Western Gulf Forest Pest Management Cooperative

Report on
Research Accomplishments in 2002

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2002 WGFPMC Members:

International Paper Company
Plum Creek Timber Company, Inc.
Potlatch Corporation
Temple-Inland Forest Products Corporation
Texas Forest Service
U.S.D.A. Forest Service - Forest Health Protection R8
Weyerhaeuser Company
Anthony Forest Products Company

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Executive Summary

The Western Gulf Forest Pest Management Cooperative (WGFPMC) made significant strides in 2002. A brief summary of WGFPMC activities is given below. Two primary research projects (systemic injection studies and tip moth impact/hazard-rating/control) were continued from 2001. Seven other smaller studies was initiated and/or completed. Separate detailed reports for each project 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 2003 Project Proposals.

Membership in the WGFPMC changed dramatically in 2002. We welcomed Potlatch Corporation, Anthony Forest Products Company and Weyerhaeuser Company (through a merger with Willamette Industries) as new members. Unfortunately, we lost two others, Louisiana Pacific and Dow AgroSciences.

Seasonal technicians, Jamie Burns, Joanne Murphy, Matthew Phillips and Javier Vara, were hired to provide assistance with field studies and continue development of the pesticide web site. We appreciate the assistance provided by Allen Smith, Southern Pine Beetle Prevention Specialist, with cone evaluations and GPS/GIS work.

Service to members continues to be an important part of the WGFPMC. To this end, four issues of the PEST newsletter were prepared and distributed. Also, 9 presentations, 14 meeting requests, and 73 phone/e-mail requests were addressed relating to the following topics: leaf-cutting ants/Volcano®, pine tip moth, reproduction weevils, bark beetles (*Ips* and black turpentine), cone and seed insects (coneworm and seed bug), spider mites, phylloxeran (aphid) and needle midge.

Given that Volcano® leafcutter ant bait is expected to be phased out in 6 – 9 years, trials were initiated in 2001 to evaluate the effectiveness of another citrus pulp bait containing the active ingredient fipronil (Blitz®, produced by Aventis). As a result of these trials, a manuscript entitled "Attractiveness and efficacy of fipronil and sulfluramid for control of the Texas leaf-cutting ant" was published in the Sept.-Dec. 2002 issue of the Southwestern Entomologist (see attached reprint). In addition, a registration package was submitted to the Environmental Protection Agency (EPA) to register this formulation in the U.S. under the new product name "BES 100." We await final EPA approval. A small study was conducted in 2002 to evaluate the effectiveness of several different bait application techniques. All techniques ultimately proved to be equally effective in halting leaf-cutting ant activity.

Rainfall was normal (46+ inches) for the second straight year in the Western Gulf region after nearly five years (1996 – 2000) with severe drought conditions. However, as usually is the case, we received relatively little rainfall from June through September. The effects of the 1999 and 2000 droughts on tree survival as well as indirect effects on insect population development appear to have subsided. Outbreaks of forest tent caterpillar were reported in the river bottoms of southeast Texas and of red oak borer in central and northern Arkansas. On the positive side, pine tip moth populations appeared to have declined somewhat in 2002 compared to previous years and no infestations of the southern pine beetle were reported in Texas, Louisiana, Arkansas or Oklahoma in 2002.

In 1999 and 2000, it was hypothesized that severe drought conditions caused significant second year cone mortality (40%+) at the TFS Magnolia Spring Seed Orchard in Texas. This hypothesis was supported in 2001 and 2002 when little second year cone mortality occurred under more normal rainfall conditions. Progress continues on the evaluation and development of systemic insecticides and injection systems. For the fourth year in a row, trees injected a single time in 1999 with emamectin benzoate and thiamethoxam had significantly reduced levels of coneworm damage. A manuscript entitled "Systemic insecticide injections for control of cone and seed insects in loblolly pine seed orchards – 2 year results" was published in the August 2002 issue of the Southern Journal of Applied Forestry (see attached reprint). A second study, initiated in 2001, was continued to determine the optimal application rates for emamectin benzoate and thiamethoxam. The WGFPMC assisted in two other seed orchard studies; one to test some new options for scale control and the other to reevaluate Imidan® and Capture® for cone and seed insect control.

The tip moth project, established in 2001, to evaluate the true impact of pine tip moth on the growth of loblolly pine and identify site characteristics that influence the occurrence and severity of pine tip moth infestations, was expanded in 2002. Twenty-four impact plots on 13 sites are now established in the Western Gulf region. Results indicate that multiple applications of Mimic® significantly reduced infestation levels of pine tip moth compared to untreated trees during each of five moth generations. Higher tip moth populations on two-year old sites continued to have a significant impact on the growth of unprotected trees. In contrast, moth populations were too low on one-year old sites to impact tree growth. An additional 25 hazard-rating plots were established in 2002, bringing the total to 41. The development of a hazard-rating model is on going. Additional systemic insecticide trials revealed that one chemical, fipronil, was capable of reducing tip moth damage for at least one full growing season (5 moth generations). The WGFPMC assisted in two other tip moth studies; one to validate spray timing dates for sites in Texas, Louisiana and Arkansas and the other to evaluate the use of pheromone trap catches to predict subsequent tip moth damage.

The "Forestry Pesticides" web page was unveiled on the TFS web site in October 2002. Nearly all known forestry-related pesticides (insecticides, herbicides and fungicides) were cross-referenced with pest and site uses, resulting in over 500,000 pest cases. We are currently working out the "bugs" and expect to update the database on regular basis.

2002 Leaf-cutting Ant Trials

Highlights:

- Blitz® bait, applied loose, bagged, spread and piled, were essentially equal (83-100%) in their effectiveness in halting TLCA activity 16 weeks after treatment. However, Blitz® spread loose over CNA reduced ant activity at a faster rate.
- A registration package has been submitted to EPA to register the Blitz® formulation in the U.S. under the new product name "BES 100."

Objectives: 1) Evaluate the efficacy of the Blitz® fipronil bait in reducing activity in Texas leaf-cutting ant colonies, 2) evaluate the effects of application technique on treatment efficacy, and 3) determine the effect of season on treatment efficacy.

Study Sites: 50 active colonies were located in east Texas on lands owned by Louisiana Pacific, Temple-Inland and private landowners.

Insecticide:

Fipronil – slow-acting poison on a citrus pulp carrier.

Blitz® - concentration (0.03% a.i.); citrus pulp (orange); packing (tight); color (dark brown); size (uniform 4 mm).

Research Approach:

Efficacy Trial: Application rates were based on the area (length X width) of the central nest.

Fipronil (Blitz®) -

1) Loose bait spread(*) evenly over entire CNA at 10 g/m^2 during the spring and summer trials.
2) Loose bait placed in two piles within CNA at 10 g/m^2 during the spring and summer trials.
3) Bait bags (10 g of bait per bag) spread evenly over entire CNA at 10 g/m^2 during the spring and summer trials.
4) Bait bags (10 g of bait per bag) placed in two piles within CNA at 10 g/m^2 during the spring and summer trials.

Check - untreated colonies

*A cyclone spreader was used in 2002 to evenly spread measured amounts of fipronil bait over the CNA.

Application Dates:

Spring 2002: Treatments applied in April and May.
Summer 2001: Treatments applied in August.

Data Collection: The number of active entrance/exit mounds was counted prior to treatment and periodically following treatment at 2, 8, and 16 weeks. Six and four untreated colonies were included as checks and monitored in spring and summer treatments, respectively, 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:

Efficacy Trial (Spring 2002): - Both loose and bagged and spread and piled treatments were 100% effective in completely halting ant activity within 8 weeks of treatment (Table 1). However, the proportion of colonies inactive and the level of remaining ant activity at 2 weeks post-treatment indicates that the loose/spread treatment generally reduced/halted ant activity more rapidly than the other bait treatments. The loose/pile treatment eventually had one failure. The failure may have resulted from some of the bait getting wet in a rainstorm shortly after being applied.

Efficacy Trial (Summer 2002): All treatments were again 100% effective in completely halting TLCA activity after 8 weeks (Table 1). The reduction in ant activity was much more pronounced for the two loose bait treatments after 2 weeks compared to the bag treatments. The bags require more time and effort by the ants to find and retrieve the bait.

Seasonality: The proportion of colonies inactive was markedly higher and the level of remaining ant activity lower at 2 weeks post-treatment in the summer trial compared to the spring trial. Seasonal differences may have occurred because during most of the year (summer through winter), leafcutting ant behavior consists primarily of foraging and colony maintenance. However, in the spring (April through June) the ants reduce their foraging and begin preparing the colony for the nuptial (mating) flight.

Summary: Evaluations of Blitz® again indicate that it is highly effective in reducing/halting ant activity with a single dose. However, the application technique can make a difference in how quickly ant activity is reduced and halted. These trials showed that loose Blitz® generally reduces ant activity at a faster rate compared to bagged Blitz® and bait spread evenly over the entire CNA reduces ant activity at a faster rate compared to bait placed in piles.

The future availability of Volcano® is limited due to the persistence of sulfluramid in the environment (e.g., chemicals related to sulfluramid have been found in the blood of factory workers). EPA and Griffin L.L.C. recently reached an agreement to halt production of technical sulfluramid. Griffin will be permitted to produce and sell Volcano® until their supply of technical sulfluramid has been utilized. Griffin estimates that Volcano® should be available for the next 6 – 9 years before phase out. Another provision of the EPA/Griffin agreement was that the use language would be changed from “Pine Forest Sites” to “Pine Reforestation Sites.” This new use language restricts application to ant colonies in harvested areas being replanted in pine and includes areas directly adjacent to these sites.

In early 2002, Aventis (now merged with Bayer) submitted a registration package to the Environmental Protection Agency (EPA) to register the Blitz® formulation in the U.S. under the new product name “BES 100.” The site uses are to be expanded to include all pertinent sites except pastures and within citrus orchards. The sale and use of the BES-100 bait is to be restricted to licensed applicators. Recently, Terry Mitchell (Texas Dept. of Agr.) had a conversation with Adrian Krygsman, (Bayer product manager for BES-100). According to Mr. Krygsman, Bayer has been asked to submit a second registration package to EPA within the next 90 days. The package is to include additional formula information. Mr. Krygsman mentioned to Mr. Mitchell that "EPA has concerns about fipronil because it is such an active molecule." In other words EPA IS MOVING SLOW on the registration of this product. We await EPA approval of the BES 100 registration.

Table 1. Efficacy of fipronil (Blitz®) applied loose or in bags and spread over central nest area or in piles to control the Texas leaf-cutting ant (*Atta texana*) in east Texas (Spring and Summer 2002).

Treatment	Period Colonies Treated	No. of Colonies Treated	Mean Nest Area (m^2)	Mean # Mounds @ Trt.	Mean % initial activity [a] (% inactive colonies): 2 wk		8 wk		16 wk	
Fipronil (Blitz®) loose bait spread over CNA @ 10g/m2	4/30 - 5/22	6	30	186	19.3	(50)	0.0	(100)	0.0	(100)
	8/8 - 8/19	3	37	94	0.0	(100)	0.0	(100)	0.0	(100)
		9	32	155	12.9	(67)	0.0	(100)	0.0	(100)
Fipronil (Blitz®) loose bait in 2 piles in CNA @ 10g/m2	4/30 - 5/22	6	27	164	35.1	(17)	0.0	(100)	1.4	(83)
	8/8 - 8/19	3	44	123	3.2	(67)	0.0	(100)	0.0	(100)
		9	33	150	24.5	(33)	0.0	(100)	1.0	(89)
Fipronil (Blitz®) bagged bait spread over CNA @ 10g/m2	4/30 - 5/22	6	45	217	25.4	(17)	0.0	(100)	0.0	(100)
	8/8 - 8/19	4	35	157	9.4	(50)	0.0	(100)	0.0	(100)
		10	41	193	19.0	(30)	0.0	(100)	0.0	(100)
Fipronil (Blitz®) bagged bait in 2 piles in CNA @ 10g/m2	4/30 - 5/22	6	24	170	28.8	(17)	0.0	(100)	0.0	(100)
	8/8 - 8/19	4	35	114	13.1	(0)	0.0	(100)	0.0	(100)
		10	28	151	21.0	(11)	0.0	(100)	0.0	(100)
Check (no treatment)	4/30 - 5/22	6	25	124	95.2	(0)	74.3	(0)	56.5	(0)
	8/8 - 8/19	4	23	121	84.8	(0)	117.4	(0)	114.6	(0)
		10	25	124	91.0	(0)	91.5	(0)	79.7	(0)
	Total	48								
	Mean		32	155						

CNA = Central Nest Area

1999-2002 Systemic Insecticide Duration Study - Magnolia Springs, TX

Highlights:

- Single and double Systemic Tree Injection Tube (STIT) injections of treatments containing emamectin benzoate continued to reduce coneworm damage by 45 - 58% in 2002 – 4 years after initial injection.
- STIT injection treatments containing emamectin benzoate or thiamethoxam did not significantly reduce seed bug damage or improve filled seed yield in 2002 – 30 months post treatment. Control of seed bug using thiamethoxam will require yearly injections.

Objectives: 1) Continue evaluations on the residual activity of emamectin benzoate and emamectin benzoate/thiamethoxam mixture, applied by the STIT injector in 1999 and 2000 for control of coneworm and seed bugs in loblolly pine seed orchards.

Study Site: 20 acre "082" orchard (drought-hardy loblolly pine) removed from production in 1995 -- Texas Forest Service Magnolia Springs Seed Orchard, Jasper Co., TX.

Insecticides:

Emamectin benzoate (Arise SL®) -- avermectin derivative

Thiamethoxam (Novartis 293) -- experimental insecticide with similar activity compared to imidacloprid.

Design: Randomized complete block with clones as blocks. 10 treatments X 10 clones reduced to 5 treatments X 10 clones (= 50 ramets) used for study in 2002.

Application Methods:

STIT Injection – In 1999 and 2000, a 3/8 in diameter hole, 11 cm (4.5 in) deep was drilled parallel to the ground; number of holes was equal to the volume of insecticide solution to be applied divided by 50 ml (the capacity of each injector); holes were placed at a height of 1 m. -- the prefilled injector was hammered into the drill hole, and pressurized to 50 psi. Most treatment solutions drained within 15 minutes. The volume of insecticide solution applied was based on the diameter of each treatment tree as follows:

Tree	Treatments	
Diameter	1 and 2	3 and 4
<15 cm	20 ml	40 ml combined
16 - 20 cm	20 - 40 ml	40 - 80 ml
21 - 25 cm	40 - 60 ml	80 - 120 ml
26 - 30 cm	60 - 80 ml	120 - 160 ml
>30 cm	+20 ml/5 cm dia. increment	+40 ml/5 cm dia. increment

Treatments:

1) 4% emamectin benzoate (Arise SL®) by STIT injector (applied April 1999) (N = 10)
2) 4% emamectin benzoate (Arise SL®) by STIT injector (applied April 1999 & April 2000) (N = 10)
3) 1:1 mixture of 4% emamectin benzoate (Arise SL®) and 5% thiamethoxam by STIT injector (applied April 1999) (N = 10)
4) 1:1 mixture of 4% emamectin benzoate (Arise SL®) and 5% thiamethoxam by STIT injector (applied April 1999 & April 2000) (N = 10)
5) Check (N = 10)

Data Collection:

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

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

Results: The orchard block containing the treatment trees had not been sprayed since 1995, suggesting that pressure from coneworms and seed bugs would be moderate to high. This was confirmed for coneworms by over 32% damage on check cones in 2002, close to the high damage levels (34%) observed in 2001 (Table 2). Moderate numbers of seed bugs were observed in the trees in 2002. This was confirmed by the 31% damage by seed bugs to seed from check trees (Table 3), compared to 53% in 1999, 24% in 2000 and 33% in 2001. Seedworm damage to seed from check trees was considered insignificant (1% or less in 2001), so the data were not included in the analysis.

<u>*Treatment Effect on Coneworm Damage*</u>: In 1999 and 2000, treatments containing emamectin benzoate (alone or combined with thiamethoxam) significantly reduced early and late coneworm damage compared to the check (Table 2). Overall reductions for both emamectin benzoate alone and emamectin benzoate plus thiamethoxam treatments were >96% compared to the check. Overall reductions declined somewhat in 2001 (range 84% to 91%). In 2002, the treatment effects declined further; reduction in coneworm damage ranged from 45 to 58%. The addition of thiamethoxam did not improve or reduce the performance of emamectin benzoate against coneworm. Results for two-injection treatments containing emamectin benzoate did not differ significantly from single-injection treatments. Therefore, a single injection of emamectin benzoate is sufficient to protect trees against coneworm for four full years. Only the double dose of emamectin benzoate alone saw significantly higher proportions of healthy cones compared to the check.

<u>*Treatment Effect on Seed Bug Damage:*</u> In 2002, seed bug damage levels (32%) were moderate in check cones compared to levels in 1999 (54%), 2000 (24%) and 2001 (33%) (Table 3). The higher level of damage late in the growing season compared to earlier in the year again indicates that the shieldbacked pine seed bug had a much greater impact on seed production at this orchard than did the leaffooted pine seed bug. None of the treatments significantly reduced early and late seed bug damage or increased the number of full seeds per cone compared to the

check. This indicates that the yearly treatments of thiamethoxam are necessary to maintain adequate protection against seed bugs.

Treatment Effect on Overall Insect Damage: An estimate of the combined losses due to two primary insect pest groups, coneworms and seed bugs, can be calculated by adding the proportion of coneworm-damaged cones to the proportion of all seed in "apparently" healthy cones damaged by seed-bug. (**Note:** this does not take into account the portion of sound seed that might be retrieved from some of the less damaged "other" cones.) In this study, it is conservatively estimated that coneworms and seed bugs in combination reduced the potential seed crops of check trees in 2002 by 51%; compared to 41% in 1999, 29% in 2000 and 51% in 2001 (Table 4). One treatment continues to stand out with regard to its ability to reduce overall insect damage: emamectin benzoate + thiamethoxam. Two injections of this treatment in 2000 continued to reduce overall insect damage by 36% in 2002.

