaeuser Co., Columbus, MS
Mr. Bill Stansfield	The Campbell Group, Diboll, TX
Mr. Jeff Hall	Forest Investment Associates, Jackson, MS
Mr. Andy Burrow	Potlatch Forest Holdings, Moscow, ID

Study Sites: FPMC 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, with each plot containing 126 trees (9 rows X 14 trees). The internal 50 trees were evaluated for tip moth damage.

Site Characteristics Data: Site characteristics data collected from 42 Western Gulf plots (15 - first-year and 13 - second-year) in 2008 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 had the expertise the FPMC 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 18 shows the distribution of all 135 hazard-rating sites established in the Western Gulf Region from 2001 to 2008.

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 19).

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 20). Specifically, ìgoodî 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.

Although additional data had been collected, time constraints prohibited Mr. Burrow from running any additional analyses and he had to resign from the project in late 2008. Dr. Dean Coble, Stephen F. Austin & State University, has agreed to provide assistance with future analyses and model development. We are in the process of consolidating all available data (2001 – 2008) for Dr. Coble.

Acknowledgments: We greatly appreciate the efforts of Peter Burk (Weyerhaeuser), Al Cook (independent contractor for International Paper and Plum Creek), Jeff Earl (independent contractor for Plum Creek), Conner Fristoe (Plum Creek), Nick Chappell (Potlatch), Emily Goodwin (Temple-Inland), 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 his time and efforts in the initial model development phase.

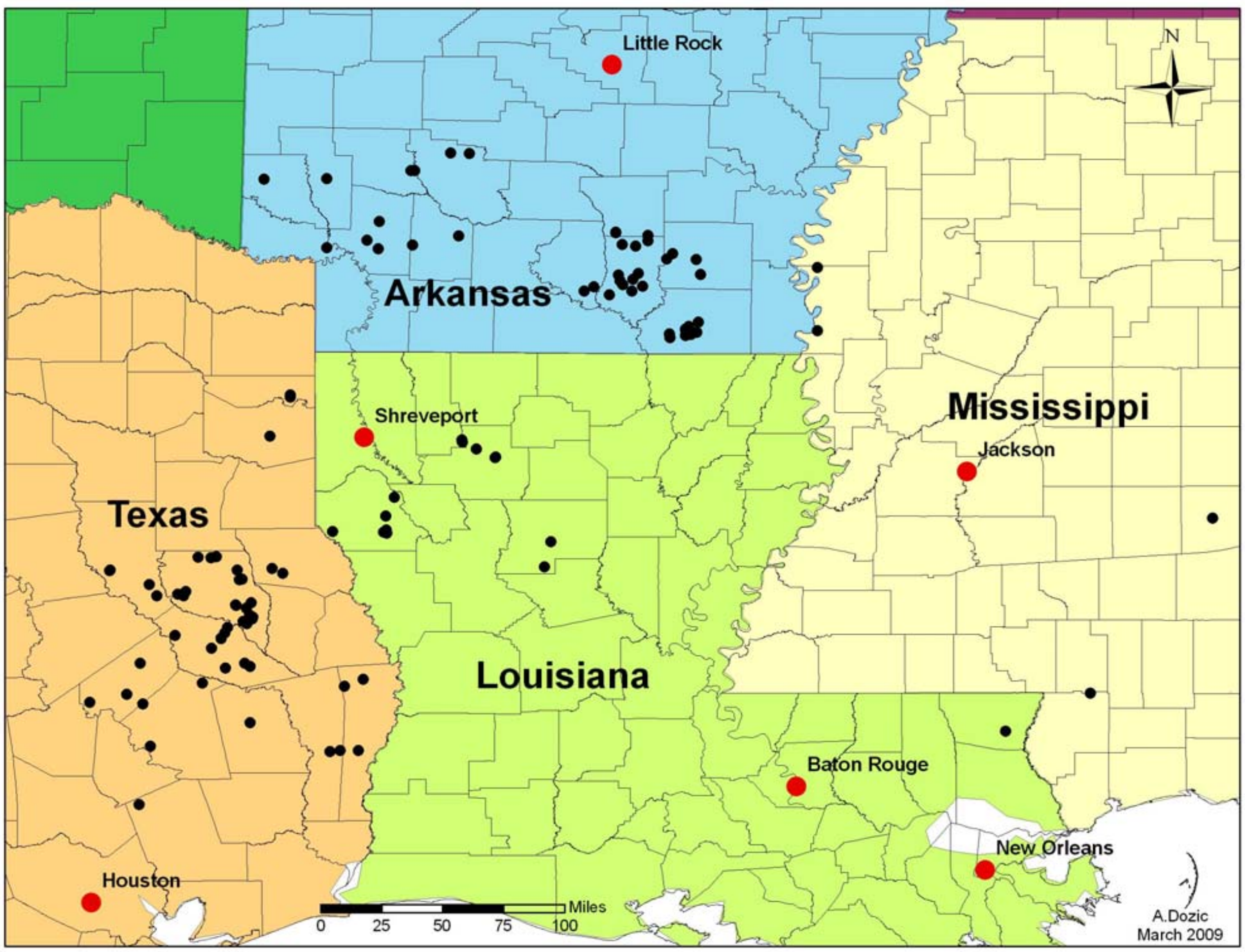


Figure 18. Distribution of 135 hazard-rating plots (●) established from 2001 - 2008 in the Western Gulf Region.

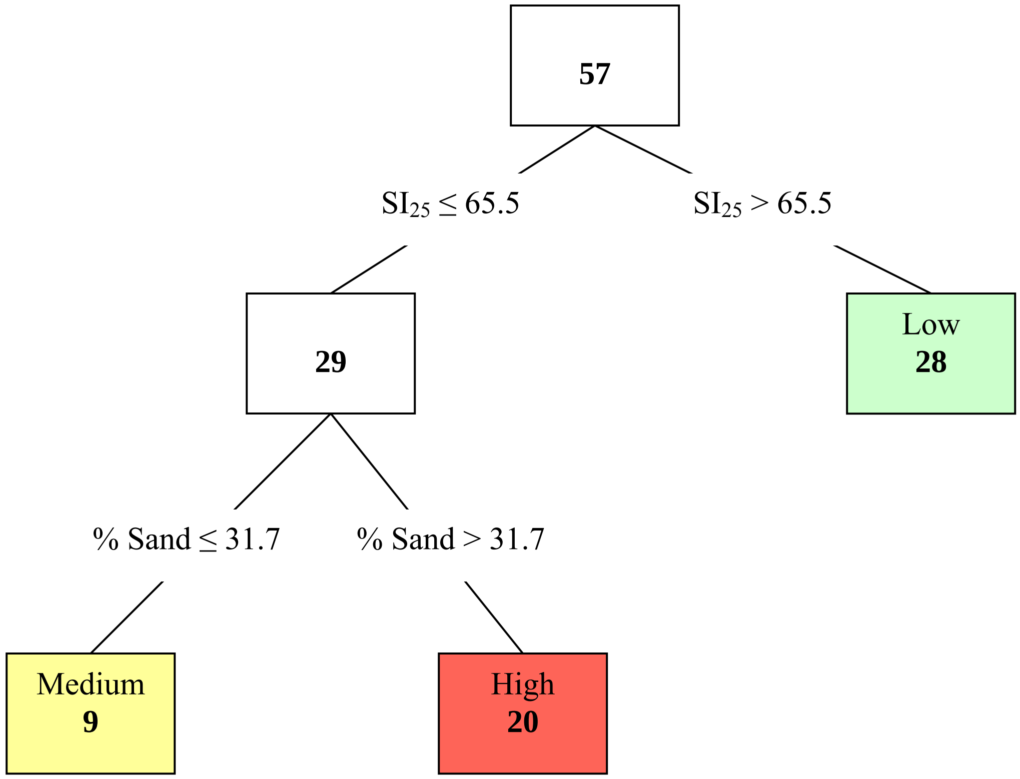
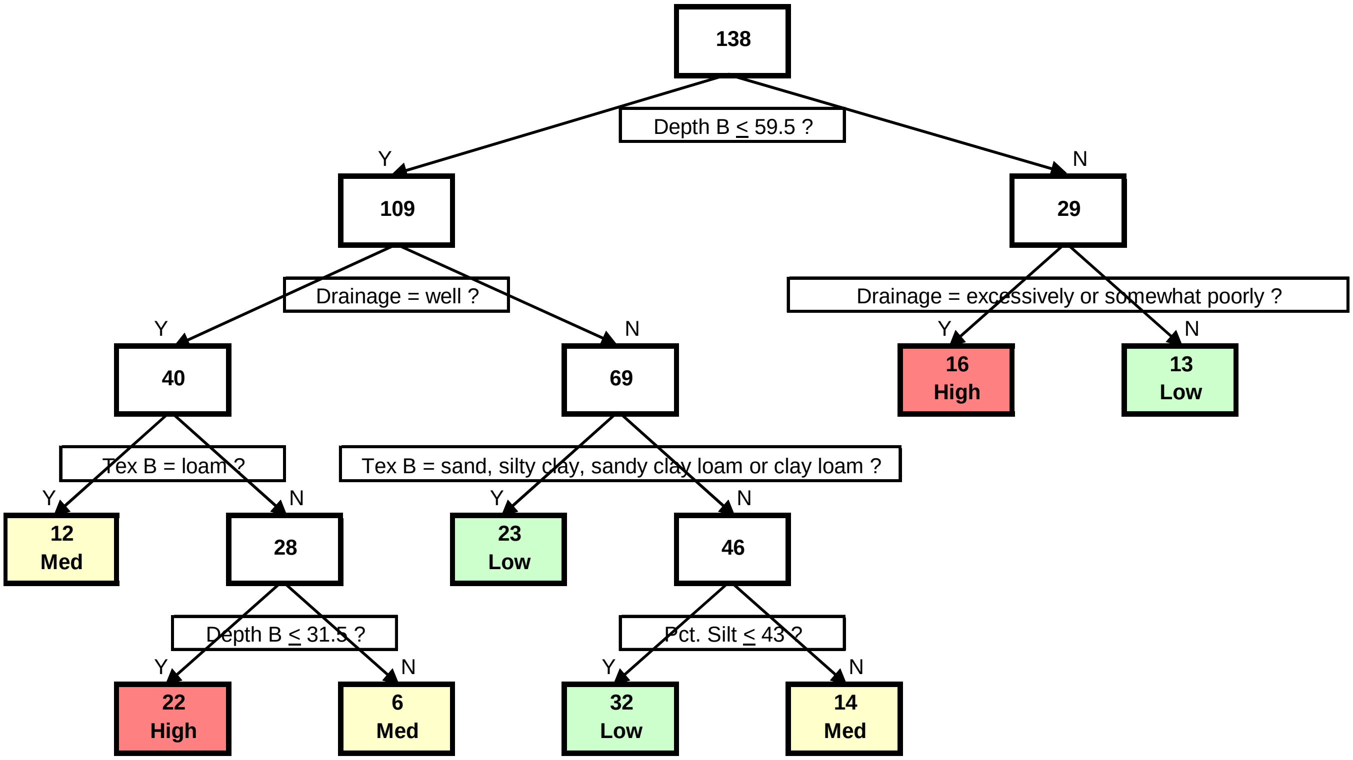


Figure 19. Classification tree describing a hazard rating system for tip moth infestation in one (1) and two (2) year old pine plantations. Bold numbers represent the number of sample points at each node.