Summary: Over the past four years, emamectin benzoate has exhibited the best overall protection against coneworms, but was less effective against seed bugs. The data suggest that a single injection of emamectin benzoate can protect trees against coneworm for 48 months or longer. A second injection is not necessary during the second growing season. The Arise SL® formulation of emamectin benzoate is reported to be highly effective (providing 4+ years of protection) in Japan against the pinewood nematode, *Bursaphelenchus xylophilus*, and its cerambycid vector, *Monochamus alternatus* (David Cox , Syngenta, personal communication). The maximum duration of this chemical's residual activity against cone and seed insects has yet to be determined.

In contrast, thiamethoxam provided good protection against seed bugs during the year following injection, but generally showed little or inconsistent effects against coneworms. Thiamethoxam does provided some extended protection (18 mo.), but not as extensive as was found for emamectin benzoate against coneworms. Protection improved significantly with a second injection of thiamethoxam. An additional study was initiated in 2001 to determine optimal application rates of emamectin benzoate and thiamethoxam.

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, as suggested by DeBarr (1971). With these criteria, only 10 – 25% of the ramets in an orchard might need to be protected with insecticides. In turn, the pesticide load (amount of pesticide per acre) produced by conventional application techniques could be substantially reduced. Potential environmental concerns from insecticides in runoff water could be virtually eliminated because insecticides would be contained in the tree. Specific situations where systemic injections may be particularly useful include protecting seeds on trees with control pollinated crosses, protecting selected ramets of genetically-valued clones in early-generation orchards after emphasis shifts to newer orchards, and providing insect control in orchards located in environmentally sensitive sites where conventional air and ground sprays may be hazardous.

Syngenta Crop Protection recently registered emamectin benzoate (Proclaim®, Denim®) and thiamethoxam (Actera®) with EPA in the United States. However, the small seed orchard market and the flammability of the product carrier has discouraged Syngenta from pursuing registration of the Arise® (emamectin benzoate) formulation in this country. A preliminary trial in 2002 indicates that the Denim® formulation can be injected into loblolly pine using the STIT injector. However, the rate of injection of Denim® was slower (50 ml in 15 minutes) compared to the Arise® formulation (50 ml in 4 minutes). A small injection study is proposed for 2003 to test the efficacy of the Denim® formulation for control of cone and seed insects.

An attempt is being made to expand the forestry market through trials with other tree and pest species. For example, emamectin benzoate injected into several species of hardwood was nearly as effective as imidacloprid in causing mortality to larvae of the Asian longhorned beetle (Therese Poland, personal communication). In another trial, emamectin benzoate was injected into two white pine trees near Blackburg, VA in early August 2002. Twigs, taken from these injected trees two weeks later, were presented to male and female pales weevils, *Hylobius pales*, in petri dishes. Feeding activity was considerably reduced compared to untreated twigs and 100% mortality of both weevil sexes occurred within two weeks after exposure to treated twigs (Jeff Fidgeon, unpublished data).

The STIT injector, developed by Dr. Blair Helson, was successful in injecting 50 ml of insecticide into loblolly pine. However, the system has several limitations. The STIT injector is not manufactured, so considerable effort is required to make and maintain functional injectors. The effort and time required to load and clean each injector is considerable. Two manufactured injection systems are/will be available in 2003 – the Arborjet™ and Sidewinder™ systems. We are in the process of testing a new model of the Arborjet system that may allow faster injections into pine. Unfortunately, the Arborjet system, the newest one on the market, currently costs $4,200. The Sidewinder system (base price $1,800) has not yet been tested on loblolly pine.

Table 2. Mean percentages (± SE) of cones killed early and late by coneworms, other-damaged cones, and healthy cones on loblolly pine protected with systemic injection of emamectin benzoate (EB), emamectin benzoate + thiamethoxam (EB + Thia.), imidacloprid (Imid.) or foliar treatments of imidacloprid or Asana XL®, Magnolia Springs Seed Orchard, Magnolia Springs, Jasper Co., TX, 1999 - 2002.

				Mean Coneworm Damage (%)				
Year	Treatment	Application Technique, Treatment Date(s)	N	Early (small dead)	Late (large dead and infested)	Total	Mean Other Damage (%) *	Mean Healthy (%)
1999	EB	STIT - Apr., '99	20	1.0 ± 0.3 **a†**	0.3 ± 0.1 **a**	1.3 ± 0.4 **a**	41.3 ± 4.4 **a**	57.4 ± 4.5 **b**
	EB + Thia.	STIT - Apr., '99	20	3.3 ± 0.6 **b**	0.9 ± 0.2 **a**	4.2 ± 0.8 **b**	42.5 ± 3.2 **a**	53.3 ± 3.2 **b**
	Imid.	STIT - Apr., '99	20	6.3 ± 0.8 **c**	5.4 ± 1.3 **b**	11.8 ± 1.8 **c**	38.6 ± 2.7 **a**	49.6 ± 3.8 **b**
	Imid.	Hydraulic Foliar 5X in '99	10	9.8 ± 1.3 **d**	8.1 ± 1.7 **c**	17.9 ± 2.8 **d**	33.9 ± 3.9 **a**	48.1 ± 4.7 **ab**
	Check		10	12.0 ± 1.7 **d**	9.4 ± 2.8 **c**	21.4 ± 3.8 **d**	41.1 ± 2.7 **a**	37.6 ± 3.8 **a**
2000	EB	STIT - Apr., '99	10	0.1 ± 0.1 **a**	0.5 ± 0.3 **a**	0.6 ± 0.3 **a**	47.0 ± 7.7 **a**	52.4 ± 7.8 **a**
	EB	STIT - Apr., '99 & '00	10	0.4 + 0.3 **a**	0.1 ± 0.1 **a**	0.5 ± 0.3 **a**	60.1 ± 5.9 **a**	39.4 ± 5.9 **a**
	EB + Thia.	STIT - Apr., '99	10	0.2 ± 0.1 **a**	0.5 ± 0.4 **a**	0.7 ± 0.5 **a**	51.6 ± 6.1 **a**	47.8 ± 6.2 **a**
	EB + Thia.	STIT - Apr., '99 & '00	10	0.5 ± 0.3 **a**	0.4 ± 0.2 **a**	0.8 ± 0.3 **a**	55.1 ± 7.2 **a**	44.6 ± 7.3 **a**
	Imid.	STIT - Apr., '99	10	3.4 ± 1.1 **b**	17.7 ± 4.2 **b**	21.1 ± 5.0 **b**	44.8 ± 6.4 **a**	34.1 ± 6.9 **a**
	Imid.	STIT - Apr., '99 & '00	10	4.3 ± 1.3 **b**	12.1 ± 4.4 **b**	16.4 ± 4.3 **b**	44.2 ± 4.9 **a**	39.3 ± 6.0 **a**
	Asana XL	Hydraulic Foliar 5X in '00	10	5.0 ± 1.1 **b**	7.4 ± 2.2 **b**	12.4 ± 2.9 **b**	43.5 ± 5.5 **a**	44.1 ± 7.0 **a**
	Check		10	4.0 ± 0.9 **b**	17.1 ± 4.2 **b**	21.1 ± 4.3 **b**	51.3 ± 3.6 **a**	27.6 ± 5.0 **a**
2001	EB	STIT - Apr., '99	6	3.3 + 1.0 **a**	1.8 + 0.9 **a**	5.0 + 1.3 **a**	27.1 + 8.4 **a**	67.8 + 9.4 **b**
	EB	STIT - Apr., '99 & '00	6	4.3 + 1.0 **a**	1.1 + 0.4 **a**	5.4 + 1.1 **a**	30.7 + 8.2 **a**	63.9 + 9.0 **b**
	EB + Thia.	STIT - Apr., '99	6	3.1 + 1.3 **a**	1.3 + 0.4 **a**	4.4 + 1.4 **a**	28.8 + 7.6 **a**	66.7 + 8.6 **b**
	EB + Thia.	STIT - Apr., '99 & '00	5	2.8 + 2.0 **a**	0.3 + 0.2 **a**	3.1 + 2.1 **a**	28.3 + 5.2 **a**	71.4 + 5.4 **b**
	Check		6	14.9 + 2.2 **b**	19.2 + 3.6 **b**	34.2 + 3.3 **b**	17.3 + 3.6 **a**	48.5 + 5.1 **a**
2002	EB	STIT - Apr., '99	10	6.8 + 1.6 **a**	8.6 + 1.2 **ab**	15.4 + 2.5 **a**	10.7 + 4.3 **a**	74.0 + 6.2 **ab**
	EB	STIT - Apr., '99 & '00	10	7.4 + 2.5 **a**	7.1 + 1.8 **a**	14.5 + 3.6 **a**	7.8 + 3.4 **a**	77.7 + 5.9 **b**
	EB + Thia.	STIT - Apr., '99	9	6.3 + 1.1 **a**	11.3 + 2.1 **ab**	17.6 + 2.6 **a**	12.9 + 4.9 **a**	69.5 + 7.1 **ab**
	EB + Thia.	STIT - Apr., '99 & '00	9	5.3 + 0.7 **a**	8.1 + 1.4 **ab**	13.5 + 1.6 **a**	12.5 + 3.2 **a**	74.0 + 3.9 **ab**
	Check		10	20.0 + 3.6 **b**	12.2 + 1.9 **b**	32.2 + 4.4 **b**	8.6 + 2.7 **a**	59.2 + 4.0 **a**

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

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

Table 3. Seed bug damage, seed extracted, and seed quality (Mean ± SE) from second-year cones of loblolly pine protected with systemic injection of emamectin benzoate (EB), emamectin benzoate + thiamethoxam (EB + Thia.), imidacloprid (Imid.) or foliar treatments of imidacloprid or Asana XL®, Magnolia Springs Seed Orchard, Magnolia Springs, Jasper Co., TX, 1999 - 2002.

				Mean Seed Bug Damage (%)			Mean No.	Mean No.	Mean No.
		Application Technique,		Early			Seeds	Filled Seed	Empty Seed
Year	Treatment	Treatment Date(s)	N	(2nd Yr Abort)	Late	Total	per Cone	per Cone	per Cone
1999	EB	STIT - Apr., '99	20	0.7 ± 0.2 **b***	34.4 ± 3.7 **c**	35.1 ± 3.8 **c**	66.4 ± 7.0 **a**	32.1 ± 6.5 **ab**	13.3 ± 2.4 **a**
	EB + Thia.	STIT - Apr., '99	20	0.4 ± 0.1 **ab**	24.6 ± 3.9 **b**	25.0 ± 3.9 **b**	83.1 ± 6.9 **a**	48.4 ± 6.2 **c**	16.1 ± 1.8 **a**
	Imid.	STIT - Apr., '99	20	0.4 ± 0.2 **a**	9.2 ± 1.2 **a**	9.6 ± 1.3 **a**	78.7 ± 6.5 **a**	60.5 ± 5.8 **c**	10.6 ± 1.2 **a**
	Imid.	Hydraulic Foliar 5X in '99	10	0.9 ± 0.3 **b**	28.1 ± 2.2 **bc**	29.0 ± 2.2 **bc**	68.1 ± 7.0 **a**	35.3 ± 4.5 **bc**	12.0 ± 2.2 **a**
	Check		10	1.7 ± 0.3 **c**	51.3 ± 5.3 **d**	53.0 ± 5.5 **d**	60.2 ± 6.9 **a**	18.6 ± 5.8 **a**	10.5 ± 1.6 **a**
2000	EB	STIT - Apr., '99	10	0.5 ± 0.3 **a**	15.6 ± 2.8 **b**	16.1 ± 3.0 **b**	81.3 ± 11.5 **a**	59.1 ± 9.6 **ab**	7.6 ± 1.1 **a**
	EB	STIT - Apr., '99 & '00	10	0.6 ± 0.2 **ab**	14.4 ± 2.0 **b**	15.1 ± 2.1 **b**	89.0 ± 9.1 **a**	62.6 ± 7.5 **abc**	10.2 ± 1.6 **a**
	EB + Thia.	STIT - Apr., '99	10	0.4 ± 0.1 **a**	17.2 ± 2.8 **bc**	17.6 ± 2.9 **bc**	97.6 ± 7.2 **a**	66.1 ± 6.0 **bcd**	12.2 ± 2.3 **a**
	EB + Thia.	STIT - Apr., '99 & '00	10	0.7 ± 0.3 **ab**	6.9 ± 1.4 **a**	7.6 ± 1.5 **a**	103.8 ± 6.9 **a**	86.8 ± 7.4 **d**	8.7 ± 1.1 **a**
	Imid.	STIT - Apr., '99	10	0.5 ± 0.2 **a**	14.4 ± 3.1 **b**	14.9 ± 3.2 **b**	96.5 ± 9.9 **a**	68.9 ± 9.2 **bcd**	12.3 ± 2.1 **a**
	Imid.	STIT - Apr., '99 & '00	10	0.2 ± 0.1 **a**	5.5 ± 1.5 **a**	6.1 ± 1.5 **a**	105.6 ± 10.3 **a**	86.1 ± 8.5 **cd**	11.1 ± 1.9 **a**
	Asana XL	Hydraulic Foliar 5X in '00	10	0.3 ± 0.2 **a**	5.2 ± 0.8 **a**	5.5 ± 0.8 **a**	93.3 ± 5.5 **a**	75.1 ± 5.1 **bcd**	10.4 ± 1.1 **a**
	Check		10	1.3 ± 0.5 **b**	23.0 ± 3.2 **c**	24.3 ± 3.5 **c**	75.8 ± 10.3 **a**	48.3 ± 6.9 **a**	8.8 + 2.3 **a**
2001	EB	STIT - Apr., '99	6	0.7 + 0.3 **a**	39.1 + 8.3 **a**	39.8 + 8.2 **a**	76.1 + 17.5 **a**	44.0 + 15.8 **a**	5.9 + 2.0 **a**
	EB	STIT - Apr., '99 & '00	6	1.0 + 0.4 **a**	36.2 + 2.3 **a**	37.2 + 2.6 **a**	94.7 + 13.9 **a**	50.2 + 8.6 **a**	8.7 + 1.7 **a**
	EB + Thia.	STIT - Apr., '99	6	0.3 + 0.1 **a**	32.9 + 2.5 **a**	33.2 + 2.7 **a**	87.2 + 13.2 **a**	50.1 + 8.3 **a**	7.4 + 3.1 **a**
	EB + Thia.	STIT - Apr., '99 & '00	5	0.7 + 0.2 **a**	20.1 + 2.9 **a**	20.8 + 2.9 **a**	103.0 + 11.4 **a**	75.2 + 10.4 **a**	6.1 + 1.4 **a**
	Check		6	0.5 + 0.2 **a**	32.5 + 5.1 **a**	33.0 + 5.0 **a**	84.5 + 9.6 **a**	51.5 + 8.4 **a**	5.3 + 1.7 **a**
2002	EB	STIT - Apr., '99	10	6.2 + 4.3 **b**	28.3 + 3.7 **a**	34.4 + 5.0 **a**	65.3 + 9.2 **a**	42.4 + 9.1 **a**	3.0 + 0.6 **a**
	EB	STIT - Apr., '99 & '00	10	2.3 + 1.1 **ab**	28.6 + 6.5 **a**	30.9 + 6.3 **a**	82.1 + 8.8 **a**	57.1 + 8.3 **a**	3.0 + 0.4 **a**
	EB + Thia.	STIT - Apr., '99	9	1.6 + 0.8 **ab**	34.0 + 7.0 **a**	35.6 + 7.6 **a**	76.9 + 9.1 **a**	49.4 + 9.3 **a**	4.2 + 0.7 **a**
	EB + Thia.	STIT - Apr., '99 & '00	9	0.6 + 0.1 **a**	25.2 + 2.6 **a**	25.8 + 2.7 **a**	84.9 + 3.8 **a**	59.1 + 4.4 **a**	3.3 + 0.5 **a**
	Check		10	0.5 + 0.1 **a**	31.2 + 1.7 **a**	31.6 + 1.7 **a**	83.4 + 6.2 **a**	53.1 + 4.8 **a**	3.0 + 0.5 **a**

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

Table 4. Mean % (+ SE) cone and seed losses from insects (coneworms and seed bugs) and reductions in damage from second-year cones of loblolly pine protected with systemic injection of emamectin benzoate (EB), emamectin benzoate + thiamethoxam (EB + Thia.), imidacloprid (Imid.) or foliar treatments of imidacloprid or Asana XL, Magnolia Springs Seed Orchard, Magnolia Springs, Jasper Co., TX, 1999 - 2002.

		1999			2000			2001			2002		
Treatment	Application Technique, Treatment Date(s)	N	Mean Combined Losses (%)	Mean Reduction (%)	N	Mean Combined Losses (%)	Mean Reduction (%)	N	Mean Combined Losses (%)	Mean Reduction (%)	N	Mean Combined Losses (%)	Mean Reduction (%)
EB	STIT - Apr., '99	20	20.1 + 2.4 **a***	51.0									
EB	STIT - Apr., '99	10			10	9.2 + 2.4 **ab**	67.5	6	32.7 + 7.0 **b**	36.3	10	39.8 + 4.3 **ab**	21.7
EB	STIT - Apr., '99 & '00	10			10	6.0 + 1.2 **a**	79.0	6	29.4 + 2.8 **b**	42.7	10	39.1 + 5.6 **ab**	23.0
EB + Thia.	STIT - Apr., '99	20	17.4 + 2.2 **a**	57.7									
EB + Thia.	STIT - Apr., '99	10			10	8.0 + 0.8 **ab**	71.9	6	27.4 + 3.3 **ab**	46.6	9	38.9 + 3.8 **ab**	23.4
EB + Thia.	STIT - Apr., '99 & '00	10			10	4.1 + 0.7 **a**	85.7	5	17.7 + 2.8 **a**	65.5	9	32.7 + 2.1 **a**	35.6
Imid.	STIT - Apr., '99	20	15.9 + 1.7 **a**	61.2									
Imid.	STIT - Apr., '99	10			10	25.6 + 4.8 **de**	9.7						
Imid.	STIT - Apr., '99 & '00	10			10	18.9 + 4.2 **cd**	33.4						
Imid.	Foliar Spray 5X in '99	10	31.6 + 2.7 **b**	23.1									
Asana XL	Foliar Spray 5X in '00	10			10	14.8 + 2.7 **bc**	47.7						
Check		10	41.1 + 3.6 **b**		10	28.4 + 3.0 **e**		6	51.3 + 3.4 **c**		10	50.8 + 3.8 **b**	

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

2001-2002 Systemic Insecticide Injection Rate Study - Magnolia Springs, TX

Highlights:

- Emamectin benzoate plus thiamethoxam (20 ml) injected in April 2001 improved conelet survival by 9% and cone survival by 39% in 2002.
- Single injections of emamectin benzoate alone or in combination with thiamethoxam at high (20 ml) rates reduced coneworm damage by 71% and seed bug damage by 12 – 20% in 2002.
- Overall insect damage (coneworm + seed bug) was reduced to the greatest extent (42% and 36%) by emamectin benzoate plus thiamethoxam injected at rates of 20 ml and 10ml, respectively.

Objectives: 1) Evaluate the efficacy of systemic injections of emamectin benzoate and thiamethoxam, alone or combined, in reducing seed crop losses in loblolly pine seed orchards; 2) evaluate the combination treatment, emamectin benzoate plus thiamethoxam, applied at three rates using a pressurized injection system; and 3) determine the duration of treatment efficacy.

Study Site: 20 acre orchard block containing 11 year-old drought-hardy loblolly pine -- Texas Forest Service Magnolia Springs Seed Orchard, Jasper Co., TX.

Insecticides:

Emamectin benzoate (Arise SL®) -- avermectin derivative

Thiamethoxam (Novartis 293) -- experimental insecticide with similar activity compared to imidacloprid.

Design: Randomized complete block with clones as blocks. 7 treatments X 10 clones = 70 ramets used for study.

Application Methods:

STIT Injection – In April 2001, a 3/8 in diameter hole, 11 cm (4.5 in) deep was drilled parallel to the ground at each injection site; number of holes was equal to the volume of insecticide solution to be applied divided by 50 ml (the capacity of each injector); holes were placed at a height of 1 m. The prefilled injector was hammered into the drill hole and pressurized to 50 psi. Most treatment solutions drained within 15 minutes. The volume of insecticide solution applied was based on the diameter of each treatment tree as follows:

Tree	Treatments		
Diameter	1, 4 & 5	2	3
11 - 15 cm	20 ml	10 ml	3 ml
16 - 20 cm	20 - 40 ml	10 - 20 ml	3 - 6 ml
21 - 25 cm	40 - 60 ml	20 - 30 ml	6 - 9 ml
26 - 30 cm	60 - 80 ml	30 - 40 ml	9 - 12 ml
>30 cm	+20 ml/5 cm dia. increment	+10 ml/5 cm dia. increment	+3 ml/5 cm dia. increment

Treatments:

1) 20 ml rate each for 4% emamectin benzoate (Arise SL®) and 5% thiamethoxam (25WG) by injector
2) 10 ml rate each for 4% emamectin benzoate (Arise SL®) 5% thiamethoxam (25WG) by injector
3) 3 ml rate each for 4% emamectin benzoate (Arise SL®) 5% thiamethoxam (25WG) by injector
4) 20 ml rate for 4% emamectin benzoate (Arise SL®) alone by injector
5) 20 ml rate for 5% thiamethoxam (25WG) alone by injector
6) Asana XL (standard) applied by hydraulic sprayer to foliage 5 times per year at 9.6 oz/100 gal at 5-week intervals beginning in April.
7) Check

Data Collection:

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

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

Seed Bug Damage -- 10 healthy 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: The orchard block containing the treatment trees has not been sprayed since establishment - suggesting that pressure from coneworms and seed bugs would be moderate to high. This was confirmed for coneworms by over 30% damage on check cones in 2001 (Table 5). Moderate numbers of both leaf-footed and sheildbacked pine seed bugs were observed in the trees in 2002. This was reflected by the 33% damage to seed from check trees (Table 6). Seedworm damage to seed from check trees was considered insignificant (1% or less in 2002), so the data were not included in the analysis.

<u>*Treatment Effect on Conelet and Cone Survival*</u>: Cones on tagged branches were examined in April and October. All injection and foliar treatments significantly improved survival of cones compared to check trees. However, only the thiamethoxam alone treatment significantly improved conelet survival (13%) (Table 7). Overall, the higher rates of emamectin benzoate alone (20 ml) and in combination with thiamethoxam (20 ml and 10 ml) provided the best protection of cones, significantly improving survival by 36%, 37% and 36%, respectively, over that of the check (Table 7). Logarithmic curves show a good relationship between rates of emamectin benzoate and thiamethoxam applied and cone survival (r^2 = 0.523), but not conelet survival (r^2 = 0.117) (Figs. 1 & 2).

<u>*Treatment Effect on Coneworm Damage*</u>: All injection treatments significantly reduced early and late coneworm damage compared to the check (Table 5). Overall, the high rate of emamectin benzoate alone provided the greatest reduction in total coneworm damage (83%) compared to the check. The higher rates of emamectin benzoate plus thiamethoxam (20 ml and

10 ml) were only slightly less effective; reducing damage by 76% and 75%, respectively. All injection treatments had significantly higher proportions of healthy cones compared to the check. A good relationship was found between rates of emamectin benzoate and thiamethoxam applied and incidence of coneworm damage (r^2 = 0.681) (Fig. 3).

Treatment Effect on Seed Bug Damage: In 2002, seed bug damage levels (33%) were moderate in check cones, and the same as 2001 levels (33.0%) (Table 6). The higher level of damage late in the growing season compared to earlier in the year again indicates that the shieldbacked pine seed bug had a much greater impact on seed production at this orchard than did the leaffooted pine seed bug. None of the injection treatments significantly reduced total seed bug damage. Nor did these treatments increase the number of full seeds per cone compared to the check. A poor relationship was found between rates of emamectin benzoate and thiamethoxam applied and incidence of seed bug damage (r^2 = 0.084) (Fig. 4)

Treatment Effect on Overall Insect Damage: An estimate of the combined losses due to 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. (**Note:** this does not take into account the portion of sound seed that might be retrieved from some of the less damaged "other" cones.) In this study, it is conservatively estimated that in 2002 coneworms and seed bugs in combination reduced the potential seed crops of check trees by 51%; down from 60% in 2001 (Table 8). As in 2001, three treatments were most effective in reducing overall insect damage: 20 ml of emamectin benzoate alone and the two higher rates (10 ml and 20 ml) of emamectin benzoate plus thiamethoxam. Injections of these treatments in 2002 reduced overall insect damage by 42%, 48% and 42%, respectively. A fair relationship was found between rates of emamectin benzoate and thiamethoxam applied and overall insect losses (r^2 = 0.381) (Fig. 5)

Summary: This study again demonstrates that emamectin benzoate, alone or in combination with thiamethoxam, is effective at protecting cones against coneworms. Surprisingly, thiamethoxam alone has been nearly as effective as emamectin benzoate at reducing coneworm damage during the first two seasons after injection. Regression curves indicate that 20ml of the emamectin benzoate and thiamethoxam is necessary to maintain highest levels of reduction of coneworm and seed bug damage and provides the greatest gain in cone survival and filled seed per cone.

Unfortunately, all injection treatments showed a marked reduction in efficacy in 2002 compared to results observed in 2001. This is in contrast to the increased efficacy observed in the second year of the Duration Study. The reason may be due to a combination of factors. One factor may include the fact that due to the smaller size of trees in the Rate Study orchard (8.9 in. DBH) compared to the Duration Study orchard (16.8 in DBH), lower volumes of insecticides were required and subsequently fewer injection points (2.2 versus 2.8) were used per tree. The reduced number of injection points on the Rate Study trees may have limited the distribution of the insecticide into the canopy of the trees. Another factor may be the amount of insect pressure on trees in a given year. Check trees in Duration Study had relatively low levels of coneworm damage during the first two years (21%) and less than half the amount of seed bug damage (24%) in the second year of the study (2000) compared to the first year (53%). In contrast, check trees in the Rate Study orchard had high levels of coneworm damage (46% in

2001 and 31% in 2002) and the same level of seed bug damage in 2002 (33%) compared to 2001 (33%).

The small injection study proposed for 2003 to test the efficacy of the Denim® (emamectin benzoate) formulation will necessitate the use of twice the volume of product because the concentration of active ingredient in Denim (1.9%) is less than half that of the Arise formulation (4%). The study design will call for 4 or more injection points per tree to insure adequate distribution of the product within the tree.

Table 5. Mean percentages (± SE) of cones killed early and late by coneworms, other-damaged cones, and healthy cones on loblolly pine protected with systemic injection of emamectin benzoate (EB), thiamethoxam (Thia.), emamectin benzoate + thiamethoxam (EB + Thia.) or foliar treatments of Asana XL®, Magnolia Springs Seed Orchard, Magnolia Springs, Jasper Co., TX, 2001 - 2002.

				Mean Coneworm Damage (%)				
Year	Treatment	Application Technique, Treatment Date(s)	N	Early (small dead)	Late (large dead and infested)	Total	Mean Other Damage (%) *****	Mean Healthy (%)
2001	EB (20)	STIT - Apr., '01	10	1.5 ± 0.5 **a†**	1.0 ± 0.4 **a**	2.5 ± 0.7 **ab**	19.6 ± 7.0 **a**	77.9 ± 6.9 **bc**
	EB + Thia. (20)	STIT - Apr., '01	10	1.0 ± 0.3 **a**	1.5 ± 1.0 **a**	2.5 ± 1.2 **b**	14.3 ± 5.6 **a**	83.2 ± 6.7 **c**
	EB + Thia. (10)	STIT - Apr., '01	10	1.2 ± 0.4 **a**	1.5 ± 0.4 **ab**	2.7 ± 0.7 **ab**	17.4 ± 4.4 **a**	79.9 ± 4.5 **bc**
	EB + Thia. (3)	STIT - Apr., '01	10	2.6 ± 0.6 **a**	2.6 ± 0.7 **ab**	5.2 ± 1.3 **ab**	18.5 ± 5.1 **a**	76.3 ± 4.8 **bc**
	Thia. (20)	STIT - Apr., '01	10	2.7 ± 1.0 **a**	3.1 ± 1.2 **bc**	5.8 ± 2.0 **b**	15.5 ± 6.2 **a**	78.7 ± 6.2 **bc**
	Asana XL	Hydraulic Foliar 5X in '01	10	7.8 ± 1.5 **b**	12.0 ± 2.5 **c**	19.8 ± 3.2 **c**	11.8 ± 2.0 **a**	68.4 ± 5.0 **b**
	Check		10	16.3 ± 2.4 **c**	29.5 ± 1.9 **d**	45.8 ± 3.4 **d**	9.9 ± 1.3 **a**	44.3 ± 3.2 **a**
2002	EB (20)	STIT - Apr., '01	9	2.4 ± 0.5 **a**	2.9 ± 0.8 **a**	5.3 ± 1.1 **a**	3.5 ± 0.6 **a**	91.1 ± 1.4 **c**
	EB + Thia. (20)	STIT - Apr., '01	9	2.8 + 1.0 **a**	4.5 ± 1.4 **ab**	7.3 ± 1.9 **ab**	5.4 ± 1.7 **a**	87.2 ± 2.8 **bc**
	EB + Thia. (10)	STIT - Apr., '01	9	3.6 ± 1.1 **ab**	4.0 ± 0.9 **ab**	7.6 ± 1.7 **ab**	5.7 ± 1.9 **a**	86.7 ± 2.8 **bc**
	EB + Thia. (3)	STIT - Apr., '01	9	6.1 ± 1.1 **b**	6.3 ± 1.3 **ab**	12.4 ± 2.0 **b**	6.2 ± 1.6 **a**	81.4 ± 2.9 **b**
	Thia. (20)	STIT - Apr., '01	9	5.4 ± 1.2 **ab**	5.7 ± 1.3 **ab**	11.1 ± 1.7 **ab**	5.5 ± 1.4 **a**	83.4 ± 2.5 **b**
	Asana XL	Hydraulic Foliar 5X in '02	8	4.8 ± 1.5 **ab**	7.1 ± 2.1 **b**	11.8 ± 3.1 **b**	3.2 ± 1.2 **a**	85.0 ± 3.3 **bc**
	Check		9	18.5 ± 2.9 **c**	12.0 ± 1.1 **c**	30.5 ± 3.0 **c**	6.6 ± 1.9 **a**	63.0 ± 4.3 **a**

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

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

Table 6. Seed bug damage, seed extracted, and seed quality (Mean ± SE) from second-year cones of loblolly pine protected with systemic injection of emamectin benzoate (EB), thiamethoxam (Thia.), emamectin benzoate + thiamethoxam (EB + Thia.) or foliar treatments of Asana XL®, Magnolia Springs Seed Orchard, Magnolia Springs, Jasper Co., TX, 2001 - 2002.

				Mean Seed Bug Damage (%)			Mean No.	Mean No.	Mean No.
Year	Treatment	Application Technique, Treatment Date(s)	N	Early (2nd Yr Abort)	Late	Total	Seeds per Cone	Filled Seed per Cone	Empty Seed per Cone
2001	EB (20)	STIT - Apr., '01	10	0.7 ± 0.2 **a***	19.8 ± 4.2 **cd**	20.5 ± 4.3 **cd**	120.1 ± 6.0 **a**	80.7 ± 7.3 **cd**	13.9 ± 1.6 **a**
	EB + Thia. (20)	STIT - Apr., '01	10	0.6 ± 0.1 **a**	15.8 ± 3.4 **bc**	16.4 ± 3.4 **bc**	122.2 ± 7.6 **a**	88.5 ± 7.8 **cd**	12.6 ± 2.0 **a**
	EB + Thia. (10)	STIT - Apr., '01	10	0.6 ± 0.1 **a**	14.3 ± 3.3 **ab**	14.9 ± 3.4 **ab**	118.7 ± 6.4 **a**	86.1 ± 8.9 **cd**	15.3 ± 3.1 **a**
	EB + Thia. (3)	STIT - Apr., '01	10	1.4 ± 0.4 **a**	25.1 ± 4.3 **d**	26.5 ± 4.5 **d**	109.1 ± 7.8 **a**	64.6 ± 7.3 **ab**	15.2 ± 2.0 **a**
	Thia. (20)	STIT - Apr., '01	10	0.8 ± 0.2 **a**	19.6 ± 4.1 **cd**	20.4 ± 4.1 **cd**	115.5 ± 7.9 **a**	79.0 ± 9.5 **bc**	13.5 ± 2.0 **a**
	Asana XL	Hydraulic Foliar 5X in '01	10	0.6 ± 0.3 **a**	9.9 ± 3.2 **a**	10.5 ± 3.3 **a**	118.8 ± 7.5 **a**	94.3 ± 8.2 **d**	11.2 ± 1.5 **a**
	Check		10	0.8 ± 0.2 **a**	31.7 ± 2.9 **e**	32.5 ± 2.9 **e**	105.7 ± 6.4 **a**	56.9 ± 4.3 **a**	13.5 ± 2.3 **a**
2002	EB (20)	STIT - Apr., '01	9	1.1 ± 0.3 **a***	25.4 ± 4.7 **ab**	26.4 ± 4.7 **ab**	78.4 ± 8.7 **a**	53.1 ± 9.9 **a**	5.9 ± 1.6 **a**
	EB + Thia. (20)	STIT - Apr., '01	9	1.3 ± 0.3 **a**	20.5 ± 3.2 **ab**	21.8 ± 3.3 **ab**	90.6 ± 7.3 **ab**	66.1 ± 8.0 **ab**	5.2 ± 1.2 **a**
	EB + Thia. (10)	STIT - Apr., '01	9	1.4 ± 0.4 **a**	23.3 ± 4.5 **ab**	24.7 ± 4.7 **ab**	84.6 ± 11.0 **a**	62.5 ± 11.2 **ab**	3.6 ± 0.7 **a**
	EB + Thia. (3)	STIT - Apr., '01	9	1.3 ± 0.4 **a**	25.5 ± 5.1 **b**	26.9 ± 5.3 **ab**	81.1 ± 10.7 **a**	56.4 ± 10.2 **a**	4.6 ± 0.8 **a**
	Thia. (20)	STIT - Apr., '01	9	1.2 ± 0.2 **a**	23.5 ± 4.0 **ab**	24.7 ± 4.1 **ab**	90.8 ± 8.0 **ab**	64.9 ± 8.8 **ab**	4.5 ± 1.0 **a**
	Asana XL	Hydraulic Foliar 5X in '02	8	1.3 ± 0.4 **a**	14.6 ± 4.2 **a**	15.9 ± 4.6 **a**	117.3 ± 8.4 **b**	96.1 ± 11.6 **b**	4.3 ± 0.8 **a**
	Check		9	1.8 ± 0.3 **a**	31.5 ± 4.5 **b**	33.3 ± 5.0 **b**	72.8 ± 10.8 **a**	46.2 ± 10.1 **a**	4.3 ± 1.1 **a**

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

Table 7. Mean percentages (± SE) of surviving conelets and cones on branches of loblolly pine protected with systemic injection of emamectin benzoate, thiamethocxam alone, emamectin benzoate + thiamethoxam, or foliar treatments of imidacloprid or Asana XL®, Magnolia Springs Seed Orchard, Magnolia Springs, Jasper Co., TX, 2001 - 2002.