Predictor value importance ranking:

Depth to B	100	Percent Sand	68
Texture of B	95	Percent Clay	68
Drainage class	85	Site Index 25	63
Percent Silt	75	Age	45

Hazard Ranking
- Low
- Medium
- High

Figure 20. 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

Evaluation of Fipronil Treatments for Containerized Pine Seedlings

Highlights:

- In 2007, fipronil treatments (1X and 5X) applied to containerized seedlings provided exceptional protection against tip moth throughout the first growing season: 99% and 100% reduction in damage compared to check. Fipronil soil injection to bare root seedlings was less effective, but still reduced damage by 75%. All fipronil treatments significantly improved height, diameter and volume growth
- In 2008, tip population pressures were severe (81 – 100% shoot infestation during generations 4 & 5). Both containerized treatments (1X and 5X) still provided good protection against tip moth through the second growing season: 52% and 65% reduction in damage compared to check. However, effectiveness of the soil injection treatment nearly disappeared after the second generation. Volume growth improvements made by fipronil treatments ranged from 64 – 94%.

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

Cooperators:

Mr. Bill Stansfield	The Campbell Group, Diboll, TX
Dr. Harry Quicke	BASF Co., Auburn, AL

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

Insecticides:

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

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 Check (untreated)	
4) Bare Root Fipronil (12 ml/seedling) -	Soil injection next to transplant in March
5) Bare Root Single Mimic® Foliar -	Mimic® applied 5X /year
6) Bare Root Check (untreated)	

Research Approach:

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

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

Treatment Evaluation: Tip moth damage was evaluated on 50 seedlings located on the interior of each plot after each tip moth generation (3-4 weeks after peak moth flight) by 1) identifying if the tree was infested or not, 2) if infested, the proportion of tips infested on the top whorl and terminal was calculated; and 3) separately, the terminal was identified as infested or not. Observations also were made as to the occurrence and extent of damage caused by other insects, i.e., aphids, weevils, coneworms, etc. The trees were measured for height and diameter (at 6") in December following planting. Data were analyzed by GLM and the Fisher's Protected LSD test using Statview or SAS statistical programs.

Results: In 2007, tip moth populations were quite low on both sites during the first generation; $\leq$ 2% of the shoots were infested on check trees. As a result of the low tip moth pressure, none of the treatments significantly reduced tip moth infestation of top whorl shoots compared to the check during the first generation (Table 41). 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 41). However, the Mimic spray treatment had no apparent effect on any of the growth parameters compared to check trees.

In 2008, tip moth population pressure was much greater, with an average of >90% of the top-whorl shoots infested on check trees during the 4th and 5th generations and a mean of >57% shoots infested over the entire growing season (5 generations) (Table 42). Efficacies of the two fipronil containerized treatments declined through the second year, but the treatments were able to still reduce overall damage by 52 – 65%. The soil injection treatment only slightly reduced tip moth damage after the second generation. All treatments significantly improved height, diameter and volume index compared to check trees (Tables 43). Volume growth improvements attributed to fipronil treatments ranged from 64 – 94%. Protection from Mimic actually improved with the application of new product and crop oil surfactant, thus the effect of spray treatment on all growth parameters becomes significant compared to check trees.

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

Table 41. Effect of fipronil application technique and rate on pine tip moth infestation of loblolly pine shoots after each of 5 generations on two sites in East Texas - 2007.

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

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

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

Table 42. Effect of fipronil application technique and rate on pine tip moth infestation of loblolly pine shoots after each of 5 generations on two sites in East Texas - 2008.

Mean Percent of Loblolly Pine Shoots Infested (**Pct. Reduction Compared to Check**)

Treatment §	N	Generation 1 Ang.	Generation 1 Polk	Generation 1 Mean		Generation 2 Ang.	Generation 2 Polk	Generation 2 Mean		Generation 3 Ang.	Generation 3 Polk	Generation 3 Mean	
Containerized FIP 3 ml	200	4.7 *	12.0 *	8.3 *	**65**	13.0 *	10.1 *	11.6 *	**73**	16.3 *	32.4 *	24.3 *	**61**
Containerized FIP 15 ml	200	3.8 *	11.1 *	7.4 *	**69**	4.5 *	8.9 *	6.7 *	**84**	10.9 *	31.2 *	21.0 *	**66**
Containerized Check	200	23.5	24.1	23.8		46.6	39.9	43.2		50.0	73.2	61.6	
BR FIP SI 12 ml	100	11.2	15.1	13.1	**29**	33.0	15.2 *	24.1 *	**34**	43.5	46.9 *	45.2	**6**
BR Mimic	100	8.0 *	8.8 *	8.4 *	**54**	11.0 *	3.6 *	7.3 *	**80**	17.9 *	7.1 *	12.5 *	**74**
BR Check	100	15.9	20.9	18.4		37.4	35.8	36.6		36.5	59.8	48.2	

Treatment §	N	Generation 4 Ang.	Generation 4 Polk	Generation 4 Mean		Generation 5 Ang.	Generation 5 Polk	Generation 5 Mean		Mean Ang.	Mean Polk	Mean Mean	
Containerized FIP 3 ml	200	23.8 *	70.4 *	47.1 *	**48**	39.8 *	70.1 *	57.3 *	**37**	20.5 *	39.1 *	29.8 *	**52**
Containerized FIP 15 ml	200	15.0 *	51.6 *	33.2 *	**63**	23.2 *	61.0 *	44.1 *	**52**	11.9 *	32.4 *	22.1 *	**65**
Containerized Check	200	82.0	98.4	90.2		77.9	97.2	91.3		57.8	66.9	62.4	
BR FIP SI 12 ml	100	86.3	95.0	90.7	**0**	65.7 *	93.0	82.7 *	**12**	49.4	53.0 *	51.2 *	**11**
BR Mimic	100	34.3 *	15.3 *	24.8 *	**73**	30.9 *	30.6 *	33.0 *	**65**	20.9 *	12.7 *	16.8 *	**71**
BR Check	100	81.4	100.0	90.7		83.0	96.0	94.1		52.7	62.8	57.6	

§ SI- Fipronil soil injection

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

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

Table 43. Effect of fipronil application technique and rate on loblolly pine growth during the first years on two sites in East Texas - 2007 & 2008.

			Mean End of Season Tree Measurements (**Growth Difference (cm or cm^3) Compared to Check**)														
Year	Treatment	N	Height (cm)					Diameter (cm)					Volume (cm^3)				
			Ang.	Polk	Mean			Ang.	Polk	Mean			Ang.	Polk	Mean		
2007	Containerized FIP 3 ml	100	78.2	93.0	85.6	**16.6**	*	1.31	1.53	1.42	**0.27**	*	165.3	248.7	207.0	**86.9**	*
	Containerized FIP 15 ml	100	77.9	97.0	87.4	**18.4**	*	1.21	1.76	1.49	**0.33**	*	146.7	353.8	250.2	**130.1**	*
	Containerized Check	100	57.6	80.4	69.0			0.96	1.35	1.16			75.8	165.6	120.2		
	BR FIP SI 12 ml	50	64.9	95.2	80.1	**12.4**	*	1.35	1.88	1.62	**0.39**	*	193.4	409.9	301.6	**160.4**	*
	BR Mimic	50	69.3	86.7	78.0	**10.4**		1.35	1.65	1.50	**0.28**		179.5	294.1	236.8	**95.6**	
	BR Check	50	51.0	84.3	67.6			0.94	1.50	1.22			62.4	220.1	141.2		
2008	Containerized FIP 3 ml	100	137.6	163.1	150.3	**29.4**	*	2.59	3.36	2.97	**0.48**	*	1127.2	2130.8	1629.0	**634.4**	*
	Containerized FIP 15 ml	100	132.0	177.6	154.7	**33.7**	*	2.51	3.65	3.08	**0.59**	*	1091.3	2768.3	1925.6	**931.0**	*
	Containerized Check	100	104.6	137.4	121.0			1.99	2.99	2.49			607.9	1381.3	994.6		
	BR FIP SI 12 ml	50	130.1	176.2	153.1	**33.2**	*	2.50	3.84	3.17	**0.55**	*	1264.5	3027.6	2146.0	**915.9**	*
	BR Mimic	50	149.4	181.2	165.3	**45.4**	*	2.85	3.68	3.27	**0.65**	*	1658.1	2853.7	2255.9	**1025.8**	*
	BR Check	50	92.0	149.0	119.9			1.83	3.43	2.62			423.2	2070.6	1230.1		

***** 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 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 - 51% compared to check trees. Only the shallow (4") soil injection and Mimic® spray treatments significantly improved tree growth.

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

Cooperators

Dr. Harold Quicke	BASF, Auburn, AL
Ms. Francis Peavy	Private landowner, Hudson, TX

Study Sites: A one-year-old plantation (planted in 2007) near Hudson, Texas, was selected. The plots contained 6 treatments and 300 trees (5 rows X 50 trees).

Insecticides:

Fipronil – PTM® SC Insecticide (0.9 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 site X 6 treatments X 50 trees = 300 monitored trees.

Treatments:

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

Treatment Methods: A 1-acre (approximate) area within each site was selected. A randomized complete block design was established with beds (or rows of trees) serving as blocks, i.e., each treatment was randomly selected for placement along a bed. Fifty trees for each treatment were selected on each site. Ten trees were assigned a given treatment on each of five beds (see Plot Design Example). The fipronil soil injection treatments were applied 13 February 2008

All soil injection treatments were applied in February 2008 using the PTM 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 the 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; 5 generations in TX) by 1) identifying if the tree was infested or not, 2) if infested, the proportion of tips infested on the top whorl and terminal were calculated; and 3) separately, the terminal was identified as infested or not. Each tree was measured for diameter (at 6") and height in winter 2008.

Results:

In 2008, tip moth populations were quite high throughout the year with damage levels ranging from 14% of the shoots infested on check trees after generation 1 to >80% after the 5th generation (Table 42). As a result of the late treatment application date, none of the soil injection treatments significantly reduced tip moth infestation of top whorl shoots compared to the check during the first generation. However, all fipronil treatments, regardless of depth or placement, provided moderate to good protection against tip moth during 2nd, 3rd, 4th and 5th generations. Overall reduction in damage compared to checks ranged from 45% to 51%. None of the fipronil treatments negatively affected seedling survival after 5 generations. On Peavy 1, none the treatments significantly improved tree growth parameters (height, diameter or volume index) compared to check trees (Table 43 & 44). In contrast, growth (height, diameter & volume) was significantly greater for shallow (4î) soil injection treatments and Mimic.

Acknowledgments: Thanks go to Ms. Francis Peavy for providing research sites. We also thank Dr. Harry Quicke, BASF, for providing the fipronil formulation, PTM™ SC Insecticide, for the project.

Table 1. Effect of fipronil application depth and placement on pine tip moth infestation of loblolly pine shoots after each of 5 generations on two sites in East Texas - 2008.

Treatment §	N	P 1	P 2	Mean		P 1	P 2	Mean		P 1	P 2	Mean	
		Mean Percent of Loblolly Pine Shoots Infested (**Pct. Reduction Compared to Check**)											
		Generation 1				Generation 2				Generation 3			
Single 12 ml SI @ 4" depth	100	12.8	17.9 *	15.2	**27**	13.3 *	27.3 *	20.3 *	**50**	13.5 *	14.2 *	13.9 *	**67**
Single 12 ml SI @ 8" depth	100	12.7	25.8	19.3	**8**	15.2 *	31.0 *	23.2 *	**42**	10.0 *	18.9 *	14.5 *	**65**
Double 6 ml SI @ 4" depth	100	11.6	26.2	18.9	**9**	11.4 *	24.9 *	18.1 *	**55**	8.3 *	16.9 *	12.6 *	**70**
Double 6 ml SI @ 8" depth	100	15.9	16.7 *	16.3	**22**	14.4 *	26.1 *	20.3 *	**50**	8.4 *	24.6 *	16.5 *	**61**
Mimic	100	2.8 *	3.9 *	3.3 *	**84**	18.7 *	23.1 *	20.9 *	**48**	6.0 *	9.6 *	7.7 *	**82**
Check	100	14.1	27.7	20.9		33.3	47.4	40.3		29.2	55.2	42.1	
		Generation 4				Generation 5				Mean			
Single 12 ml SI @ 4" depth	100	28.7 *	38.7 *	33.7 *	**51**	37.0 *	39.3 *	38.1 *	**49**	21.0 *	27.8 *	24.4 *	**51**
Single 12 ml SI @ 8" depth	100	31.5 *	36.1 *	33.9 *	**51**	45.6 *	44.5 *	45.1 *	**40**	23.0 *	31.3 *	27.2 *	**45**
Double 6 ml SI @ 4" depth	100	20.3 *	37.7 *	28.9 *	**58**	31.0 *	51.0 *	41.0 *	**45**	16.7 *	31.2 *	24.0 *	**51**
Double 6 ml SI @ 8" depth	100	36.9 *	39.7 *	38.3 *	**44**	38.4 *	51.9 *	45.2 *	**40**	22.5 *	31.9 *	27.2 *	**45**
Mimic	100	4.0 *	2.1 *	3.1 *	**96**	5.7 *	3.1 *	4.4 *	**94**	7.6 *	8.4 *	8.0 *	**84**
Check	100	62.3	75.1	68.7		68.9	81.1	74.9		41.5	57.3	49.4	

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

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

Table 43. Effect of fipronil application depth and placement on loblolly pine growth 8 months after treatment on two sites in East Texas - 2007.

Treatment	N	Mean End of Season Tree Measurements (**Growth Difference (cm or cm3) Compared to Check**)											
		Height (cm)				Diameter (cm)				Volume (cm^3)			
		P1	P2	Mean		P1	P2	Mean		P1	P2	Mean	
Single 12 ml SI @ 4" depth	100	157.1	115.6 *	136.6 *	**8.2** *	3.43	2.50	2.97	**0.14**	2066.5	833.3 *	1456.1 *	**15**
Single 12 ml SI @ 8" depth	100	140.2	106.7	123.3	**-5.1**	3.14	2.27	2.70	**-0.13**	1675.8	666.0	1165.8	**-275**
Double 6 ml SI @ 4" depth	100	156.9	118.7 *	137.8 *	**9.4** *	3.52	2.56 *	3.04 *	**0.21** *	2136.1	887.3 *	1511.7 *	**71**
Double 6 ml SI @ 8" depth	50	158.8	108.8	133.6	**5.2**	3.60	2.33	2.96	**0.12**	2438.3	654.5	1537.2	**96**
Mimic	50	148.7	115.6 *	142.1 *	**13.7** *	3.28	3.00 *	3.14 *	**0.31** *	1890.3	1349.2 *	1619.8 *	**179**
Check	50	153.2	103.1	128.4		3.38	2.28	2.83		2242.2	623.4	1441.0	

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

Table 3. Effect of fipronil application depth and placement on loblolly pine growth 8 months after treatment on two sites in East Texas - 2007.

Treatment	N	Mean 2nd Year Height Growth (**Growth Difference (cm or cm3) Compared to Check**)			
		P1	P2	Mean	
Single 12 ml SI @ 4" depth	100	87.1	68.0	77.6 *	**5.1**
Single 12 ml SI @ 8" depth	100	74.7	63.5	69.0	**-3.6**
Double 6 ml SI @ 4" depth	100	88.6	70.6 *	79.6 *	**7.0**
Double 6 ml SI @ 8" depth	100	88.3	62.9	75.5	**2.9**
Mimic	100	79.1	80.7 *	79.9 *	**7.3**
Check	100	84.3	60.6	72.6	

* 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 Region

Highlights:

- Fipronil, applied via the machine planter, was successfully used to treat a series of plots on five sites over two years. The machine-applied fipronil treatment was effective in reducing tip moth damage by an average of 58%. The hand-applied fipronil was generally less effective than the machine application.
- Fipronil applied by hand and SilvaShield™ Forestry Tablets were nearly equal in efficacy against tip moth. However, only the fipronil treatment applied by hand improved tree growth.

Objective: 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. Wilson Edwards	Weyerhaeuser Co., New Bern, NC
Mr. Randy Winston,	Private landowner, Lufkin, TX
Ms. Lou Ann Miller	Private landowner, Nacogdoches, TX
Mr. Jim Rogers and Mr. Lane Day	Precision Machine Services, Lufkin, TX
Dr. Harry Quicke	BASF Co., Auburn, AL

Study Sites: Two first-year plantations were selected in Texas near Lufkin and Nacogdoches in November 2006 and one in AR near Oak Grove, in February 2007. Two other were selected and planted in early 2008, one near Many, Louisiana and the other near Mineral Springs, Arkansas.

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:

Sites 1, 2 & 3:

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).

Sites 4 & 5:

<u>Main plots</u>

1) MF = seedlings machine planted with fipronil applied at 0.1g active ingredient (in 37 ml water) per seedling as they are planted.
2) MC = seedlings machine planted; no additional treatment (Check).

<u>Subplot</u>

3) MFS = seedlings machine planted; afterwards foliar spray (Pounce® or Mimic®2LV (0.6 ml / liter of water)) applied (5X)
4) MW = seedlings machine planted with 37 ml water per seedling.
5) HF = seedlings hand planted; afterwards fipronil applied at 0.1 g active ingredient (in 12 ml water) per seedling using a Kioritz or PTM Spot gun.
6) HSS = seedlings hand planted; afterwards one SilvaShield Forestry Tablet was pushed into the soil 4" deep next to each seedling.
7) HC = seedlings hand planted; no additional treatment (Check)

Research Approach:

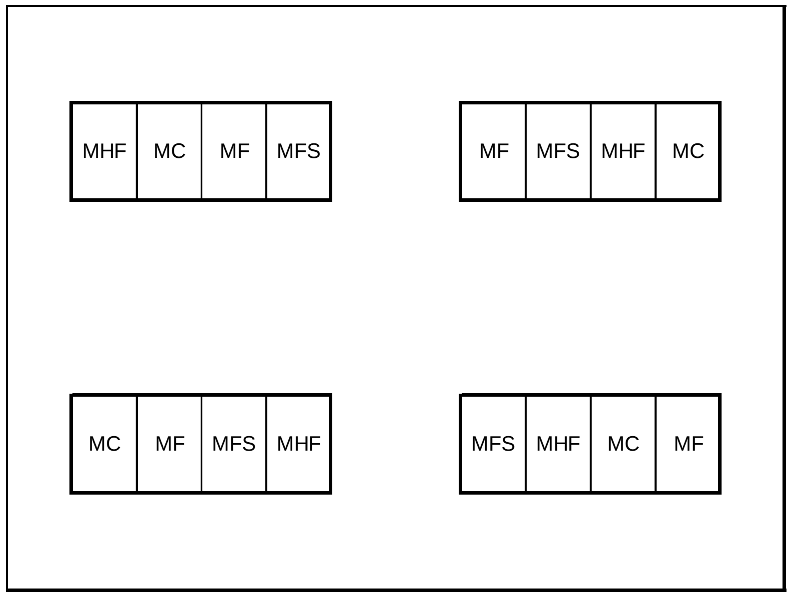
A single family of loblolly pine containerized seedlings was selected at International Paper's Nursery in Bullard, AR for sites 1 & 2 in 2007. For site 3, 4 & 5, Weyerhaeuser's bare root loblolly pine seedlings from Magnolia, AR were used. Seedlings were lifted in February in a manner to cause the least breakage of roots, culled of small and large caliper seedlings, root-sprayed with clay slurry, bagged and stored briefly in cold storage.