Year	Treatment	Application Technique, Treatment Date(s)	N	Mean Survival (%) Conelets	Mean Survival (%) Cones
2001	Emamectin benzoate (20)	STIT - Apr., '01	10	78.5 ± 9.0 **bc†**	87.8 ± 4.4 **c**
	EB + Thia. (20)	STIT - Apr., '01	10	91.3 ± 3.6 **d**	94.4 ± 2.3 **c**
	EB + Thia. (10)	STIT - Apr., '01	10	89.4 ± 4.8 **cd**	92.3 ± 3.0 **c**
	EB + Thia. (3)	STIT - Apr., '01	10	79.7 ± 5.9 **ab**	89.4 ± 3.8 **c**
	Thiamethoxam (20)	STIT - Apr., '01	10	85.9 ± 4.8 **bcd**	88.6 ± 4.0 **c**
	Asana XL	Hydraulic Foliar 5X in '01	10	91.4 ± 2.5 **d**	78.4 ± 4.3 **b**
	Check		10	70.0 ± 4.3 **a**	58.4 ± 6.9 **a**
2002	Emamectin benzoate (20)	STIT - Apr., '01	9	81.7 ± 3.3 **ab**	92.5 ± 0.7 **c**
	EB + Thia. (20)	STIT - Apr., '01	9	85.7 ± 4.1 **ab**	92.8 ± 1.3 **c**
	EB + Thia. (10)	STIT - Apr., '01	9	84.8 ± 3.2 **ab**	92.3 ± 2.1 **c**
	EB + Thia. (3)	STIT - Apr., '01	9	84.5 ± 2.6 **ab**	86.9 ± 4.0 **bc**
	Thiamethoxam (20)	STIT - Apr., '01	9	87.8 ± 3.2 **b**	86.4 ± 1.8 **bc**
	Asana XL	Hydraulic Foliar 5X in '02	8	86.7 ± 2.3 **ab**	79.4 ± 5.2 **b**
	Check		9	77.6 ± 2.6 **a**	67.8 ± 4.7 **a**

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

Table 8. Mean % ($\pm$ SE) cone and seed losses from insects (coneworms and seed bugs) and reductions in damage from second-year cones of loblolly pine protected with systemic injection of emamectin benzoate (EB), thiamethoxam (Thia.), emamectin benzoate + thiamethoxam (EB + Thia.), or foliar treatments of Asana XL®, Magnolia Springs Seed Orchard, Magnolia Springs, Jasper Co., TX, 2001 - 2002.

		2001			2002		
Treatment	Application Technique, Treatment Date(s)	N	Mean Combined Losses (%)	Mean Reduction (%)	N	Mean Combined Losses (%)	Mean Reduction (%)
EB 20 ml	STIT - Apr., '01	10	16.7 $\pm$ 2.3 **ab***	72.2	9	29.6 $\pm$ 3.8 **a**	41.6
EB + Thia. 20 ml	STIT - Apr., '01	10	16.0 $\pm$ 3.0 **ab**	73.4	9	26.2 $\pm$ 3.5 **a**	48.3
EB + Thia. 10 ml	STIT - Apr., '01	10	14.6 $\pm$ 2.6 **a**	75.7	9	29.2 $\pm$ 4.0 **a**	42.4
EB + Thia. 3 ml	STIT - Apr., '01	10	25.5 $\pm$ 3.8 **c**	57.6	9	34.4 $\pm$ 4.3 **a**	32.2
Thia. 20 ml	STIT - Apr., '01	10	22.0 $\pm$ 3.8 **bc**	63.4	9	32.2 $\pm$ 3.0 **a**	36.6
Asana XL	Hydraulic Foliar 5X in '01 & '02	10	27.1 $\pm$ 3.4 **c**	54.9	8	24.6 $\pm$ 5.9 **a**	51.4
Check		10	60.1 $\pm$ 2.9 **d**		9	50.7 $\pm$ 4.4 **b**	

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

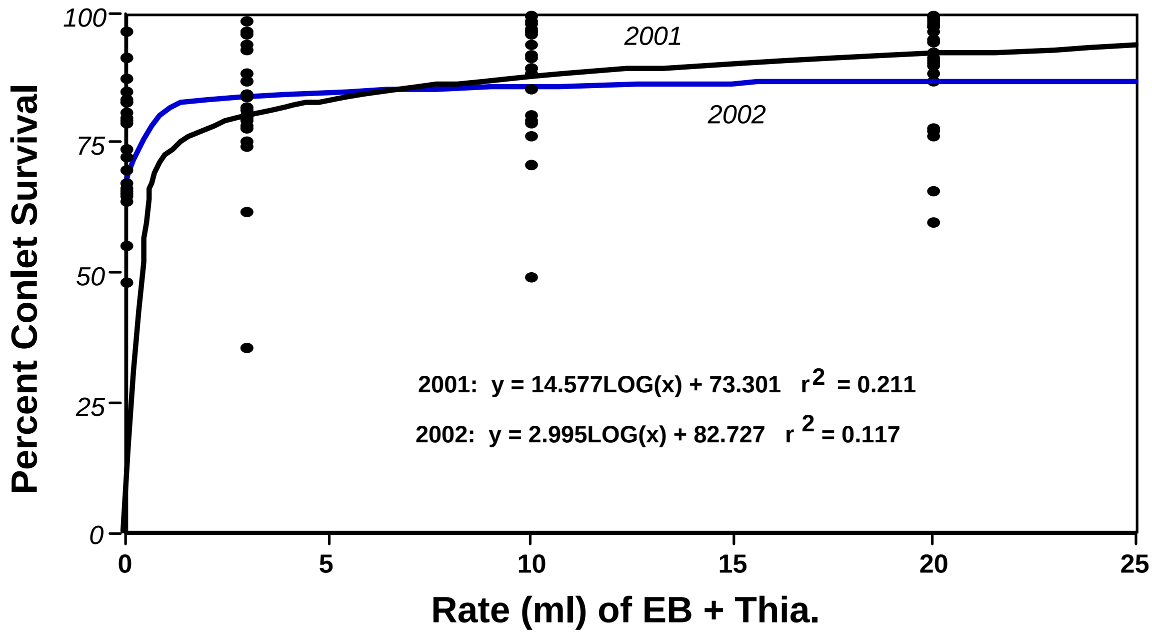

Figure 1. Relationship between loblolly pine conelet survival and rate of emamectin benzoate + thiamethoxam injected into loblolly pine trees, Magnolia Springs Seed Orchard, Magnolia Springs, Jasper Co., TX, 2001 - 2002.

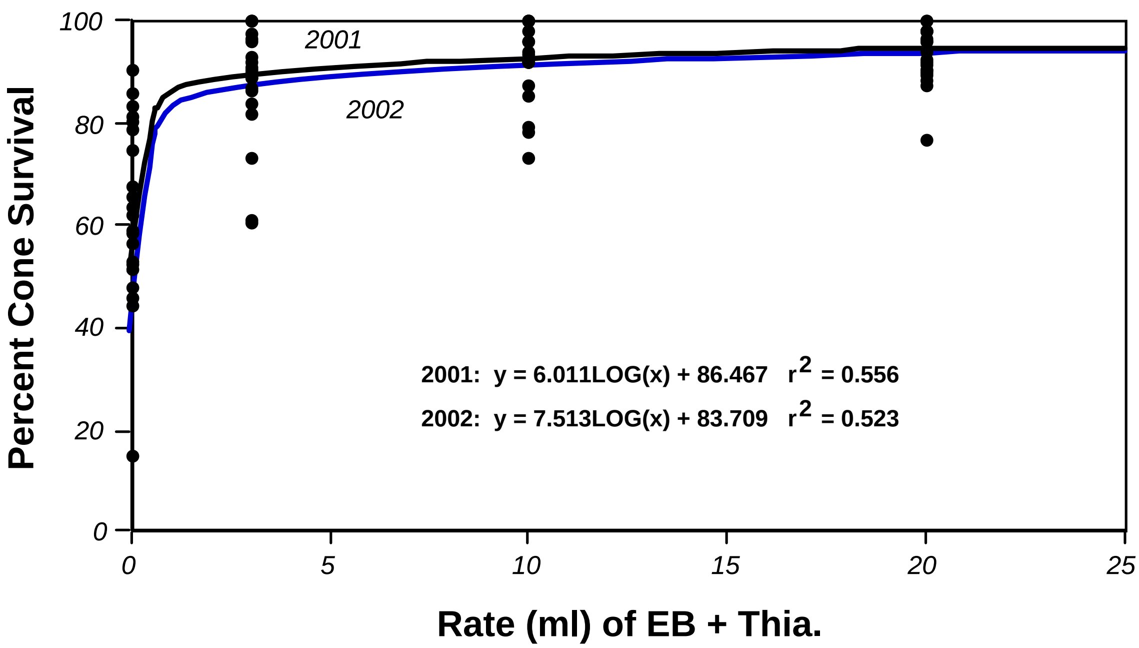

Figure 2. Relationship between loblolly pine cone survival and rate of emamectin benzoate + thiamethoxam injected into loblolly pine trees, Magnolia Springs Seed Orchard, Magnolia Springs, Jasper Co., TX, 2001 - 2002.

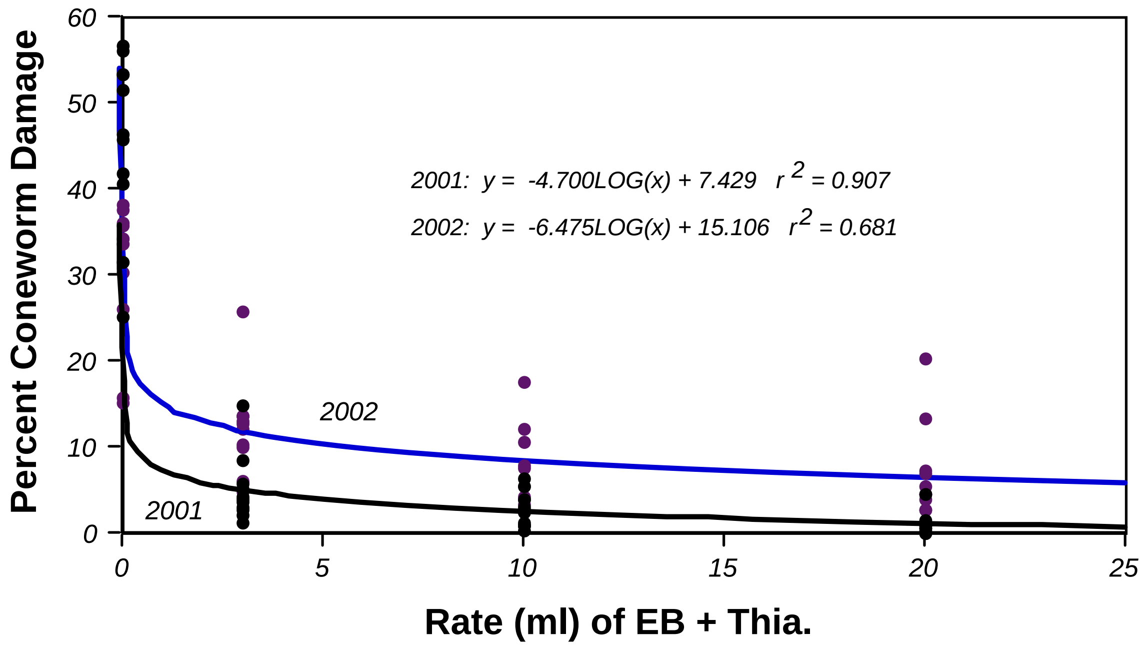

Figure 3. Relationship between coneworm (*Dioryctria* spp.) damage and rate of emamectin benzoate + thiamethoxam injected into loblolly pine trees, Magnolia Springs Seed Orchard, Magnolia Springs, Jasper Co., TX, 2001 - 2002.

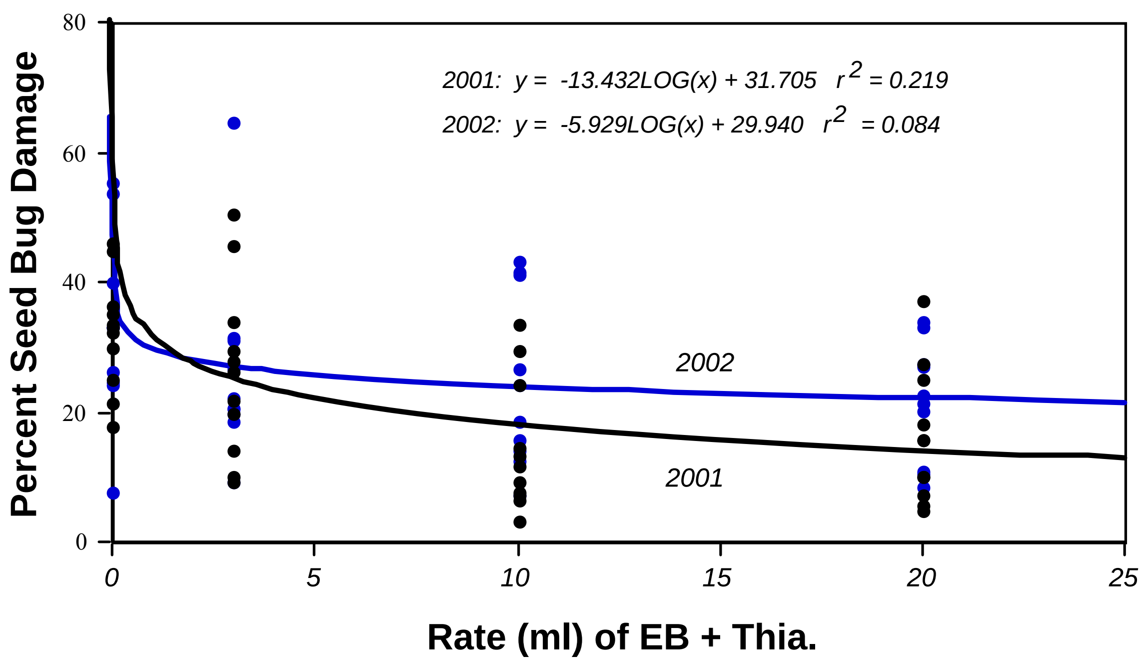

Figure 4. Relationship between seed bug (*Tetyra* sp. and *Leptoglossus* sp.) damage and rate of emamectin benzoate + thiamethoxam injected into loblolly pine trees, Magnolia Springs Seed Orchard, Magnolia Springs, Jasper Co., TX, 2001 - 2002.

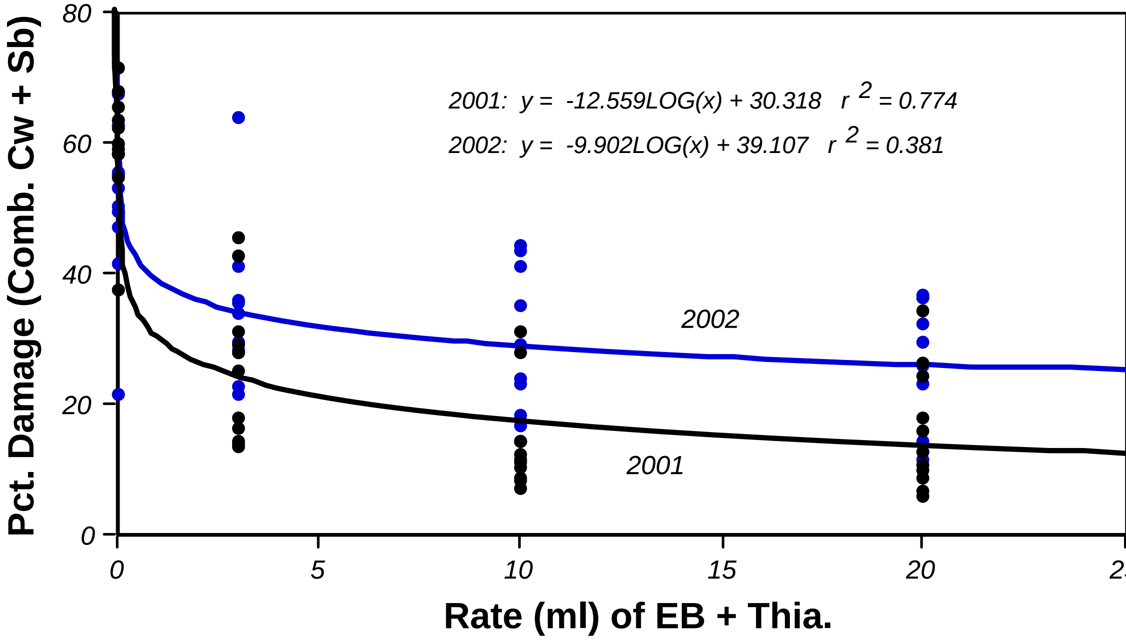

Figure 5. Relationship between overall insect damage (coneworm + seed bug) and rate of emamectin benzoate + thiamethoxam injected into loblolly pine trees, Magnolia Springs Seed Orchard, Magnolia Springs, Jasper Co., TX – 2001.

2001 - 2002 Systemic Insecticide Study – Marianna, FL

Highlights:

- Single STIT injections of emamectin benzoate into loblolly pine at the Bellamy SO in Florida in 2001 continued to reduced coneworm damage by 51% in 2002 – comparable to results in Texas.
- STIT injections of emamectin benzoate significantly increased the number of cones and seeds per cone compared to check trees.

Objectives: 1) Evaluate duration of emamectin benzoate, applied by the STIT injector, for control of coneworm and seed bugs in a Florida loblolly pine seed orchards.

Cooperators: Dr. R. Scott Cameron and Mr. Tim Slichter, International Paper Company

Study Sites: International Paper's Bellamy seed orchard (containing loblolly pine) at Marianna, FL.

Insecticides:

Emamectin benzoate (Arise SL®) -- avermectin derivative

Design: Randomized complete block with clones as blocks (loblolly pine). 2 treatments X 4 clones X 3 ramets/clone (= 24 ramets).

Application Methods:

STIT Injection –A 3/8 in diameter hole, 11 cm (4.5 in) deep was drilled parallel to the ground at each injection site; number of holes was equal to the volume of insecticide solution to be applied divided by 50 ml (the capacity of each injector); holes were placed at a height of 1 m. -- the prefilled injector was hammered into the drill hole, and pressurized to 50 psi. Most treatment solutions drained within 15 minutes. The volume of insecticide solution applied was based on the diameter of each treatment tree as follows:

Tree Diameter	Treatment Rate
<15 cm	20 ml
16 - 20 cm	20 - 40 ml
21 - 25 cm	40 - 60 ml
26 - 30 cm	60 - 80 ml
>30 cm	+20 ml/5 cm dia. increment

Treatments:

1) 4% emamectin benzoate (Arise SL®) by STIT injector (applied Mar. 2001)
2) Check (untreated)

Data Collection:

***Dioryctria* Attacks** -- All cones that could be reached by bucket truck were picked in early October; cones were categorized as coneworm-damaged or healthy.