When ready, seedlings were hand- or machine-planted (spacing was 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 Texas, Arkansas or Louisiana based on uniformity of soil, drainage and topography in each pair of stands. All tracts were intensively site prepared, i.e., subsoiled, bedded, and/or treated with herbicide.

At sites 1, 2 & 3, four replicates of 4 – 0.5 acre plots (16 plots total) were established in 2007 (Fig. 21). A soil injection system (designed by Lane Day and Jim Rogers, Precision Machine Services, Lufkin, TX in cooperation with the FPMC), was installed on a C&G planter (owned by Acorn Outdoor Services, Lufkin, TX). The planter was fitted with a 50-gallon tank, electrical pump, tubing and valves (Figs. 23 – 25). 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. On 4 preselected plots, the fitted machine planter 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 modified cattle drencher (Figs. 26 & 27) or with a foliar spray (5X / year).

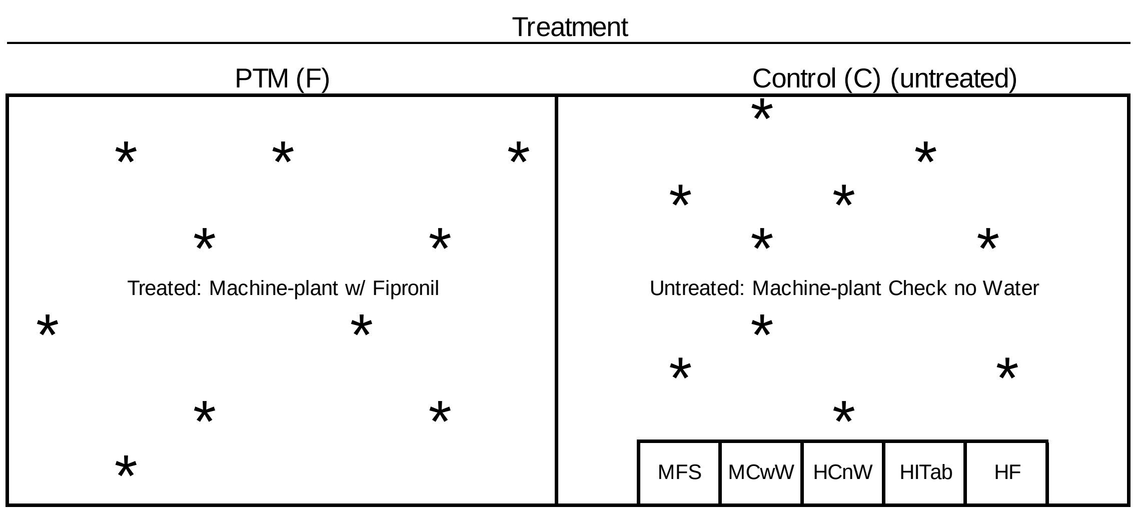
To evaluate the effects of treatment on large area tip moth damage levels over a large area, a randomized complete block design, with sites as blocks, was used in 2008 (Figure 22). Plantations at sites 4 & 5 were divided in half. One half was operationally machine planted without additional treatment. On the other half, the fitted C&G planter was again used to treat containerized seedlings with PTM (fipronil) as they were planted in furrows. To further evaluate the effects of treatment on



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 21. Generalized Plot Design for two Texas sites established in December 2006 and one Arkansas site established in February 2007.



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

Sub-Plot Treatments:

MFS = Machine-plant + Foliar spray;
MCwW = Machine-plant Check with Water;
HCnW = Hand-plant Check no Water;
HITab = Hand-plant + Imid Tablet;
HF = Hand-plant + PTM

Figure 22. Generalized Plot Design for one Louisiana and one Arkansas sites established in February 2008.

Figure 23. Machine planter and injection system on Winston tract, Lufkin, TX

Figure 24. Injection system (tank, pump and battery power) fitted to top of machine planter.

Figure 25. Dispensing fipronil solution from tubing in planter sleeve.

Figure 26. Jason Helvey with Kioritz soil injector.

Figure 27. Bill Upton with modified drencher applicator.

tip moth damage levels, a subplot was measured. At each site, four 0.5 acre plots were established. Each treatment was randomly assigned to one of the four internal plots in each main treatment plot half.

The sites and cooperators included:

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

Tip moth damage was evaluated at all 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 (@ 6î) 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:

Sites 1, 2 & 3 - 2007: Initially, tip moth damage on check trees was low (2%) but climbed to fairly high levels by the 4th 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 did 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).

2008: Tip moth damage on check trees was much higher with averages ranging from 18% of shoots infested during the 1st generation to 73% by the 5th generation (Table 44). The machine- and hand-applied fipronil treatments were nearly equal in their effectiveness in reducing tip moth damage (45% and 40%, respectively) compared to the check. All treatments (both fipronils and Mimic®) significantly improved all growth parameters compared to the check. The Mimic® treatment provided the greatest improvements overall (Tables 45).

Sites 4 & 5 - 2008: Initially, tip moth damage on check trees was low (1-2%) but increased to fairly high levels by the 4th generation (15-45%) (Table 46). On the main plots, the machine-applied fipronil was effective in reducing tip moth damage (50%) compared to the check at the Many site, but showed little effect at Mineral Springs. In the subplots, the fipronil applied by hand and SilvaShield tablet were nearly equal in effectiveness and both significantly reduced damage (54%). All treatments (fipronils and Mimic®) except SilvaShield significantly improved height growth compared to the check (Tables 47).

Conclusions: The data (2007 & 2008) from Sites 1-5 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 uptake and 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 Arkansas. Thanks also go to Mr. Randy Winston and Ms. Lou Ann Miller for providing additional research sites in Texas. 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 44. Effect of fipronil (FIP) 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 & 2008.

Year	Treatment §	N	Gen 1			Gen 2			Gen 3			Gen 4**			Gen 5			Mean**		
			Mean Percent of Loblolly Pine Shoots Infested (**Pct. Reduction Compared to Check**)																	
2007	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		
2008	Machine FIP	500	8.6	**51**	*	15.6	**54**	*	14.2	**55**	*	33.2	**49**	*	47.2	**35**	*	23.4	**45**	*
	Machine + Hand FIP SI	494	8.6	**51**	*	19.4	**43**	*	13.9	**56**	*	29.2	**55**	*	49.8	**32**	*	25.4	**40**	*
	Machine + Mimic Spray	499	4.7	**73**	*	13.3	**61**	*	12.3	**62**	*	13.2	**80**	*	34.0	**53**	*	16.6	**61**	*
	Machine Only (Check)	499	17.7			33.9			32.0			64.5			73.0			42.6		

§ 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.

** Winston and Miller sites only

Table 45. Effect of fipronil (FIP) application technique on loblolly pine growth parameters after the first and second year on three sites in East Texas and Southwest Arkansas - 2007 & 2008

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 SI	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		
2008	Machine + FIP	550	131.0	*	**16.5**	2.56	*	**0.23**	1168	*	**242.0**
	Machine + Hand FIP SI	550	126.8	*	**12.3**	2.52	*	**0.18**	1031	*	**105.0**
	Machine + Mimic Spray	550	147.5	*	**33.0**	2.92	*	**0.59**	1691	*	**765.0**
	Machine + Check	550	114.5			2.33			926		

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

Table 46. Effect of fipronil application depth and placement on pine tip moth infestation of loblolly pine shoots after each of 5 generations on two sites (Many, LA and Mineral Springs, AR) - 2008.

Treatment §	N	Mean Percent of Loblolly Pine Shoots Infested (**Pct. Reduction Compared to Check**)											
		Many	MS	Mean		Many	MS	Mean		Many	MS	Mean	
		Generation 1				Generation 2				Generation 3			
Machine FIP	200	1.4 *	0.2	0.8 *	**95**	4.3 *	20.5	12.4 *	**39**	8.8 *	21.9	15.4	**23**
Machine Only (Check)	200	5.2	0.0	2.6		14.2	26.3	20.3		17.4	22.3	19.9	
Machine + Mimic	100	1.2	0.0	0.6 #	**51**	3.5	20.2	11.8	**-33**	2.2 *	35.7 *	18.9	**-29**
Machine + water	100	6.5	0.0	3.3 #	**-171**	5.9	18.5	12.2	**-38**	20.2	41.3 *	30.8 *	**-109**
Hand FIP SI	100	1.0	0.0	0.5 #	**58**	0.5	14.6	7.6	**15**	3.7 *	9.8	6.7	**54**
Hand + SS Tablet	100	0.0	0.0	0.0 #	**100**	0.0	7.0	3.5	**61**	1.1 *	16.3	8.7	**41**
Hand (Check)	100	2.4	0.0	1.2		3.7	14.8	8.9		13.8	15.9	14.7	
		Generation 4				Generation 5				Mean			
Machine FIP	200	15.4 *		15.4 *	**42**	12.4 *	14.5	13.4 *	**36**	8.5 *	14.3	11.4 *	**33**
Machine Only (Check)	200	26.5		26.5		22.0	19.9	20.9		17.0	17.1	17.1	
Machine + Mimic	100	4.4 *		4.4 *	**82**	3.3 *	45.8 *	24.6	**22**	2.9 *	25.4 *	14.2	**0**
Machine + water	100	21.5		21.5	**10**	20.1 *	40.3 *	30.2	**4**	14.8 *	25.0 *	19.9 *	**-41**
Hand FIP SI	100	10.5 *		10.5 *	**56**	4.0 *	10.5	7.2 *	**77**	3.9 *	8.7	6.3 *	**55**
Hand + SS Tablet	100	2.2 *		2.2 *	**91**	3.7 *	23.7	13.7 *	**57**	1.4 *	11.7	6.6 *	**54**
Hand (Check)	100	23.9		23.9		45.4	15.3	31.5		17.8	9.9	14.2	

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

Table 47. Effect of fipronil application technique on loblolly pine growth 8 months after treatment on two sites (Many, LA and Mineral Springs, AR) - 2008.

Treatment	N	Mean End of Season Tree Measurements (**Growth Difference (cm or cm^3) Compared to Check**)											
		Height (cm)				Diameter (cm)				Volume (cm^3)			
		Many	MS	Mean		Many	MS	Mean		Many	MS	Mean	
Machine FIP	200	48.9	42.6 *	45.7 *	**3.4**	0.83	0.81	0.82 *	**0.14**	43.1	34.8 *	38.9 *	**11.4**
Machine Only (Check)	200	48.2	36.4	42.3		0.77	0.60 *	0.68		38.7	16.3	27.5	
Machine + Mimic	100	45.2 *	40.2 *	42.7 *	**5.8**	0.86	0.89 *	0.88 *	**0.19**	42.4	39.3 *	40.8 *	**16.9**
Machine + water	100	55.1 *	39.0	47.1 *	**10.1**	1.03 *	0.77 *	0.90 *	**0.21**	70.3 *	28.9 *	49.6 *	**25.7**
Hand FIP SI	100	38.6	47.9 *	43.2 *	**6.3**	0.76	0.87 *	0.82 *	**0.13**	31.3	43.3 *	37.3 *	**13.4**
Hand + SS Tablet	100	39.9	32.9	36.4	**-0.5**	0.79	0.61	0.70	**0.01**	32.7	16.6	24.7	**0.8**
Hand (Check)	100	38.8	34.7	36.9		0.80	0.56	0.69		32.6	13.8	23.9	

* 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 Region

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 sixth year.
- All imidacloprid treatments (tablet, gel & granular), applied in 2006, provided good to excellent protection through the second year; reducing overall damage levels by 60 – 93%. Differences between treated and untreated trees for height, diameter and volume continued to expand through the third year.
- All imidacloprid tablet treatments, applied in 2007, significantly reduced tip moth damage levels on nearly all sites through the second year. The tablets significantly improved growth parameters on four of six sites.
- All imidacloprid tablet treatments, applied in 2008, significantly reduced tip moth damage levels on all sites through the first year. The tablets only improved growth parameters on sites treated after planting and tree growth improved with higher rates.

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 or resident seedlings; 3) determine the effect of imidacloprid alone or combined with fertilizer on seedling growth; and 4) determine the duration of chemical activity.

Cooperators:

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

Study Sites: In 2003, one second-year plantation was selected near Huntington, Texas 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, Texas. In 2006, a second-year site was selected near Winnfield, Louisiana. In 2007, 6 second-year sites were selected in TX (2 near Colmesneil), Mississippi (near Millard) and Arkansas (1 each near Crossroads, Warren and Crossett). Second-year plantations were used in the study because tip moth populations are usually well established at this age, increasing the likelihood that significant tip moth pressure would be placed on treated seedlings. The plots contained 4 - 11 treatments with 50 trees per treatment. In 2008, two separate trials were established on three sites in Texas.

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

2008 Trial 2:

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

Research Approach:

In all research years (2003 – 2008), a single family of loblolly pine bare root seedlings was selected at the Texas Forest Service Indian Mounds Nursery, Alto, Texas or ArborGen SuperTree Nursery, Livingston, Texas. All seedlings were operationally lifted by machine in January or February, culled of small and large caliper seedlings, treated with Terrasorb™ or clay slurry root coating, bagged and stored briefly in cold storage.

Fifty seedlings for each treatment were planted (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 2008, a lance was used to make a 4” or 8” deep hole. The tablet(s) was then dropped in the hole. In 2005 - 2008, one to three tablets were dropped into the plant hole just prior to placement of the seedling in the same 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 Fisher’s Protected LSD using Statview statistical programs.

Results:

<u>Insecticide/fertilizer spikes</u>

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 (Table 49). 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 had 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 (Table 49). 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.

In 2007 and 2008, insecticide/fertilizer treatments again had significantly greater height, diameter and volume growth compared to check trees (Table 49). 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 formulations (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 50). 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 51). 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 50). Most treatments containing imidacloprid alone or combined with fertilizer provided good protection through the 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 51). Only the MeritÆ balls (1X and 2X) applied in plant holes significantly improved tree height compared to check trees.

Again in 2008, only the MeritÆ balls (1X and 2X) applied in plant holes significantly improved tree height compared to check trees (Table 51). In addition, several treatments (all tablet treatments, ImidFip Combo, ConfidorÆ and fertilizer alone) showed significant gains in diameter and volume growth.

Imidacloprid Tablets (2007)
In 2007, tip moth populations were quite variable across the six sites with mean percent shoots infested on checks ranging from 0% after the first generation on one TX site to 45% and 55% at the end of the year on two AR sites (Table 52 & 53). 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 54).

In 2008, 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 55 & 56). 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 57).

Imidacloprid Tablets (2008)
Rate at Planting: Tip moth populations were low on the single site during the first and second generations with averages of 0.5% and 2.5% of the shoots infested on check trees, respectively (Table 58). As a result of the low tip moth pressure, none of treatments significantly reduced tip moth infestation levels compared to the check during the first generation. In contrast, all tablet treatments provided very good protection during the third through fifth generations, reducing damaged by 78 – 100% (77 – 96% overall). The post plant tablet and fipronil soil injection (at planting) both had similar effects on tip moth damage levels. Surprisingly, none of the study treatments significantly improved any of the growth parameters compared to check trees (Table 59).

Rate and Depth Just After Plant: Tip moth populations again were low on the both sites during the first generation with averages of 0.8% (Loving Ferry) and 0% (Moffet) of the shoots infested on check trees (Table 60). As a result of the low tip moth pressure, none of treatments significantly reduced tip moth infestation levels compared to the check during the first generation. In contrast, nearly all treatments provided very good protection during the second through fifth generations, reducing damaged by 48 – 100% (62 – 99% overall). Treatment efficacy against tip moth did not appear to be influenced by dose rate or treatment depth. However, height and diameter growth tended to improve with dose rate compared to check trees (Table 61). Growth parameters did not appear to be affected by treatment depth.

Rate and Depth 1 year after Plant: Understandably, tip moth populations were higher during the first generation on this second-year site with an average of 15% of the shoots infested on check trees (Table 62). Because of the late treatment date, none of treatments significantly reduced tip moth infestation levels compared to the check during the first generation. In contrast, all treatments provided very good protection during the second through fifth generations, reducing damaged by 35 – 99% (49 – 83% overall). Treatment efficacy against tip moth appears to be influenced by dose rate but not treatment depth. However, growth parameters did not appear to be affected by treatment depth (Table 63).

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

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.

			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		
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.
= 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 - 2008.

			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 % 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	
2008	Imidacloprid + Fert.	45	731	*	**55**	10.9	*	**1.6**	88963	*	**27363**	90	
	Disulfoton + Fert.	47	725	*	**49**	10.4	*	**1.1**	82212	*	**20612**	94	
	Check	85	676			9.3			61600			85	

[a] Diameter taken at 6" above ground in 2003 and 2004; at breast height in 2005, 2007 & 2008.

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

Table 50. 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.

[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 51. 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

			Growth Measurements (**Growth Difference (cm or cm^3) Compared to Check**)						Mean % Tree Survival (**Pct. Gain Compared to Check**)	
Year	Treatment §	N	Height (cm)		Diameter (cm)		Volume (cm^3)			
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	
2008	20% Merit Ball 2X	50	255.2 *	**46.6**	2.74 *	**1.25**	2456 *	**1764**	68	**10**
	20% Merit Ball 1X	50	250.6 *	**42.0**	2.43 *	**0.93**	1661 *	**969**	70	**13**
	20% Merit Burst 1X	50	225.8	**17.2**	2.05 *	**0.56**	1358 *	**667**	82 *	**32**
	Imid 5% gel 10g	50	199.8	**-8.8**	1.62	**0.13**	707	**16**	36 *	**-42**
	ImidFip Comb 10g	50	233.4	**24.8**	2.22 *	**0.72**	1670 *	**979**	38 *	**-39**
	Confidor 70 WG	50	217.4	**8.8**	1.97 *	**0.47**	1213	**521**	74	**19**
	Merit 20% Ball Soil	50	225.2	**16.5**	2.25 *	**0.75**	1578 *	**886**	78	**26**
	Fertilizer	50	218.7	**10.1**	1.88 *	**0.38**	985 *	**294**	82 *	**32**
	Mimic spray	50	214.9	**6.3**	1.90	**0.40**	1508	**817**	74	**19**
	Check	50	208.6		1.50		691		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 52. Effect of Bayer tablets on percent shoots infested by pine tip moth after each of five generations during the first growing season on six sites - 2007.

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

		Generation 1								Generation 2							
Treatment §	N	TX1	AR1	TX2	AR2	AR3	MS1	Mean		TX1	AR1	TX2	AR2	AR3	MS1	Mean	
20% FXT Ball PH	50	0.0	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	

		Generation 3								Generation 4							
Treatment §	N	TX1	AR1	TX2	AR2	AR3	MS1	Mean		TX1	AR1	TX2	AR2	AR3	MS1	Mean	
20% FXT Ball PH	50	0.0 *	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	

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

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

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

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

Table 53. Effect of Bayer tablets on percent shoots infested by pine tip moth after each of five generations during the first growing season on six sites - 2007.

		Mean Percent Shoots Infested (Pct. Reduction Compared to Check)							
		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 54. Effect of Bayer tablets on height, diameter and volume index after the first growing season on six sites - 2007.