Seed Bug Damage – all seed were extracted from each cone and counted. The number of seed per cone was calculated.

Results:

Treatment Effect on Coneworm Damage: Treatment of trees with emamectin benzoate significantly reduced coneworm damage compared to the check (Table 9). Overall reduction for emamectin benzoate was 51% compared to the check. This is a decline in efficacy from the 87% reduction in damage observed in 2001. The injection treatment also had a significantly higher proportion of healthy cones (18%) compared to the check in 2002.

Treatment Effect on Seed Bug Damage: Seed analysis to determine the effect of emamectin benzoate on seed bug damage levels in 2001 was on going in early 2002. Ultimately, the analysis showed the emamectin benzoate treatment did significantly reduce both early and late seed bug damage by 69% and 21%, respectively (Table 10). In addition, the treatment significantly increased the number of filled seed per cone by 54%. Seed analysis to determine 2002 seed bug damage levels is on going.

Treatment Effect on Overall Insect Damage: As in the Texas injection studies, an estimate of the combined losses in 2001 due to coneworms and seed bugs at the Bellamy Seed Orchard was calculated. In this study, it is conservatively estimated that in 2001 coneworms and seed bugs in combination reduced the potential seed crops of check trees by 34% (Table 11). The results of the 2002 seed analysis will be used to determine treatment effect on overall insect damage in 2002.

Summary: The Florida trial continues to indicate that the efficacy of STIT injections of emamectin benzoate is not geographically restricted. The WGFPMC is working with Dave Cox, Syngenta, towards the registration of this product in the United States.

Table 9. Mean percentages (± SE) of cones killed early and late by coneworms, other-damaged cones, and healthy cones on loblolly pine protected with systemic injection of emamectin benzoate alone (EB), Bellamy Seed Orchard, Marianna, Jackson Co., FL, 2001 - 2002.

				Mean Coneworm Damage (%)				
Year	Treatment (Rate in ml)	Application Technique, Treatment Date(s)	N	Early (small dead)	Late (large dead and infested)	Total	Mean Other Damage (%) *	Mean Healthy (%)
2001	EB (20)	STIT - Apr., '01	12	0.1 ± 0.0 **a†**	0.7 ± 0.2 **a**	0.8 ± 0.2 **a**	4.3 ± 1.5 **a**	94.9 ± 1.7 **b**
	Check		12	1.5 ± 0.4 **b**	4.8 ± 0.7 **b**	6.3 ± 1.0 **b**	3.1 ± 0.4 **a**	90.6 ± 1.2 **a**
2002	EB (20)	STIT - Apr., '01	12			12.9 ± 3.3 **a**		87.1 ± 3.3 **b**
	Check		12			26.2 ± 4.9 **b**		73.8 ± 4.9 **a**

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

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

Table 10. Seed bug damage, seed extracted, and seed quality (Mean ± SE) from second-year cones of loblolly pine protected with systemic injection of emamectin benzoate alone (EB), Bellamy Seed Orchard, Marianna, Jackson Co., FL, 2001 - 2002.

Year	Treatment	Application Technique, Treatment Date(s)	N	Mean Seed Bug Damage (%) Early (2nd Yr Abort)	Late	Total	Mean No. Seeds per Cone	Mean No. Filled Seed per Cone	Mean No. Empty Seed per Cone
2001	EB (20)	STIT - Apr., '01	12	2.5 ± 0.4 **a***	30.5 ± 2.0 **a**	33.1 ± 2.2 **a**	132.2 ± 5.2 **a**	80.3 ± 5.1 **b**	8.8 ± 1.6 **a**
	Check		12	8.1 ± 1.5 **b**	38.5 ± 1.9 **b**	46.7 ± 2.1 **b**	113.5 ± 7.4 **a**	52.2 ± 5.2 **a**	8.1 ± 1.5 **a**
2002	EB (20)	STIT - Apr., '01	12						
	Check		12						

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

Table 11. Mean % (± SE) cone and seed losses from insects (coneworms and seed bugs) and reductions in damage from second-year cones of loblolly pine protected with systemic injection of emamectin benzoate (EB), Bellamy Seed Orchard, Marianna, Jackson Co., FL, 2001 - 2002.

			2001		2002	
Treatment	Application Technique & Rate & Treatment Date	N	Mean Combined Losses (%)	Mean Reduction (%)	Mean Combined Losses (%)	Mean Reduction (%)
EB	STIT - 20 ml - Apr., '01	12	32.0 ± 2.1 **a***	34.0		
Check		12	48.5 ± 2.2 **b**			

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

Asana® Rate Study - Southwide

Highlights:

- Only the current registered rate of Asana XL® (0.19 lbs ai/ac) significantly reduced coneworm damage compared to the check.
- All three rates (0.19, 0.10 and 0.03 lbs ai/ac) of Asana XL® significantly reduced the damaged caused by seed bug and improved the number of good seed per original flower.
- Scale infestations increased noticeably at the 0.10 and 0.19 lbs ai/ac application rates.

Objective: Evaluate the efficacy of different rates of esfenvalerate, Asana XL®, for coneworm and seed bug control in loblolly and slash pine seed orchards across the South. The current labeled rate and two lower rates were compared to a check having no insecticide application.

Cooperators, Site & Tree Species:

Florida Department of Forestry, Baker Seed Orchard; slash pine
International Paper, Springhill Seed Orchard, loblolly pine
International Paper, Pensacola (Jay) Seed Orchard, loblolly pine
Mississippi Forestry Commission; Craig Seed Orchard; loblolly pine
Temple Inland For. Prod; Forest Lake Seed Orchard; loblolly pine
Weyerhaeuser Co.; Lyons Seed Orchard, loblolly pine

Treatments:

1) Asana XL® applied at a rate of 0.19 pounds active ingredient/acre (ai/ac) at each of five monthly treatments.
2) Asana XL® applied at a rate of 0.10 pounds ai/ac at each of five monthly treatments.
3) Asana XL® applied at a rate of 0.03 pounds ai/ac at each of five monthly treatments.
4) Check (unprotected trees).

Application Methods:

The timing of the applications was identical for all treatments. For loblolly pine seed orchards, the first application was within 7 days of peak pollen flight (April). The first application in slash pine seed orchards was made about April 1. In orchards of either species, the initial application was followed by four subsequent applications made at monthly intervals (May, June, July, and August).

Fixed wing or rotary wing aircraft were used. The aircraft were set up to deliver an effective swath width of 60-ft and calibrated to deliver 5 gallons of solution per acre. The aircraft made two passes over each row or aisle to deliver a total spray volume of 10 gallons of solution per acre. This assumes a 30-ft. row spacing in the orchard. The aircraft released the insecticide 10-20 ft. above the tops of the trees.

Field Layout:

In each orchard, four treatment plots were laid out in the test area. Each plot was at least 5 rows wide and comprised at least 5 acres. There were 4 rows of buffer trees between treatments.

A complete block design was used. The experimental unit consisted of one treatment plot. Each orchard served as a replicate. Two sample ramets were selected from each of six clones in each plot for a total of 48 sample trees each orchard. These same six clones were sampled in each plot within an orchard, but clones differed among orchards. Treatments were randomly assigned to plots within each orchard.

Data Collection:

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

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

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

Secondary Pests. Test trees were visually inspected for the occurrence of homopteran insect populations (i.e., scales and mealybugs) about once a month. If it was determined that secondary pests were present, the relative population levels of the insects was determined by a scoring system (Cameron, 1989): 0 = none, 1 = few insects on scattered branches, 2 = many branches with few insects, or few branches with moderate to large numbers of insects, and 3 = many branches with many insects.

Results (provided by Dr. Tom Byram):

Data collection was completed for the 2001 Asana XL® rate study that compared 0.19, 0.10 and 0.03 lbs active ingredient per acre to an untreated control in six orchards (three in the Western Gulf region and three in the eastern United States). The objectives were to determine if lower than labeled rates could be used effectively to control cone and seed insects while avoiding build up of scale insects. Initial results indicated that any application rate controlled seed bugs. Treatments had a positive impact on first year conelet survival and percent good seed, both indications of seed bug control. Only the heaviest rate controlled coneworms and this control was significantly different only when the one slash pine orchard was excluded from the data set (Figure 6). Calculating the number of good seed per original flower (obtained by multiplying flower survival* cone survival * number of seed * percent good seed) indicated that any level of treatment provided some benefit. Treated areas had between 15 and 20 more good seed per original flower than the untreated control (Figure 7). Scale build up was observed at the 0.10 and 0.19 application rates.

While meaningful, the control of coneworms obtained with the high rate of Asana® was less than desired indicating that use of this chemical alone may not give satisfactory results. A potential caveat to this conclusion is that the large areas of each orchard in the study were left untreated or treated at levels expected to be less than optimal. This occurred because the aerial application of the pesticide required extensive use of untreated buffers between treatments. When the area in the buffers was added to the untreated control, approximately half of each orchard was untreated. The organizations participating in this study incurred both direct cost of installing the study and a significant opportunity cost in lost seed. Organizations participating

in this study were International Paper Company (2 orchards), Florida Division of Forestry, Mississippi Forestry Commission, Temple-Inland Forest, and Weyerhaeuser Company.

We appreciate the data analysis of survival, cone count and x-ray data, written summary and figures provided by Drs. Tom Byram (WGTIP and Texas Forest Service) and Dudley Huber (University of Florida). Many people were involved in making this project possible. Dr. Alex Mangini (USDA Forest Service- Forest Health Protection) was essential in seeing that the study was properly installed. Others involved with cone damage classification, seed x-ray analysis and secondary pest monitoring include Drs. Dan Miller (USDA Forest Service – Southern Research Station), Don Duerr and Steve Clarke (USDA Forest Service – Forest Health Protection) and Mr. Bill Upton (Texas Forest Service).

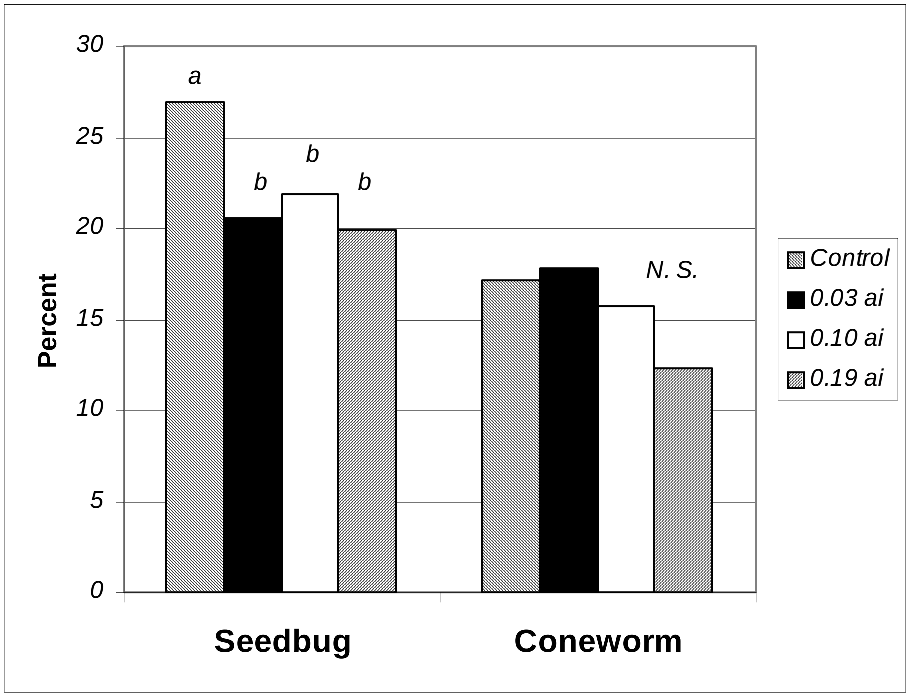

Figure 6. *Results from the Asana® rate study showing A) the percent seed damaged by seedbugs as determined by x-raying seed extracted from healthy cones and B) the percentage of total cones collected damaged by coneworms.*

Figure 7. Number of good seed estimated for each original flower. This synthetic trait was obtained as the product of first-year flower survival, second-year cone survival, seed extracted per cone, and percent good seed.

Imidan® and Capture® Efficacy Study - Southwide

Highlights:

- Data has been collected on conelet and cone survival and coneworm infestation levels. Seed analysis and other data analysis are on going.

Objective: Evaluate the efficacy of Imidan® (phosmet) and Capture® (bifenthrin) for control of coneworms and seed bugs in loblolly and slash pine seed orchards across the South. The current labeled rates will be compared to a check (no insecticide application).

Cooperators, Site & Tree Species:

Boise Co.; Evans Seed Orchard, DeRidder, LA; loblolly pine
North Carolina Forest Service; NCFS Seed Orchard, Goldsboro, NC; loblolly pine
Plum Creek Timber Co.; PC Seed Orchard, Crossett, AR; loblolly pine
Plum Creek Timber Co.; PC Seed Orchard, Jesup, GA; slash pine

Treatments:

1) Imidan® 70W applied at a rate of 1.07 pounds active ingredient/acre (ai/ac) at each of five monthly treatments.
2) Capture® 2EC applied at a rate of 0.20 pounds ai/acre at the first spray date and at the rate of 0.10 pounds ai/acre at each of the four remaining monthly treatments.
3) Check (unprotected trees).

Application Methods:

The timing of the applications was identical for all treatments. For loblolly pine seed orchards, the first application was within 7 days of peak pollen flight (April). The first application in slash pine seed orchards was made about April 1. In orchards of either species, the initial application was followed by four subsequent applications made at monthly intervals (May, June, July, and August).

Fixed wing or rotary wing aircraft were used. The aircraft were set up to deliver an effective swath width of 60-ft and calibrated to deliver 5 gallons of solution per acre. The aircraft made two passes over each row or aisle to deliver a total spray volume of 10 gallons of solution per acre. This assumes a 30-ft. row spacing in the orchard. The aircraft released the insecticide 10-20 ft. above the tops of the trees.

Field Layout:

In each orchard, three treatment plots were laid out in the test area. Each plot was at least 5 rows wide and comprised at least 5 acres. There were 4 rows of buffer trees between treatments.

A complete block design was used. The experimental unit consisted of one treatment plot. Each orchard served as a replicate. Two sample ramets were selected from each of six clones in each plot for a total of 36 sample trees each orchard. These same six clones were sampled in each plot within an orchard, but clones differed among orchards. Treatments were randomly assigned to plots within each orchard.

Data Collection:

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

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

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

Secondary Pests. Test trees were visually inspected for the occurrence of homopteran insect populations (i.e., scales and mealybugs) about once a month. If it was determined that secondary pests were present, the relative population levels of the insects was determined by a scoring system (Cameron, 1989): 0 = none, 1 = few insects on scattered branches, 2 = many branches with few insects, or few branches with moderate to large numbers of insects, and 3 = many branches with many insects.

Results:

Drs. Tom Byram and Dudley Huber are currently conducting data analysis of survival and cone count data. Seed lots are currently being radiographed by the WGFPMC. The complete results will be presented in next year's report.

Evaluation of Imidacloprid and Azadirachtin for Control of Scale Insects in Pine Seed Orchards

Highlights:
- Moderate scale and mealybug populations developed during the summer at the Craig Seed orchard, but not at the Forest Lake Seed Orchard.
- Imidacloprid and azadirachtin treatments (injection or foliar spray) did not significantly impact scale or mealybug populations compared to pretreatment levels.

Objective: Evaluate imidacloprid and azadirachtin applied either by injection or foliar spray for the remedial control of secondary pest populations in southern pine seed orchards.

Cooperators: Dr. Steve Clarke, U.S. Forest Service
Mr. Robert Stewart, Mississippi State Forestry Commission
Mr. Drew Crocker, Temple Inland Forest Products

Study Sites:
Mississippi Forestry Commission, Craig Seed Orchard, Baxterville, MS
Temple Inland Forest Products, Forest Lake Seed Orchard, Spurger, TX

Insecticides:
Imidacloprid (technical and Merit® 75WP) -- neonicotinoid
Azadirachtin (Neemix®) -- avermectin derivative

Design: At both seed orchards a randomized complete block design was used with clones as blocks (loblolly pine). 4 treatments X 4 clones X 4 ramets/clone (= 32 ramets).

Application Methods:

STIT Injection –In mid-April, A 3/8 in diameter hole, 11 cm (4.5 in) deep was drilled parallel to the ground at each injection site; number of holes was equal to the volume of insecticide solution to be applied divided by 20 ml; holes were placed at a height of 1 m. -- the prefilled injector was hammered into the drill hole, and pressurized to 50 psi. Most treatment solutions drained within 15 minutes. The volume of insecticide solution applied was based on the diameter of each treatment tree as follows:

Tree Diameter	Treatment Rate
<15 cm	20 ml
16 - 20 cm	20 - 40 ml
21 - 25 cm	40 - 60 ml
26 - 30 cm	60 - 80 ml
>30 cm	+20 ml/5 cm dia. Increment

Foliar Spray – In mid-July (when scale populations had increased), an applicator with a backpack sprayer was hoisted above and around the crown of each tree using a bucket truck. Each insecticide was applied until the foliage was moist but not to runoff.

Treatments:

1) 20 ml rate for 5% imidacloprid (technical) by injector in April
2) Imidacloprid (Merit® 75WP) applied once by backpack sprayer to foliage at 0.5 oz/100 gal in June.
3) Azadirachtin (Neemix® SC) applied once by hydraulic sprayer to foliage at 16 oz/100 gal in June.
4) Check - untreated

Data Collection:

Four branch shoots were collected from the lower to mid-canopy of each study tree using a pole pruner on the day of injection (April) and foliar spray (mid July) and 7 and 30 days post foliar spray treatment. Scales were identified to species and classified by condition (live or dead). The numbers per shoot were recorded.

Results:

The Forest Lake Seed Orchard study trees were injected in mid-April, but scale populations did not develop later in the summer (July). Therefore, the orchard was removed from further evaluation.

The Craig Seed Orchard trees did develop moderate populations of striped pine and woolly pine scales and mealybug on most study trees in July. However, none of the treatments appeared to have a significantly impact on scale numbers compared pretreatment levels (Table 12).