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

Treatment §	N	Height (cm) TX1	Height (cm) AR1	6 Trt Site Mean		Height (cm) TX2	Height (cm) AR2	Height (cm) AR3	Height (cm) MS1	4 Trt Site 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	58.0 *	**8.6**
20% FXT Ball Adjacent	50	54.6 *	58.0	56.3 *	**11.7**	40.7 *	53.9 *	39.6	97.2	57.3 *	**7.9**
Mimic foliar spray	50	45.8	48.3	47.0	**2.3**	42.9 *	56.1 *	37.9	83.6	52.4	**3.0**
Check	50	39.1	50.3	44.6		33.5	47.3	35.6	90.7	49.4	

Treatment §	N	Diameter (cm) TX1	Diameter (cm) AR1	6 Trt Site Mean		Diameter (cm) TX2	Diameter (cm) AR2	Diameter (cm) AR3	Diameter (cm) MS1	4 Trt Site 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	0.96	**0.08**
20% FXT Ball Adjacent	50	0.87 *	0.73	0.80	**0.11**	0.56	0.99	0.47	2.01	0.94	**0.06**
Mimic foliar spray	50	0.74	0.73	0.74	**0.05**	0.66 *	1.06 *	0.47	1.85	0.92	**0.04**
Check	50	0.68	0.70	0.69		0.54	0.93	0.47	1.94	0.88	

Treatment §	N	Volume Index (cm^3) TX1	Volume Index (cm^3) AR1	6 Trt Site Mean		Volume Index (cm^3) TX2	Volume Index (cm^3) AR2	Volume Index (cm^3) AR3	Volume Index (cm^3) MS1	4 Trt Site 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	96.3 *	**12.5**
20% FXT Ball Adjacent	50	51.3 *	39.1	45.0 *	**18.6**	15.6	65.6	11.7	355.0	89.7 *	**6.0**
Mimic foliar spray	50	32.5	31.7	32.1	**5.8**	21.8 *	73.7 *	10.7	346.8	86.2	**2.4**
Check	50	22.9	30.0	26.4		11.2	50.7	11.6	376.2	83.8	

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

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

Table 55. Effect of Bayer tablets on percent shoots infested by pine tip moth after each of five generations during the second growing season on six sites - 2008.

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

		Generation 1								Generation 2							
Treatment §	N	TX1	AR1	TX2	AR2	AR3	MS1	Mean		TX1	AR1	TX2	AR2	AR3	MS1	Mean	
20% FXT Ball PH	50	9.9	12.0	3.1 *	12.9 *	6.3 *	23.3	11.4 *	**57**	5.9 *	12.8 *	5.4 *	4.3 *	NA	NA	6.9 *	**78**
20% FXT Ball Adjacent	50	4.5 *	10.8	6.3 *	26.0 *	8.5 *	24.4	14.0 *	**48**	4.0 *	12.5 *	12.0 *	33.4	NA	NA	16.4 *	**47**
Mimic foliar spray	50	3.0 *	NA	6.0 *	35.4	6.1 *	29.1	16.3 *	**42**	3.7 *	NA	5.1 *	7.6 *	NA	NA	11.5 *	**63**
Check	50	13.5	20.2	26.3	46.0	17.6	34.7	26.8		17.8	32.7	31.1	41.9	NA	NA	31.2	

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

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

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

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

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

Table 56. Effect of Bayer tablets on percent shoots infested by pine tip moth after each of five generations during the second growing season on two sites - 2008.

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

Treatment §	N	Generation 1 TX1	Generation 1 AR1	Generation 1 Mean		Generation 2 TX1	Generation 2 AR1	Generation 2 Mean	
10% FXT Ball PH	50	9.3	16.5	12.8	**24**	4.4 *	18.8	10.4 *	**58**
15% FXT Ball PH	50	1.1 *	12.6	6.8 *	**59**	2.1 *	11.8 *	7.0 *	**72**
20% FXT Ball PH	50	9.9	12.0	11.0	**35**	5.9 *	12.8 *	9.4 *	**62**
20% FXT Ball Adjacent	50	4.5 *	10.8	7.7 *	**54**	4.0 *	12.5 *	8.3 *	**67**
Mimic foliar spray	50	3.0 *	NA	7.6 *	**55**	3.7 *	NA	17.9	**28**
Check	50	13.5	20.2	16.8		17.8	32.7	24.9	

Treatment §	N	Generation 3 TX1	Generation 3 AR1	Generation 3 Mean		Generation 4 TX1	Generation 4 AR1	Generation 4 Mean	
10% FXT Ball PH	50	6.1 *	17.4 *	10.8 *	**54**	11.5 *		11.5 *	**77**
15% FXT Ball PH	50	4.9 *	13.9 *	9.5 *	**60**	11.4 *		11.4 *	**77**
20% FXT Ball PH	50	1.9 *	12.0 *	7.1 *	**70**	8.9 *		8.9 *	**82**
20% FXT Ball Adjacent	50	4.9 *	16.3 *	10.7 *	**55**	11.9 *		11.9 *	**76**
Mimic foliar spray	50	0.5 *	NA	18.1	**24**	3.5 *		3.5 *	**93**
Check	50	14.4	33.9	23.8		49.3		49.3	

Treatment §	N	Generation 5 (Last) TX1	Generation 5 (Last) AR1	Generation 5 (Last) Mean		Mean TX1	Mean AR1	Mean Mean	
10% FXT Ball PH	50	15.6 *	74.9	41.1 *	**36**	9.4 *	29.8	17.7 *	**49**
15% FXT Ball PH	50	16.9 *	50.6 *	33.8 *	**47**	7.3 *	22.6 *	14.7 *	**57**
20% FXT Ball PH	50	16.6 *	53.9	36.0 *	**44**	8.6 *	22.7 *	15.8 *	**54**
20% FXT Ball Adjacent	50	16.8 *	39.9 *	28.6 *	**55**	8.4 *	19.9 *	14.3 *	**59**
Mimic foliar spray	50	0.6 *	NA	41.7 *	**35**	2.3 *	NA	21.5 *	**38**
Check	50	56.0	72.3	63.8		30.2	39.4	34.6	

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

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

Table 57. Effect of Bayer tablets on height, diameter and volume index after the second growing seasons on six sites - 2008.

		Mean Parameter Growth (**Growth Difference (cm or cm^3) Compared to Check**)									
		Height (cm)		6 Trt Site		Height (cm)				4 Trt Site	
Treatment §	N	TX1	AR1	Mean		TX2	AR2	AR3	MS1	Mean †	
10% FXT Ball PH	50	118.7 *	128.1	122.5 *	**15.3**						
15% FXT Ball PH	50	120.8 *	137.7 *	129.0 *	**21.7**						
20% FXT Ball PH	50	130.4 *	120.7	125.5 *	**18.2**	95.3 *	109.9 *	144.6 *	210.7	120.1 *	**21.8**
20% FXT Ball Adjacent	50	123.4 *	132.6	128.1 *	**20.9**	87.4	96.3 *	133.4 *	220.6	115.2 *	**16.8**
Mimic foliar spray	50	113.3	108.6	111.0	**3.7**	102.2 *	93.1 *	143.1 *	213.6	111.9 *	**13.6**
Check	50	100.5	114.6	107.3		80.5	81.5	114.7	188.0	98.4	

		Diameter @ 6" (cm)		6 Trt Site		Diameter @ 6" or DBH (cm)				4 Trt Site	
Treatment §	N	TX1	AR1	Mean		TX2	AR2	AR3	MS1	Mean	
10% FXT Ball PH	50	2.13	2.50	2.28	**0.21**						
15% FXT Ball PH	50	2.18 *	2.71	2.44 *	**0.37**						
20% FXT Ball PH	50	2.30 *	2.53	2.42 *	**0.35**	1.47 *	1.70 *	2.77 *	1.91	2.15 *	**0.38**
20% FXT Ball Adjacent	50	2.20 *	2.54	2.37 *	**0.31**	1.34	1.57	2.60 *	2.08	2.07 *	**0.30**
Mimic foliar spray	50	2.00	2.24	2.12	**0.05**	1.57 *	1.51	2.72 *	1.90	1.99 *	**0.22**
Check	50	1.80	2.36	2.07		1.17	1.39	2.15	2.10	1.77	

		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	718.4	1284.5	950.0 *	**350**						
15% FXT Ball PH	50	724.2 *	1213.2	961.1 *	**361**						
20% FXT Ball PH	50	855.9 *	1115.1	987.3 *	**387**	251.4 *	379.9 *	1246.9 *	986.5	760.6 *	**319**
20% FXT Ball Adjacent	50	722.5 *	1147.7	940.3 *	**340**	189.4 *	299.8 *	1040.1 *	1252.5	689.5 *	**248**
Mimic foliar spray	50	563.7	750.4	654.7	**55**	321.1 *	276.6	1166.5 *	972.9	606.6 *	**165**
Check	50	396.3	820.1	599.9		155.6	216.9	635.9	1117.3	441.1	

§ 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.

† Mean does not include MS1 site.

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

			Mean Percent Top Whorl Shoots Infested by Tip Moth (**Pct. Reduction Compared to Check**)											
Year	Treatment §	N	Gen 1		Gen 2		Gen 3		Gen 4		Gen 5		Overall Mean	
2008	1 Tablet at Planting	50	0.7	**-33**	0.0	**100** *	0.0	**100** *	2.2	**96** *	5.9	**91** *	0.7	**96** *
	2 Tablets at Planting	50	0.0	**100**	2.0	**25**	2.1	**84** *	11.7	**78** *	10.5	**83** *	3.9	**77** *
	3 Tablets at Planting	50	0.0	**100**	0.0	**100** *	0.0	**100** *	6.0	**89** *	9.0	**86** *	1.5	**91** *
	1 Tablet Adjacent	50	0.4	**22**	0.3	**88**	1.1	**91** *	2.7	**95** *	4.8	**92** *	1.1	**93** *
	Fipronil Adjacent	50	1.7	**-227**	0.4	**85**	0.0	**100** *	1.3	**97** *	2.0	**97** *	0.9	**95** *
	Check	100	0.5		2.7		12.6		52.6		63.3		17.5	

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

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

			Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm3) Compared to Check)**						Mean Percent
Year	Treatment	N	Height (cm)		Diameter (cm) [a]		Volume (cm^3)		Tree Survival
2008	1 Tablet at Planting	50	42.8	**-4.2**	0.77	**-0.11**	28.6	**-16.7**	96
	2 Tablets at Planting	50	44.1	**-2.8**	0.81	**-0.06**	35.1	**-10.2**	100
	3 Tablets at Planting	50	46.8	**-0.2**	0.88	**0.00**	40.1	**-5.2**	100
	1 Tablet Adjacent	50	43.4	**-3.6**	0.81	**-0.06**	35.3	**-10.0**	98
	Fipronil Adjacent	50	48.9	**1.9**	0.88	**0.01**	43.5	**-1.8**	100
	Check	50	47.0		0.87		45.3		94

[a] Diameter taken at 6" above ground.
***** Means followed by an asterik are significantly different from checks at the 5% level based on Fisher's Protected LSD.

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

			Mean Percent Top Whorl Shoots Infested by Tip Moth (**Pct. Reduction Compared to Check**)																
Site	Treatment §	N	Gen 1		Gen 2			Gen 3			Gen 4			Gen 5			Overall Mean		
Loving	1 Tablet at 4"	50	1.7	**-108**	2.6	**66**		3.2	**63**	*	5.5	**87**	*	10.0	**78**	*	4.5	**79**	*
Ferry	2 Tablets at 4"	50	1.3	**-68**	3.9	**48**		0.0	**100**	*	5.0	**88**	*	10.3	**77**	*	4.1	**81**	*
	3 Tablets at 4"	50	2.3	**-193**	1.6	**78**	*	3.0	**66**	*	9.8	**77**	*	10.0	**78**	*	5.4	**75**	*
	1 Tablet at 8"	50	0.0	**100**	0.4	**95**	*	1.2	**86**	*	13.9	**67**	*	11.7	**74**	*	5.5	**75**	*
	2 Tablets at 8"	50	1.5	**-88**	3.1	**58**		0.0	**100**	*	0.7	**98**	*	7.1	**85**	*	2.0	**91**	*
	3 Tablets at 8"	50	0.5	**36**	0.0	**100**	*	0.5	**94**	*	4.6	**89**	*	7.6	**83**	*	2.7	**88**	*
	Check	50	0.8		7.5			8.7			42.7			45.7			21.6		
Moffet	1 Tablet at 4"	50	0.5	**####**	0.0	**100**	*	3.2	**76**	*	3.0	**93**	*	1.3	**97**	*	1.6	**93**	*
	2 Tablets at 4"	50	1.0	**####**	0.0	**100**	*	0.0	**100**	*	0.0	**100**	*	0.0	**100**	*	0.2	**99**	*
	3 Tablets at 4"	50	0.0	**####**	1.5	**89**	*	1.0	**93**	*	1.0	**98**	*	1.0	**98**	*	0.9	**96**	*
	1 Tablet at 8"	50	0.7	**####**	0.0	**100**	*	0.0	**100**	*	0.0	**100**	*	0.0	**100**	*	0.1	**99**	*
	2 Tablets at 8"	50	0.8	**####**	1.8	**86**	*	5.1	**62**	*	15.4	**64**	*	18.4	**57**	*	8.5	**62**	*
	3 Tablets at 8"	50	2.9	**####**	0.5	**96**	*	0.0	**100**	*	1.4	**97**	*	0.7	**98**	*	1.1	**95**	*
	1 Tablet at 8" PH	50	0.0	**####**	0.0	**100**	*	2.0	**85**	*	0.7	**98**	*	1.1	**97**	*	0.8	**97**	*
	Check	100	0.0		12.9			13.5			43.0			42.7			22.4		

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

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

Table 61. Effect of SilvaShield tablet dose and depth on loblolly pine growth on two first year sites (Loving Ferry & Moffet) in east Texas, 2008.

Site	Treatment	N	Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm^3) Compared to Check)**						Mean Percent Tree Survival
			Height (cm)		Diameter (cm) [a]		Volume (cm^3)		
Loving Ferry	1 Tablet at 4"	50	40.2	**8.3**	0.74	**0.13**	44.6	**27.7**	92
	2 Tablets at 4"	50	43.8 *	**11.9**	0.74 *	**0.13**	33.6 *	**16.7**	88
	3 Tablets at 4"	50	44.2 *	**12.4**	0.77 *	**0.16**	36.4 *	**19.4**	88
	1 Tablet at 8"	50	39.6 *	**7.7**	0.72	**0.11**	31.2 *	**14.2**	98
	2 Tablets at 8"	50	43.8 *	**11.9**	0.81 *	**0.20**	40.4 *	**23.5**	92
	3 Tablets at 8"	50	44.6 *	**12.7**	0.82 *	**0.21**	39.1 *	**22.2**	86
	Check	50	31.9		0.61		16.9		94
Moffet	1 Tablet at 4"	50	40.1	**3.7**	0.69	**0.00**	22.1	**1.6**	100
	2 Tablets at 4"	50	38.2	**1.8**	0.68	**-0.01**	21.6	**1.1**	90
	3 Tablets at 4"	50	41.2	**4.8**	0.74	**0.05**	29.2	**8.7**	98
	1 Tablet at 8"	50	40.1	**3.7**	0.70	**0.01**	23.1	**2.6**	96
	2 Tablets at 8"	50	42.3 *	**5.8**	0.71	**0.0**	26.2	**5.7**	88
	3 Tablets at 8"	50	43.7 *	**7.3**	0.75	**0.06**	31.2 *	**10.7**	96
	1 Tablet at 8" PH	50	39.9	**3.4**	0.69	**0.0**	23.9	**3.4**	90
	Check	50	36.4		0.69		20.5		100

[a] Diameter taken at 6" above ground.

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

Table 62. Effect of SilvaShield tablet dose and depth on pine tip moth infestation of loblolly pine shoots (top whorl) on one second year site (Peavy) in east Texas, 2008.

Site	Treatment §	N	Gen 1			Gen 2			Gen 3			Gen 4			Gen 5			Overall Mean		
			Mean Percent Top Whorl Shoots Infested by Tip Moth (**Pct. Reduction Compared to Check**)																	
Peavy	1 Tablet at 4"	50	14.4	**1**		20.9	**35**	*	8.7	**64**	*	13.5	**80**	*	20.9	**65**	*	15.4	**61**	*
2nd Yr	2 Tablets at 4"	50	17.1	**-17**		14.1	**56**	*	6.2	**74**	*	5.4	**92**	*	5.7	**90**	*	9.9	**75**	*
	3 Tablets at 4"	50	13.2	**9**		7.4	**77**	*	0.9	**96**	*	0.4	**99**	*	13.2	**78**	*	7.0	**82**	*
	1 Tablet at 8"	50	12.7	**13**		15.2	**53**	*	10.2	**58**	*	30.2	**55**	*	33.3	**44**	*	20.3	**49**	*
	2 Tablets at 8"	50	13.3	**9**		5.8	**82**	*	3.7	**85**	*	7.8	**88**	*	7.3	**88**	*	7.7	**81**	*
	3 Tablets at 8"	50	14.5	**1**		11.5	**65**	*	2.5	**90**	*	3.0	**95**	*	2.5	**96**	*	6.8	**83**	*
	Check	50	14.6			32.4			24.2			66.5			59.6			39.6		

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

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

Table 63. Effect of SilvaShield tablet dose and depth on loblolly pine growth on one second year site (Peavy) in east Texas, 2008.

Site	Treatment	N	Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm^3) Compared to Check)**									Mean Percent Tree Survival
			Height (cm)			Diameter (cm) [a]			Volume (cm^3)			
Peavy	1 Tablet at 4"	50	156.2	*	**21.3**	3.31	*	**0.39**	2076	*	**775**	92
	2 Tablets at 4"	50	135.6		**0.7**	2.80		**-0.12**	1228		**-73**	96
	3 Tablets at 4"	50	141.5		**6.6**	2.90		**-0.02**	1293		**-8**	100
	1 Tablet at 8"	50	141.6		**6.7**	2.91		**-0.01**	1327		**26**	98
	2 Tablets at 8"	50	150.6	*	**15.7**	3.08		**0.16**	1632		**331**	98
	3 Tablets at 8"	50	143.4		**8.5**	2.87		**-0.04**	1401		**100**	100
	Check	50	134.9			2.92			1301			98

[a] Diameter taken at 6" above ground.

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

PINE TIP MOTH TRIALS

SilvaShieldô Operational Soil Injection Study - Western Gulf Region

Highlights:

- SilvaShield™ Forestry Tablets operationally applied by hand significantly reduced tip moth damage (by 77%) in the first year after application. The treatment significantly improved tree growth.
- Operational treatment of second-year trees only reduced overall tip moth damage by 38% compared to untreated checks, but the treatment improved height, diameter and volume growth by 10%, 17% and 42%, respectively.

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

Cooperators:

Mr. Steve Anderson	Texas Forest Service, Hudson, TX
Ms. Francis Peavy,	Private land owner, Hudson, TX
Dr. Nate Royalty	Bayer Environmental Science, Research Triangle Park, NC

Study Sites: One first-year plantation and one second-year plantation were selected east of Lufkin, TX and north of Hudson, TX in February 2008.

Insecticides:

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

Design: Randomized complete block design at each site with site areas serving as blocks, i.e., each treatment was randomly selected for placement in one-half of the area. For each treatment, one hundred seedlings were monitored in each main plot area.