Table 12. Mean number of live and dead striped pine scale per loblolly pine tree sample before and after insecticide injection or foliar spray treatments - Mississippi Forestry Commission's Craig Seed Orchard, Baxterville,

			Striped Pine Scale					
Date	Treatment	N	Live	Dead	Eaten	Parasitized	Total	Total Dead
April 25, 2002 (Day of Injection)	Imidacloprid (injection)	8	0.125 **a***	2.000 **a**	0.000 **a**	0.000 **a**	2.125 **a**	2.000 **a**
	Imidacloprid (foliar)	8	0.625 **a**	2.375 **a**	0.000 **a**	0.000 **a**	3.000 **a**	2.375 **a**
	Azadiractin (foliar)	8	0.750 **a**	0.875 **a**	0.000 **a**	0.000 **a**	1.625 **a**	0.875 **a**
	Check	8	0.625 **a**	1.750 **a**	0.000 **a**	0.000 **a**	2.375 **a**	1.750 **a**
July 16, 2002 (Day of Imid. & Aza. Foliar Spays)	Imidacloprid (injection)	8	0.375 **a**	0.250 **a**	0.000 **a**	0.125 **ab**	0.750 **a**	0.375 **a**
	Imidacloprid (foliar)	8	0.875 **a**	1.500 **a**	3.250 **a**	0.125 **ab**	5.750 **a**	4.875 **a**
	Azadiractin (foliar)	8	1.250 **a**	0.875 **a**	0.500 **a**	0.000 **a**	2.625 **a**	1.375 **a**
	Check	8	0.875 **a**	1.125 **a**	0.375 **a**	0.500 **b**	2.875 **a**	2.000 **a**
July 23, 2002 (1 Week Post-Spray)	Imidacloprid (injection)	8	0.000 **a**	0.250 **a**	0.000 **a**	0.000 **a**	0.250 **a**	0.250 **a**
	Imidacloprid (foliar)	8	1.375 **b**	2.500 **a**	0.750 **ab**	0.250 **a**	4.875 **b**	3.500 **b**
	Azadiractin (foliar)	8	1.250 **b**	1.000 **a**	1.000 **b**	0.125 **a**	3.375 **b**	2.125 **ab**
	Check	8	1.625 **b**	0.625 **a**	1.125 **b**	0.000 **a**	3.375 **b**	1.750 **ab**
August 13, 2002 (1 Month Post-Spray)	Imidacloprid (injection)	8	0.250 **a**	0.250 **a**	0.000 **a**	0.125 **a**	0.625 **a**	0.375 **a**
	Imidacloprid (foliar)	8	0.500 **a**	3.250 **b**	3.625 **a**	0.000 **a**	7.375 **a**	6.875 **ab**
	Azadiractin (foliar)	8	0.625 **a**	1.000 **ab**	0.625 **a**	0.000 **a**	2.250 **a**	1.625 **ab**
	Check	8	0.000 **a**	1.500 **ab**	2.875 **a**	0.375 **a**	4.750 **a**	4.750 **b**

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

2001-2002 Tip Moth Impact Study – Western Gulf Region

Highlights:

- Nantucket pine tip moth damage levels on first-year check trees were considerably lower in 2002 (7%) compared to 2001 (22%).
- Periodic applications of Mimic® to first and second-year pine seedlings in 2002 reduced tip moth infestation levels by 83% compared to untreated trees.
- On second-year pines only, Mimic® improved the difference between treated and untreated trees by 11% (height), 150% (diameter) and 1125% (volume).
- Overall, the exclusion of tip moth for two years on treated trees improved mean height by 11%, diameter growth by 12%, and volume index by 38% compared to check trees.
- There was no significant gain is growth (height, diameter or volume) as result of Mimic® treatments on one-year old sites.

Objectives: 1) Determine the impact of Nantucket pine tip moth infestation on height and diameter growth and form of loblolly pine in the Western Gulf region and 2) identify a treatment threshold for pine tip moth infestation.

Study Sites: Most WGFPMC members had established 2 to 3 impact study sites by 2002. In most plantation sites, two areas were selected and divided into 2 plots each - each plot containing 126 trees (9 rows X 14 trees). Tip moth populations were monitored in TFS sites in East Texas.

Population Monitoring: Tip moth populations were monitored by placing 3 Phericon 1C wing traps with Trece septa lures (Great Lakes IPM) at each site. Traps were generally positioned 50 to 100 m apart and at tree terminal height. Sticky trap bottoms were collected and replaced weekly starting in early December, 2001, and monitored until end of 2002. Lures were changed at 4 - 6 week intervals, depending on mean temperatures.

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

Design: 13 sites X 1-2 plots X 2 treatments X 50 trees = 2400 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 each site in 2001 and 2002. Pesticides were applied by backpack sprayer or spray bottle to all 126 trees within the designated Mimic® plot (treatment area) until the foliage was moist. Application dates were based on trap catches and degree day calculations, generally every 7-8 weeks starting in late February and ending in late August.

Tip Moth Damage Survey: Tip moth infestation levels were determined in each plot by surveying the internal 50 trees within each plot during the pupal stage of each tip moth generation. 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. At this time, data also were collected on tree height and diameter at 6 inches above the ground.

Results: Figure 8 shows the mean distribution of pine tip moths captured in traps at two study sites (Evans and Stevens) and two other sites near Lufkin, TX in 2002. For the fourth year in row, trap catches in the Lufkin, TX area indicate four full generation with a partial fifth generation developing late in the summer.

Based on trap catch numbers and degree day calculations in 2001, the optimal spray dates in east Texas (near Lufkin) for the first four generations were determined to be about March 24, May 28, July 12, and August 22. These dates are nearly identical to those dates recently predicted by Dr. Chris Fettig (see Tip Moth Phenology and Timing of Insecticide Applications study), i.e., March 22-26, May 21-25, July 10-14, and Aug 19-23. In contrast, optimal spray periods for southern Arkansas sites (near Crossett) are April 6-10, June 5-9, July 30-August 3, and Sept. 13-17.

Figure 9 shows the distribution of the 23 first- and second-year impact study sites in the Western Gulf Region. Overall, tip moth infestation levels on untreated first-year seedlings were 67% lower in 2002 compared to 2001 (Table 13). Although first generation infestation levels were similar both years, second and later generation damage levels were markedly lower in 2002. The Mimic® treatments continued to provide excellent protection for both first- and second-year trees during all tip moth generations (Table 13) - reducing infestation levels by an average of 80% and 83%, respectively (Table 13). Nearly all second-year Mimic®-treated plots showed markedly greater tree height and diameter growth compared to the neighboring untreated trees. The exclusion of tip moth during the second year improved the differences between protected and unprotected trees in height, diameter, and volume by 11%, 150% and 1125%, respectively (Figures 10, 11 & 12). After two years, the height, diameter, and volume of Mimic®-treated trees has been improved by 11%, 12%, and 38%, respectively, compared to check trees (Table 14). The growth (height, diameter and volume) of first-year protected trees was not significantly improved compared to check trees in 2002.

Summary: Multiple applications of Mimic® significantly reduced tip moth infestation levels in both first and second year sites in 2002. However, because Mimic® treatments did not significantly improve tree growth on first year sites, it is apparent that tip moth populations were too low (below some threshold) to impact the growth of untreated trees on these sites. In contrast, tip moth populations were high enough on second year sites to significantly impact growth of unprotected trees. It is conservatively estimated that yearly mean tip moth damage levels (percent shoots infested) need to exceed 10% before there is a significant impact on tree growth in a given year. Given the disparity in tip moth population levels over the past two years, it is suggested that additional impact sites be established in 2003. Also it is important to continue treatments on second year sites and monitor tip moth damage and impact on third year sites in 2003. It may also be advisable to spray a number of third-year sites in the beginning of 2003. Historically, field observations indicate that trees remain susceptible to high levels of tip moth damage until they exceed 10 feet in height. The two-year mean tree height was below 6 feet at 9 of 16 plots/sites; including Stevens 1 & 2, Bleakwood I & M, Cypress Springs 1 & 2, Evans 1, Crossett 1, and MoroBay. It seems likely that these sites will experience high levels of damage if not protected in 2003.

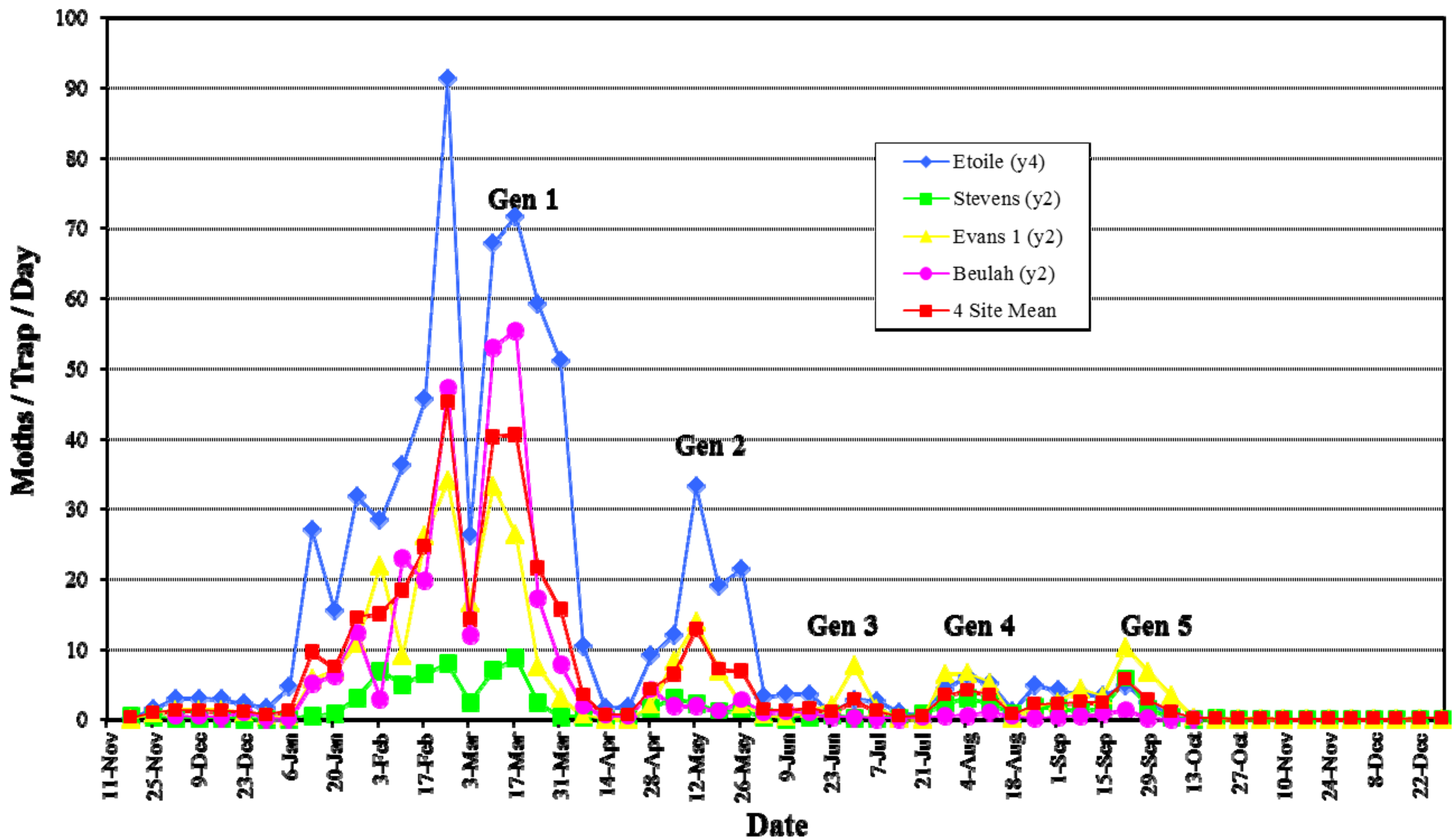

Figure 8. Mean Nantucket pine tip moth catch at four sites near Lufkin/Nacogdoches, TX - 2002

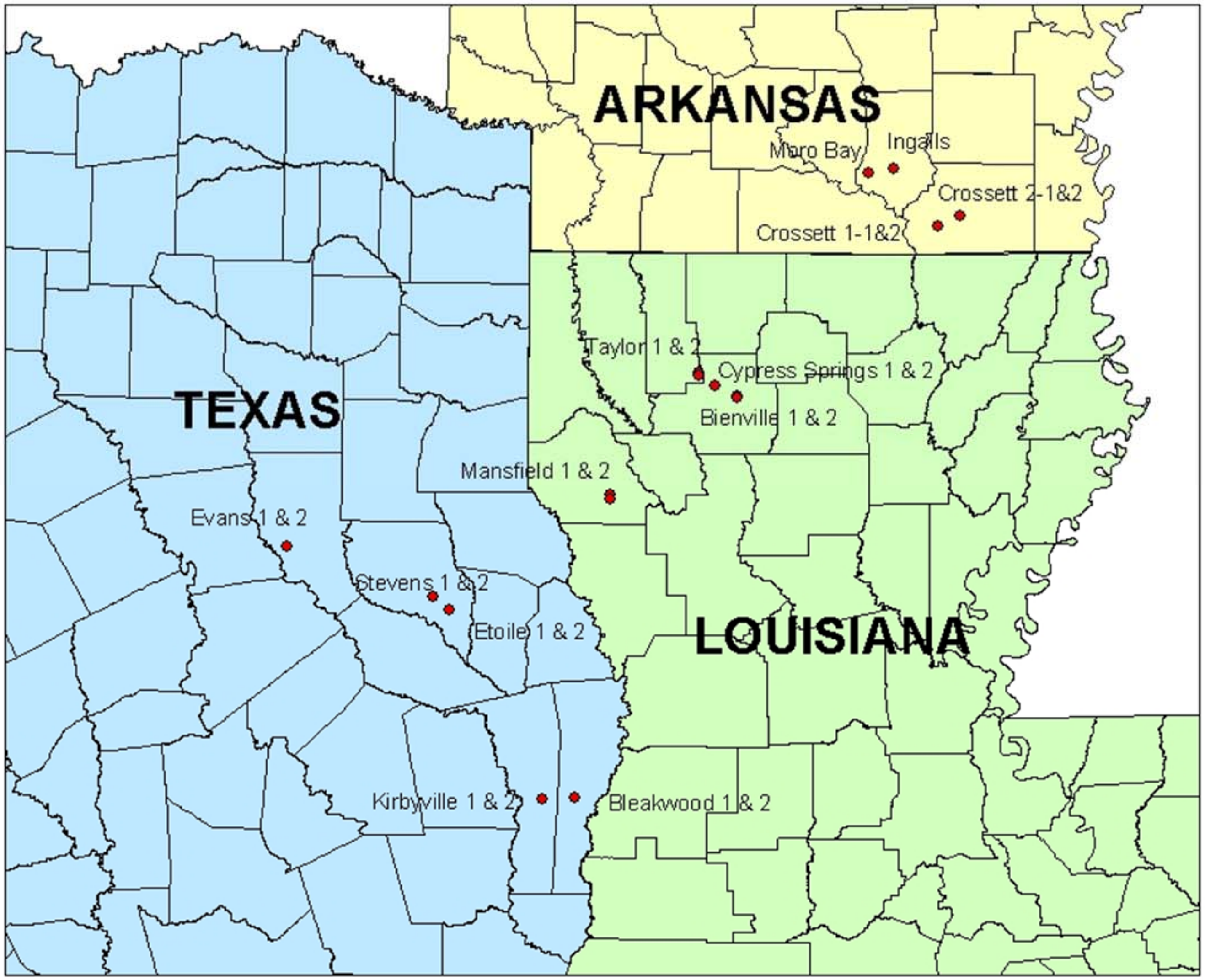

Figure 9. Distribution of tip moth impact sites established in Texas, Louisiana and Arkansas, 2001 – 2002.

Table 13. Mean percent (± SE) of loblolly 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 the each of 5 generations; Arkansas, Louisiana and Texas sites - 2001 & 2002.

Age	N Plots	Generation 1	Generation 2	Generation 3	Generation 4	Generation 5	% Reduction
2001							
Year 1 (planted 2001)							
Mimic	16	0.29 ± 0.11	1.58 ± 0.35	3.12 ± 0.42	2.23 ± 0.44	1.46 ± 0.38	**92**
Check	16	4.60 ± 0.59	23.00 ± 1.21	21.88 ± 1.18	34.29 ± 1.50	28.01 ± 1.42	
% Reduction		**94**	**93**	**86**	**93**	**95**	
2002							
Year 1 (planted 2002)							
Mimic	7	0.55 ± 0.25	2.59 ± 0.57	1.81 ± 0.46	1.73 ± 0.47	0.94 ± 0.30	**80**
Check	7	3.60 ± 0.74	8.00 ± 1.19	4.37 ± 0.73	10.90 ± 1.23	10.52 ± 1.19	
% Reduction		**85**	**68**	**59**	**84**	**91**	
Year 2 (planted 2001)							
Mimic	16	1.77 ± 0.31	1.85 ± 0.29	3.47 ± 0.40	6.19 ± 0.57	5.61 ± 0.61	**83**
Check	16	12.12 ± 0.77	16.78 ± 0.93	11.48 ± 0.76	32.21 ± 1.20	37.05 ± 1.33	
% Reduction		**85**	**89**	**70**	**81**	**85**	

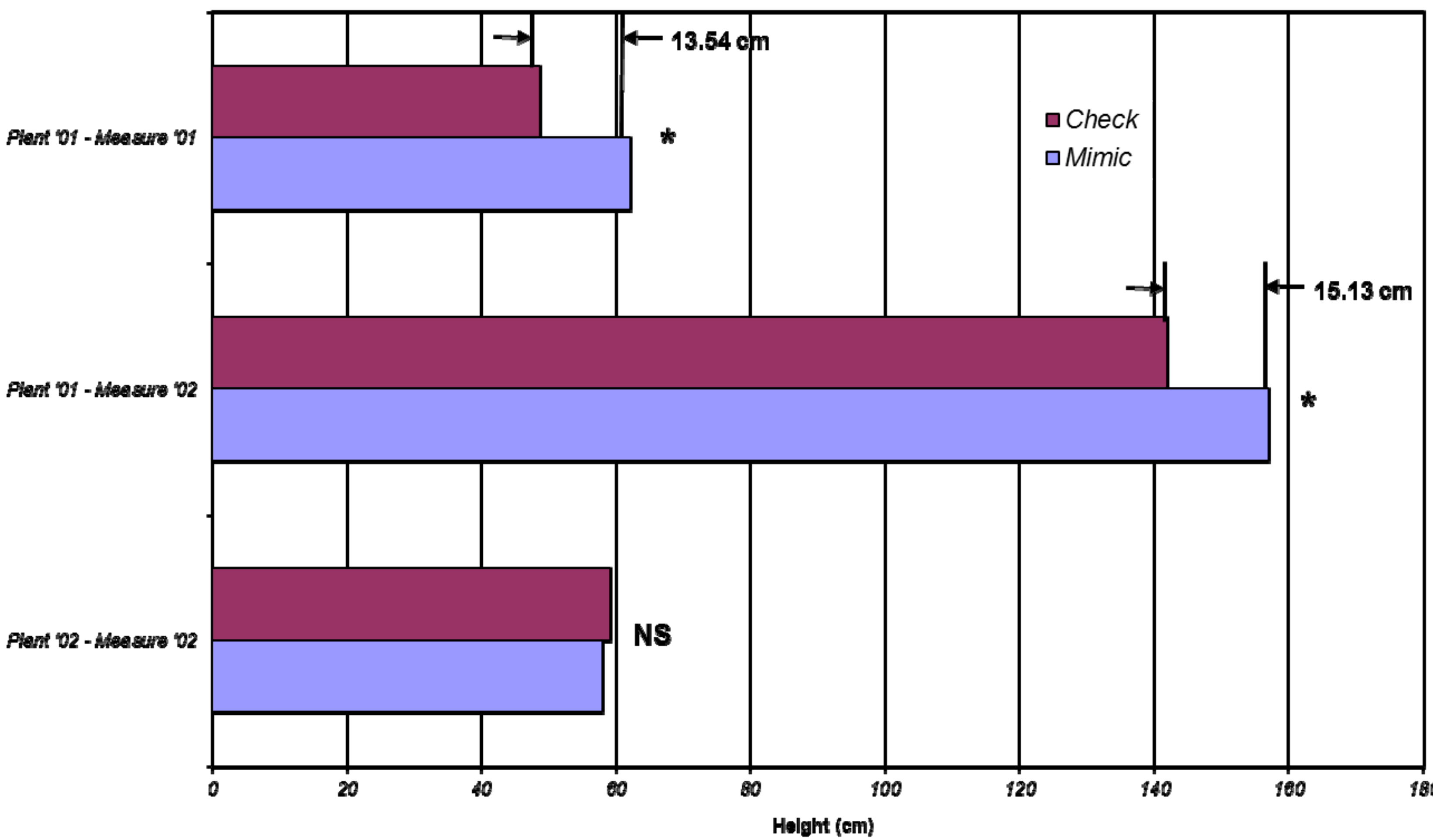

Figure 10. *Mean height (cm) of one- and two-year old loblolly pine trees treated with Mimic® compared to untreated trees in the Western Gulf Region sites, 2001 - 2002.*

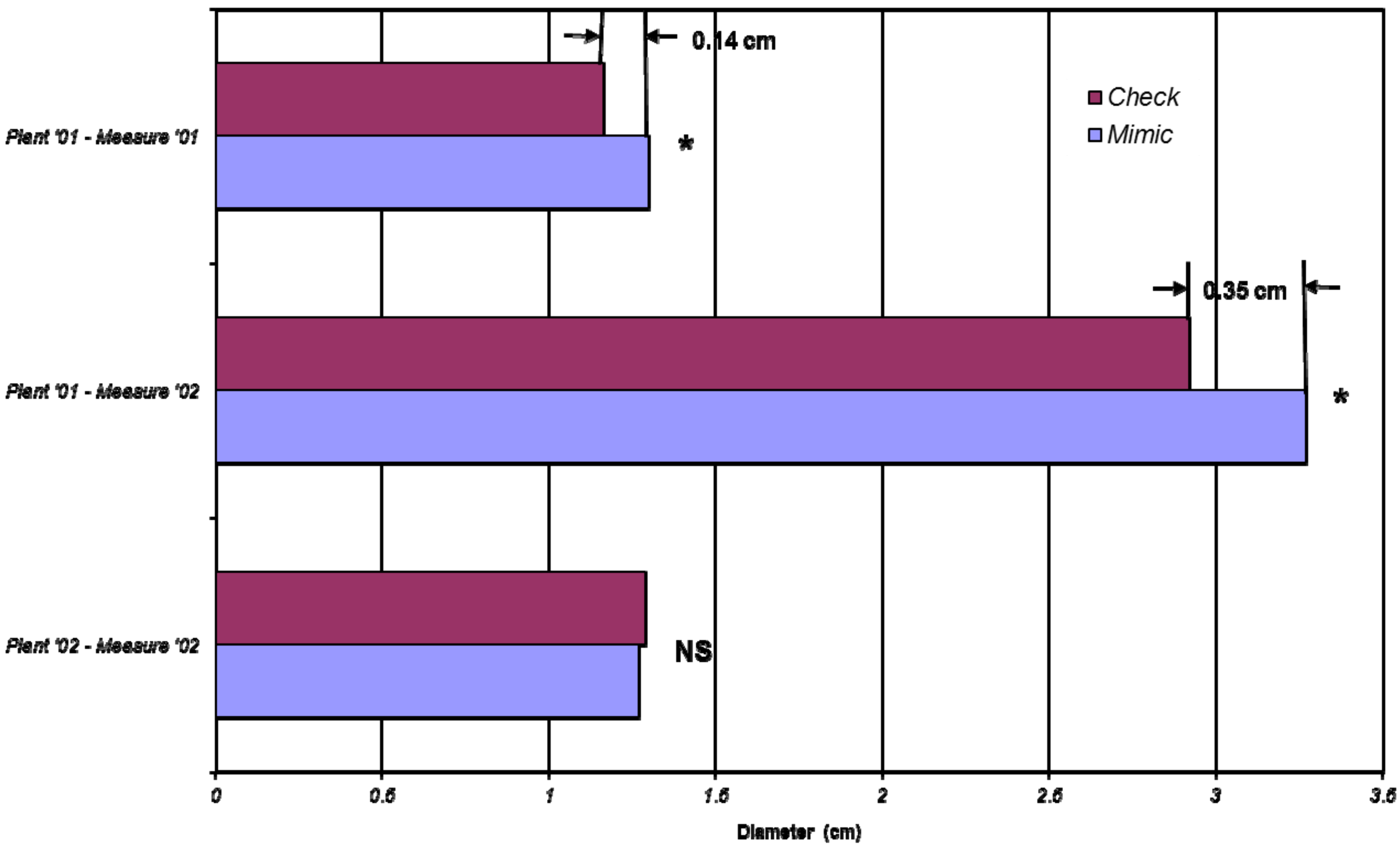

Figure 11. *Mean diameter (cm) at 6" of one- and two-year old loblolly pine trees treated with Mimic® compared to untreated trees in the Western Gulf Region sites, 2001 - 2002.*

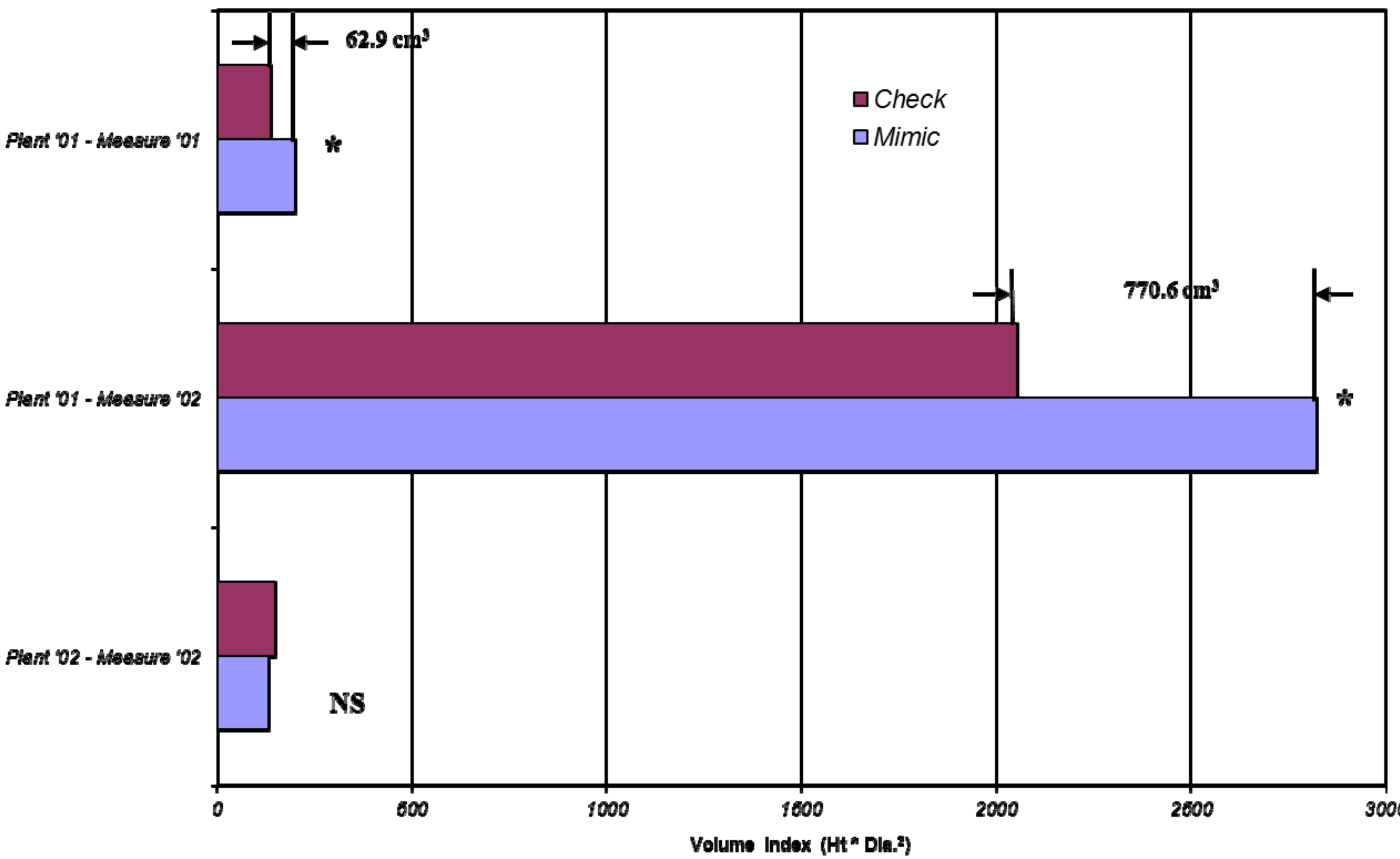

Figure 12. *Mean height (cm) of one- and two-year old loblolly pine trees treated with Mimic® compared to untreated trees in the Western Gulf Region sites, 2001 - 2002.*

Table 14. Mean (± SE) tree height, diameter and volume and percent growth gain of one- and two-year old loblolly pine following treatment with Mimic®; Arkansas, Louisiana and Texas sites - 2001 & 2002.

Age	N Plots	Height (cm)	% Gain	Diameter (cm)	% Gain	Volume (cm^3)	% Gain
2001							
Year 1 (planted 2001)							
Mimic	16	62.19 ± 1.09	**27.8** P < 0.0001	1.30 ± 0.03	**12.1** P < 0.0001	200.6 ± 14.3	**45.6** P < 0.0001
Check	16	48.65 ± 0.91		1.16 ± 0.04		137.7 ± 9.7	
2002							
Year 1 (planted 2002)							
Mimic	7	58.03 ± 1.26	**-1.9** P > 0.05	1.27 ± 0.03	**-1.6** P > 0.05	131.4 ± 8.9	**-12.2** P > 0.05
Check	7	59.18 ± 1.42		1.29 ± 0.04		149.7 ± 13.0	
Year 2 (planted 2001)							
Mimic	16	157.04 ± 2.41	**10.7** P < 0.0001	3.27 ± 0.06	**12.0** P < 0.0001	2824.1 ± 146.7	**37.5** P < 0.0001
Check	16	141.91 ± 2.11		2.92 ± 0.05		2053.5 ± 115.4	

2002 Tip Moth Hazard Rating Study – Western Gulf Region

Highlights:

- Site characteristic data were collected from 41 plots (24-1st year and 17-2nd year) in the Western Gulf region in 2002.

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

Cooperators: Western Gulf Forest Pest Management Coop. members
Dr. C. Wayne Berisford, University of Georgia
Dr. Roy Hedden, Clemson University

Study Sites: WGFPMC members selected from 1 to 11 first-year plantations (several were the same as those used in the impact study) in 2002. A plot area within each plantation was selected - each plot containing 126 trees (9 rows X 14 trees). The untreated plot was used to collect site characteristic data.

Site Characteristic Data: Site characteristic data collected from 41 Western Gulf plots (24-1st year and 17-2nd year) in 2002 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, 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 2nd 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.

Results: All 2001 data from the 17 plots has been forwarded to Dr. Roy Hedden. He has indicated that he is in the process of developing a regression model to identify the most important abiotic factors influencing tip moth occurrence and severity. Figure 13 shows the distribution of the 41 first- and second-year hazard rating sites in the Western Gulf Region. The 2002 data (41 plots) is nearly ready to be forwarded to Dr. Hedden. The results will be presented in next year's report. Tables 15 and 16 summarize the level of tip moth infestation (shoots and terminals, respectively) that has occurred on first- and second-year sites. Mean infestations levels (shoots and terminals) on first-year seedlings in 2002 were 67% and 61%, respectively, lower than in 2001. Given the variability of tip moth population levels year to year and within and between regions, it is important that hazard rating sites continue to be established on diverse sites for the duration of the 5 year study period. The mean height, diameter and volume of two-year old trees on 17 Western Gulf sites are shown in Table 17.

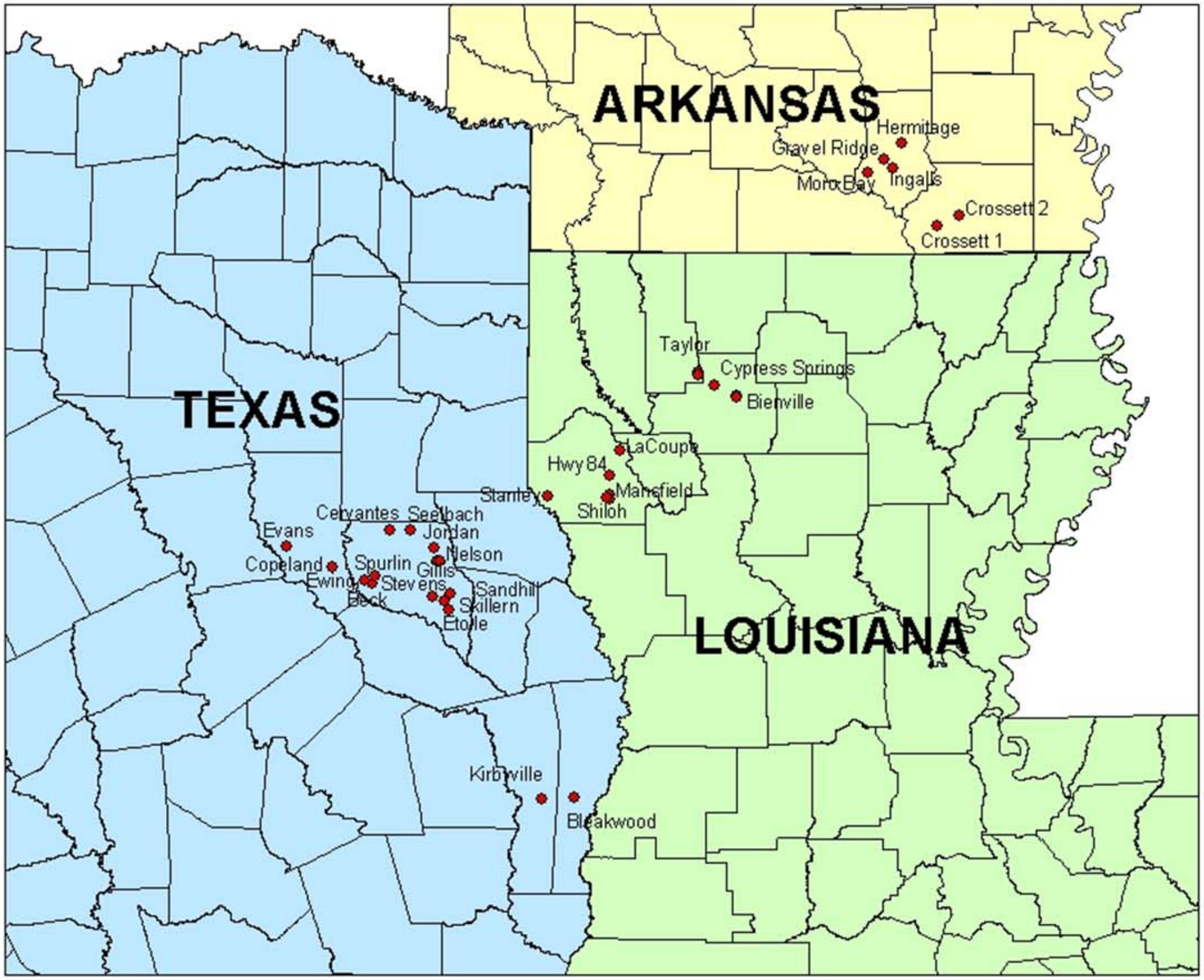

Figure 13. Distribution of tip moth impact sites established in Texas, Louisiana and Arkansas, 2001 – 2002.

Table 15. Mean percent (± SE) of loblolly pine shoots (in top whorl) infested by pine tip moth on unprotected one- and two-year old loblolly pine after each of 5 generations, Western Gulf Region, 2001 - 2002.