Treatments <u>(40 acres each):</u>

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

Research Approach:

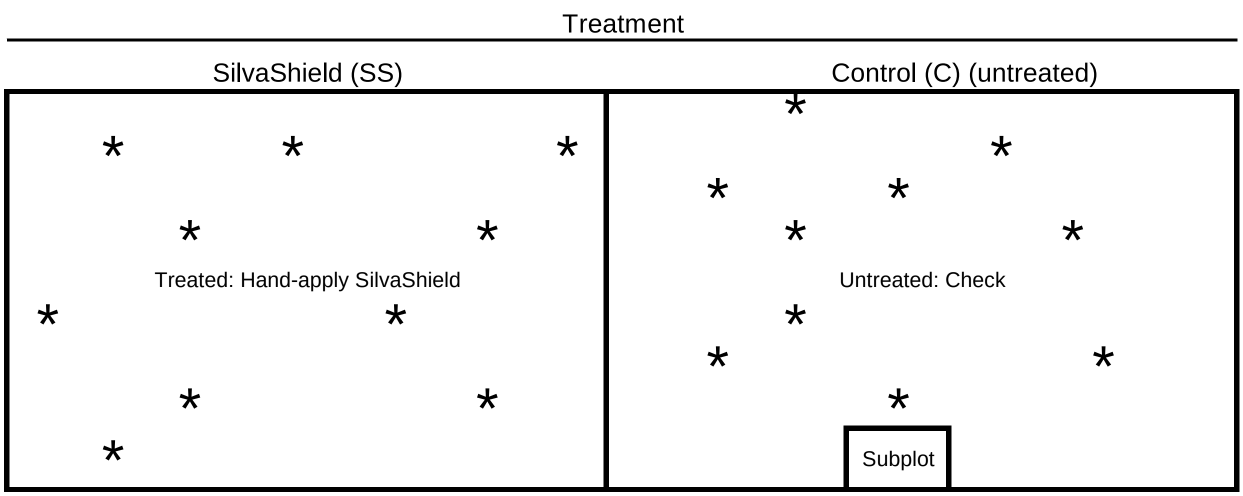
One tract about to be planted, and one one-year old tract, each 80 acres in size, were selected in Texas based on uniformity of soil, drainage, topography and susceptibility to tip moth infestation (based on FPMC Tip Moth Hazard-Rating Model, Andy Burrow, and Temple Inland Forest Products).

Each plantation was hand-planted. On one half of the plantation, the applicator applied one SilvaShield™ tablet to each seedling after planting (Figure 28). A lance was used to create an 8-inch deep hole in the soil, angled toward the seedling. The tablet was then dropped into the hole and covered up. In the other half of the plantation, seedlings were hand or machine planted at the same spacing without SilvaShield™ tablets.

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

Tip moth damage was evaluated after each tip moth generation (3-4 weeks after peak moth flight) by 1) identifying if the tree is infested or not, 2) if infested, the proportion of tips infested on the top whorl and terminal will be calculated; and 3) separately, the terminal will be identified as infested or not. Observations also were made as to the occurrence and extent of damage caused by other insects, i.e., coneworm, aphids, sawfly, etc. Each tree was measured for diameter (at ground line) and height and in the fall (November).

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



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

Figure 28. Generalized Plot Design

Results:

In 2008, tip moth populations were low on the first-year site (Moffet) during the first generation with an average of 3.4% of the shoots infested on check trees. As a result of the low tip moth pressure, the tablet treatment did not significantly reduced tip moth infestation levels compared to the check during this generation (Table 64). In contrast, the treatment provided very good protection during the second through fifth generations, reducing damaged by 74 – 85% (77% overall). The tablet treatment significantly improved all (height, diameter & volume) growth parameters compared to check trees (Table 65).

Tip moth populations were higher on the second-year site (Peavy) during the first generation with an average of 19.4% of the shoots infested on check trees. The tablet treatment was not applied until the end of March, so it is understandable that the treatment did not significantly reduced tip moth infestation levels compared to the check during this generation (Table 64). In contrast, the treatment provided good protection during the second through fifth generations, reducing damaged by 31 – 52% (38% overall). The tablet treatment significantly improved all (height, diameter & volume) growth parameters compared to check trees (Table 65).

Conclusions: The initial data (2008) from one site indicates that SilvaShield™ tablets operationally applied by hand provide good protection against tip moth and improves growth during the first year after planting. Additional date indicates that tablets applied to one-year-old trees are not as effective against tip moth, but the treatment still can improve growth. The trials will be continued in 2009 to evaluate for duration of treatment effects.

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

Table 64. Effect of SilvaShield tablet on areawide pine tip moth infestation of loblolly pine shoots (top whorl) on two sites (Moffet & Peavy) in east Texas, 2008.

Site	Treatment §	N	Gen 1			Gen 2			Gen 3			Gen 4			Gen 5			Overall Mean		
			Mean Percent Top Whorl Shoots Infested by Tip Moth (**Pct. Reduction Compared to Check**)																	
Moffet 1st Yr	1 Tablet at 8"	100	1.7	**49**		2.8	**74**	*	3.0	**76**	*	2.4	**85**	*	5.6	**77**	*	3.1	**77**	*
	Check	100	3.4			10.9			12.6			16.3			24.6			13.6		
Peavy 2nd Yr	1 Tablet at 8"	100	19.6	**-1**		25.4	**31**	*	20.2	**48**	*	37.3	**52**	*	48.4	**30**	*	30.2	**38**	*
	Check	100	19.4			36.5			38.6			78.0			69.3			48.4		

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

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

Table 65. Effect of SilvaShield tablet on areawide loblolly pine growth on two sites (Moffet & Peavy) in east Texas, 2008.

Site	Treatment	N	Mean End of Season Loblolly Pine Seeding Growth Measurements (**Growth Difference (cm or cm^3) Compared to Check)**						Mean Percent Tree Survival
			Height (cm)		Diameter (cm) [a]		Volume (cm^3)		
Moffet 1st Yr	1 Tablet at 8"	100	60.9 *	**15.9**	0.95 *	**0.23**	69.9 *	**41.6**	100
	Check	100	45.1		0.72		28.3		100
Peavy 2nd Yr	1 Tablet at 8"	100	156.2 *	**14.5**	3.10 *	**0.45**	1724.0 *	**512.0**	100
	Check	100	141.7		2.65		1212.0		100

[a] Diameter taken at 6" above ground.

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

PINE TIP MOTH TRIALS

Summary and Registration Status of Tested Systemic Insecticides

Over the past 11 years (1998 – 2008), the FPMC has been monitoring and assessing the impact of pine tip moth on pine tree growth. It has been well established through our impact, hazard-rating, and control trials that this insect significantly impacts seedling growth and form, at least in the short term. However, several questions remain to be answered in their entirety, particularly 1) What is the long term impact of tip moth on tree growth? and 2) what are the primary factors that influence the occurrence and severity of tip moth infestations? During the past eight years, we have established 103 impact plots and 135 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, had developed a preliminary hazard-rating model in 2005 that identified site index and soil texture composition as the two primary factors that influence the occurrence and severity of pine tip moth damage. A revised model developed in 2007 based on data from numerous sites indicated that sites with deep, excessively or poorly drained soils are more prone to tip moth damage. This needs to be validated with data from additional sites. Unfortunately, Mr. Burrow can no longer provide assistance. Dr. Dean Coble, Stephen F. Austin and State University has agreed to take over the development of the model in 2009. It is important that evaluations and data collections continue on already established impact and hazard-rating sites in 2009 and beyond and that new impact sites be established that utilize PTMô as the protective agent.

Fipronil: Over the past seven years (2002 – 2008), 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 envelope 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, BASF and EPA are concerned about the potential for excessive chemical exposure when treating or handling treated bare root seedlings. Given these concerns and limitations, it was decided to focus on the development of treatments made at or post plant of seedlings.

Three hand applicators, the Kioritzô ($350 - $460), PTM Spot Gunô ($80), and PTM Injection Probeô ($420), have been successfully used to apply fipronil solution by hand. Soil injection trials established in 2005-2008 showed that this application technique is consistently effective in reducing pine tip moth damage. A trial established in 2008 showed that post-plant applications of fipronil are effective even when applied at the beginning of the 2nd year. However it is important to note that fipronil solution applied directly into a plant hole at time of planting is consistently more effective in reducing tip moth damage compared to applications made to the soil after the seedlings are planted.

Planting seedlings by machine has become more popular because: 1) hand-planting crews have become scarce, 2) machine-planted seedlings tend to show better survival and growth compared to hand-planted seedlings. A safe and efficient way of treating machine-planted bare root or containerized seedlings with fipronil would be to apply the chemical as they are placed by the machine in the furrow. Mr. Lane Day and Jim Rogers, contracted by the FPMC, were able to develop and successfully test a new soil injection system in late 2006. The treatment applied by machine was consistently effective in protecting first-year seedlings on three sites through 2007. Additional machine planter trials established early in 2008 indicated that fipronil can reduce tip moth damage across large areas. These trials will be continued in 2009 and beyond to determine long-term effects on area-wide tip moth populations and damage.

Fipronil treatments with containerized seedlings and rooted cuttings also were highly effective in reducing tip moth damage in 2004. A second trial established in 2007 in which fipronil was applied to containerized plugs 7 month in advance of planting showed outstanding first year results (≥99% reduction in damage) and good results the second year (>50% reduction). As this segment of the seedling market is continuing to build, a safe and efficient method of treating these containerized and rooted cutting seedlings in trays should be developed. Unfortunately, because EPA is considering several other fipronil uses, BASF has postponed a request to modify the PTM™ label to include use on containerized seedlings.

In response to the results described above, BASF submitted a package to EPA to register a formulation of fipronil for use to protect conifers against pine tip moth in May 2006. EPA approved the full registration (Section 3) of PTM™ for use against tip moth and aphids by soil injection in June 2007. The product became available for the winter 2007/2008 planting season. Table 61 provides updated information about the PTM™ product (distributors, cost, etc.).

Additional trials are planned for 2009 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 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. As result of the above trials as well as other trials on the East Coast, Bayer requested and EPA approved a full Section 3 registration for SilvaShield™ Forestry Tablets in 2006**.** The tablets can be applied for protection of pine against tip moth, aphids and soft scales and hybrid poplar against leaf beetles. Table 61 provides updated information about the PTM™ product (distributors, cost, etc.).

Trials were established in 2008 to refine treatment rates and timing, application depth and determine effects on second year trees. Application rate or depth had no significant effect on tip moth damage and growth of first year seedling, but high rates did provide greater protection and improved growth of second-year trees.

Additional trials are planned for 2009 to determine the relative effects of input types (SilvaShield™, fertilizer and/or weed control) occurrence and severity of tip moth damage and effects on tree growth.

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: $245 per bag (contains 1200 tablets); cost depends on quantity purchased.	RRS quote: $320 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	$92.00	$52.50
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 $394.50 thru treecaresupplies.com $401.78 + shipping thru Rittenhouse.com **PTM Spot Gun** (1.2 gallon capacity) $88.00 thru feltonmedical.com $150.00 thru RRS **PTM Injection Probe** (4.0 gallon capacity) ~$255.00 for probe assembly only ~$425.00 for gun + backpack sprayer thru enviroquipinc.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.