Age	N Plots	Generation 1	Generation 2	Generation 3	Generation 4	Generation 5	Average
Year 1							
planted 2001	16	4.59 ± 0.59	22.78 ± 1.18	21.88 ± 1.18	34.29 ± 1.49	28.01 ± 1.42	22.31
planted 2002	24	3.45 ± 0.40	5.09 ± 0.48	3.98 ± 0.39	11.12 ± 0.64	12.78 ± 0.68	7.28
Year 2							
planted 2001	17	11.64 ± 0.73	15.90 ± 0.88	10.79 ± 0.72	30.81 ± 1.15	35.12 ± 1.29	20.85

Table 16. Mean percent (± SE) of loblolly pine terminals infested by pine tip moth on unprotected one- and two-year old loblolly pine after each of 5 generations, Western Gulf Region, 2001 - 2002.

Age	N Plots	Generation 1	Generation 2	Generation 3	Generation 4	Generation 5	Average
Year 1							
planted 2001	16	7.40 ± 0.90	38.90 ± 1.80	33.70 ± 1.80	47.30 ± 1.90	42.40 ± 2.00	33.94
planted 2002	24	5.20 ± 0.70	8.70 ± 0.90	8.60 ± 0.90	20.10 ± 1.20	24.10 ± 1.30	13.34
Year 2							
planted 2001	17	19.10 ± 1.40	25.70 ± 1.50	19.30 ± 1.40	43.10 ± 1.70	46.10 ± 1.80	30.66

Table 17. Mean (± SE) height, diameter and volume growth of unprotected two-year old loblolly pine on 17 Western Gulf hazard rating plots - 2002.

Age	N Plots	Height (cm)	Diameter (cm)	Volume (cm^3)
Year 2 (planted 2001)	17	149.83 ± 2.28	3.11 ± 0.06	2539.3 ± 131.7

2002 Systemic Insecticide Treatments of Loblolly Pine Seedlings for Control of Pine Tip Moth

Highlights:

- Fipronil, thiamethoxam, imidacloprid, and emamectin benzoate, all applied at lower rates as a root soak, reduced tip moth damage by 90%, 56%, 40% and 34%, respectively, compared to untreated check trees. Increasing the treatment rate two fold did not significantly improve protection provided by any of these chemicals.
- Fipronil- and imidacloprid-treated seedlings consistently had the greatest improvement in height, diameter and volume parameters compared to check trees.
- Seedlings treated with azadirachtin experienced severe phytotoxic reactions and high seedling mortality.

Objectives: The objectives of this research are to: 1) evaluate the efficacy of several systemic insecticides (emamectin benzoate, imidacloprid, thiamethoxam, fipronil, and azadirachtin) in reducing tip moth damage on loblolly pine seedlings; and 2) determine the duration of treatment efficacy.

Study Sites: Two second-year plantations were selected in the Fairchild State Forest (Cherokee Co.) in east Texas. Two plots, containing 350 trees (5 rows X 70 trees), were established in each plantation. A third plot, containing 500 trees (5 rows X 100 trees), was established near on of the other plots. Second-year plantations were used in the study because tip moth populations are usually well established at this age and would ensure that significant tip moth pressure is placed on treated seedlings.

Population Monitoring: Tip moth populations were monitored by placing 3 Phericon 1C wing traps with Trece septa lures (Great Lakes IPM) at each site. Traps were generally positioned 50 to 100 m apart and at tree terminal height. Sticky trap bottoms were collected and replaced weekly starting in early February, 2001 and monitored until the end of the year. Lures were changed at 4 - 6 week intervals, depending on mean temperatures.

Insecticides:

Proclaim® (emamectin benzoate) - an avermectin derivative with activity against Lepidoptera.
Termidor® (fipronil) – a pheny pyrazole with some systemic activity against Lepidoptera.
Imidacloprid – highly systemic neonictinoid with activity against Lepidoptera.
Actera® (thiamethoxam) – a related neonicotinoid with high systemic activity.
Neemix® (azadirachtin) – natural plant-derived compound with some systemic activity.
Mimic® (tebufenozide) – molting stimulant with specific 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. Plots 1 & 2: 2 sites X 7 treatments X 50 trees = 700 monitored trees. Plot 3: 1 site X 10 treatments X 50 trees = 500 monitored trees.

Treatments:

Plot 1 & 2:

1) Emamectin benzoate (Proclaim®) solution (0.12%) root soak
2) Fipronil (Termidor® SC) solution (0.157%) root soak
3) Imidacloprid (technical) solution (0.53%) root soak
4) Thiamethoxam (25 WP) solution (0.17%) root soak
5) Azadirachtin (Neemix® 4.5) solution (0.0000045%) root soak
6) Tebufenozide (Mimic®) foliar application (5X) prior to each generation at 0.8 oz/gal
7) Check bare root seedling (lift and plant)

Plot 3:

1) Emamectin benzoate (Proclaim®) solution (0.12%) root soak
2) Emamectin benzoate (Proclaim®) solution (0.24%) root soak
3) Fipronil (Termidor® SC) solution (0.146%) root soak
4) Fipronil (Termidor® SC) solution (0.287%) root soak
5) Imidacloprid (technical) solution (0.53%) root soak
6) Imidacloprid (technical) solution (1.064 %) root soak
7) Thiamethoxam (25 WP) solution (0.17%) root soak
8) Thiamethoxam (25 WP) solution (0.34%) root soak
9) Azadirachtin (Neemix® 4.5) solution (0.145%) root soak
10) Azadirachtin (Neemix® 4.5) solution (0.290%) root soak
11) Check bare root seedling (lift and plant)

Treatment Methods: A single family (Advanced Generation) of bare root loblolly pine seedlings was used from the Texas Forest Service Indian Mounds Nursery at Alto, TX. Bare root seedlings (150) were lifted after receiving at least 400 chilling hours (hours where temperature is below 40^{o}F). The seedlings were culled of small caliper (< 3 mm dia.) seedlings. When ready, the seedlings' roots were soaked in insecticide solution or water for 2 hours. After immersion, the seedlings were bagged and placed in cold storage until the following day. Fifty seedlings from each treatment were planted (6 X 10 ft spacing) on Plot 1 & 2. Plot 3 was planted on 3 X 10 foot spacing. Mimic® (0.8 oz/gal) was applied by backpack sprayer before each tip moth generation until the foliage was moist. Application dates were based on trap catches and degree day calculations, generally every 7-8 weeks starting in late February and ending in October.

Treatment Evaluation: Tip moth damage was evaluated after each tip moth generation (3-4 weeks after peak moth flight) by 1) identifying if the tree was infested or not, 2) if infested, the proportion of tips infested on the top whorl and terminal were calculated; and 3) separately, the terminal was identified as infested or not. Each tree was measured for diameter and height in the fall (November) following planting.

Results: Seedlings treated with azadirachtin exhibited phytotoxic symptoms within two weeks after planting and over 50% mortality after 2 month. As a result, the azadirachtin treatment was not included in the final data analysis. No other treatments exhibited any phytotoxic symptoms.

Plots 1 & 2: All chemical treatments showed significantly lower tip moth damage levels after the first two tip moth generations compared to check trees (Table 18, Figure 14). However, only fipronil, thiamethoxam and Mimic® continued to reduce damage levels through the fifth generation. The fipronil treatment (90% reduction) was comparable to the standard, Mimic® foliar treatment (92%). The fipronil, imidacloprid and thiamethoxam treatments each resulted in significant (or nearly significant) gains in tree height, diameter and volume growth compared to check trees (Table 19).

Plots 3: All chemical treatments showed significantly lower tip moth damage levels after all five tip moth generations compared to check trees (Table 20, Figure 15). Increasing the treatment rate two fold did not improve the performance of any of the bare root treatments. The fipronil treatments (single and double rate) provided the greatest reduction damage, 85% and 91%, respectively, compared to the check. Emamectin benzoate, imidacloprid and thiamethoxam were nearly equal in their effectiveness; reducing tip moth damage by 50 to 65%. The fipronil and imidacloprid treatments had the greatest impact on tree growth. Both treatments resulted in gains in tree height (23 to 42%), diameter (27 to 49%) and volume growth (91 to 178%) compared to check trees (Table 21).

Summary: Seedlings soaked in emamectin benzoate, fipronil, imidacloprid and thiamethoxam all appeared to show moderate to high resistance against tip moth for the first two generations, but only those treated with fipronil consistently retained their resistance through the fifth tip moth generation. Increasing the root soak dose rate two fold did not improve the performance of fipronil or any other chemical. Given these results further monitoring of the treatment plots are warranted through 2003. In addition, two new studies are proposed in 2003 with the following objectives: 1) further evaluate the efficacy of fipronil in reducing pine tip moth infestation levels on loblolly pine seedlings; 2) evaluate this product applied at different rates to nursery beds, lifted bare root seedlings, and plant holes; and 3) determine the duration of chemical activity.

Table 18. Effect of systemic chemical treatments on pine tip moth infestation of loblolly pine shoots (top whorl) after each of 5 generations on **Plots 1 & 2**, Evans Tract, Fairchild State Forest, Cherokee Co., TX - 2002.

Treatment §	N	Mean Percent Top Whorl Shoots Infested by Tip Moth (Pct. Reduction Compared to Check)					Mean Pct.
		Gen 1	Gen 2	Gen 3	Gen 4	Gen 5	Reduction
EB (0.12% ai)	100	2.5 **a** * (84)	14.7 **c** (49)	26.2 **c** (16)	49.4 **c** (6)	62.8 **c** (16)	**34**
FIP (0.146% ai)	100	1.3 **a** (92)	0.0 **a** (100)	6.8 **a** (78)	0.9 **a** (98)	13.4 **b** (82)	**90**
IMID (0.532% ai)	100	1.3 **a** (92)	5.1 **b** (82)	27.9 **c** (10)	47.6 **c** (10)	71.7 **d** (4)	**40**
THIA (0.17% ai)	100	0.0 **a** (100)	5.0 **ab** (83)	18.3 **b** (41)	36.0 **b** (32)	55.8 **c** (25)	**56**
Mimic® (foliar)	100	1.8 **a** (89)	0.3 **ab** (97)	7.6 **a** (76)	1.1 **a** (98)	1.5 **a** (98)	**92**
Check	100	15.4 **b**	28.6 **d**	31.1 **c**	52.8 **c**	74.5 **d**	

§ EB = emamectin benzoate, FIP = fipronil, IMID = imidacloprid, THIA = Thiamethoxam.
***** Means followed by the same letter in each column are not significantly different at the 5% level based on Fisher's Protected LSD.

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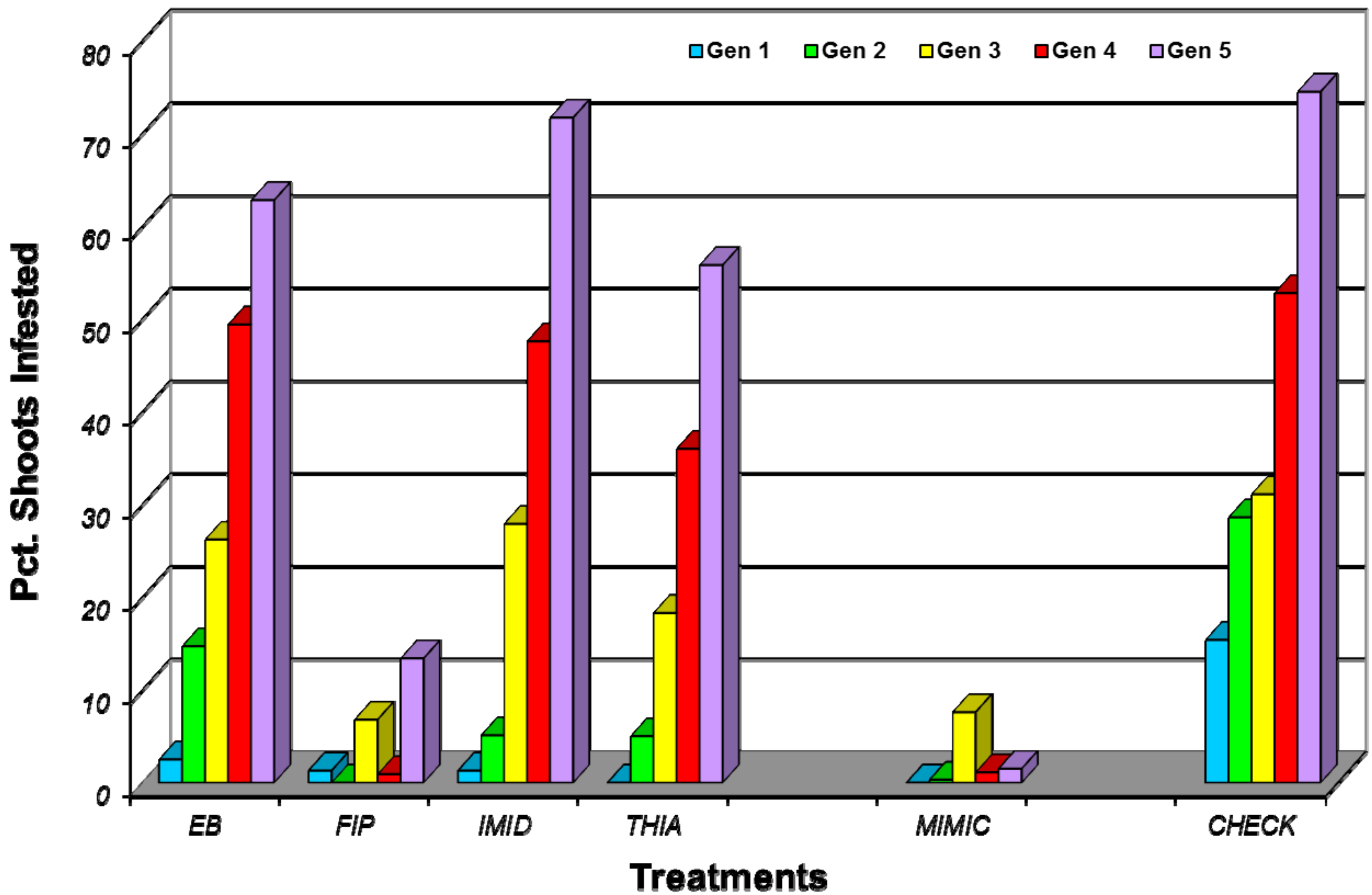

Figure 14. Effect of systemic insecticide treatments on mean percent of loblolly pine shoots (top whorl) infested by pine tip moth after each of five generations, **Plot 1 & 2**, Evans Tract, Fairchild State Forest, Cherockee Co., TX - 2002.

Table 19. Effect of systemic chemical treatments on loblolly pine growth and survival after each of 5 generations on **Plots 1 & 2**, Evans Tract, Fairchild State Forest, Cherokee Co., TX - 2002.

Treatment §	N	Mean Tree Measurements (Pct. Gain Compared to Check)			% Survival
		Height (cm)	Diameter (cm)	Volume (cm^3)	
EB (0.12% ai)	100	47.1 **a *** (0)	0.69 **a** (0)	27.3 **a** (0)	95.0 **a**
FIP (0.146% ai)	100	56.3 **cd** (9)	0.82 **ab** (9)	47.6 **b** (27)	98.0 **a**
IMID (0.532% ai)	100	55.2 **bc** (7)	0.85 **bc** (12)	47.6 **bc** (27)	99.0 **a**
THIA (0.17% ai)	100	55.1 **bc** (7)	0.84 **bc** (11)	47.4 **b** (26)	100.0 **a**
Mimic® (foliar)	100	59.9 **d** (16)	0.91 **c** (20)	60.6 **c** (61)	99.0 **a**
Check	100	51.7 **b**	0.75 **a**	37.5 **ab**	98.0 **a**

§ EB = emamectin benzoate, FIP = fipronil, IMID = imidacloprid, THIA = Thiamethoxam.
***** Means followed by the same letter in each column are not significantly different at the 5% level based on Fisher's Protected LSD.

Table 20. Effect of systemic chemical treatments on pine tip moth infestation of loblolly pine shoots (top whorl) after each of 5 generations on **Plot 3**, Evans Tract, Fairchild State Forest, Cherokee Co., TX - 2002.

Treatment §	N	Mean Percent Top Whorl Shoots Infested by Tip Moth (Pct. Reduction Compared to Check)					Mean Pct.
		Gen 1	Gen 2	Gen 3	Gen 4	Gen 5	Reduction
EB (0.12% ai)	50	1.0 **ab *** (88)	13.4 **d** (46)	15.6 **bc** (51)	37.5 **bc** (23)	35.7 **b** (40)	**50**
EB (0.24% ai)	50	1.0 **ab** (88)	12.4 **cd** (50)	10.8 **abc** (66)	40.9 **cd** (16)	42.9 **b** (28)	**50**
FIP (0.146% ai)	50	3.2 **b** (62)	0.5 **a** (98)	5.2 **a** (84)	2.1 **a** (96)	9.1 **a** (85)	**85**
FIP (0.287% ai)	50	1.4 **ab** (83)	0.0 **a** (100)	7.1 **ab** (78)	0.7 **a** (99)	3.4 **a** (94)	**91**
IMID (0.532% ai)	50	0.0 **a** (100)	6.6 **bc** (73)	18.2 **c** (42)	29.4 **b** (40)	38.6 **b** (36)	**58**
IMID (1.064% ai)	50	0.0 **a** (100)	2.0 **ab** (92)	11.6 **abc** (63)	30.3 **b** (38)	40.8 **b** (32)	**65**
THIA (0.17% ai)	50	0.0 **a** (100)	4.5 **ab** (82)	16.0 **c** (49)	34.8 **bc** (29)	42.3 **b** (29)	**58**
THIA (0.34% ai)	50	0.0 **a** (100)	2.5 **ab** (90)	15.4 **bc** (51)	27.4 **b** (44)	35.7 **b** (40)	**65**
Check	50	8.4 **c**	24.7 **e**	31.6 **d**	48.6 **d**	59.9 **c**	

§ EB = emamectin benzoate, FIP = fipronil, IMID = imidacloprid, THIA = Thiamethoxam.
***** Means followed by the same letter in each column are not significantly different at the 5% level based on Fisher's Protected LSD.

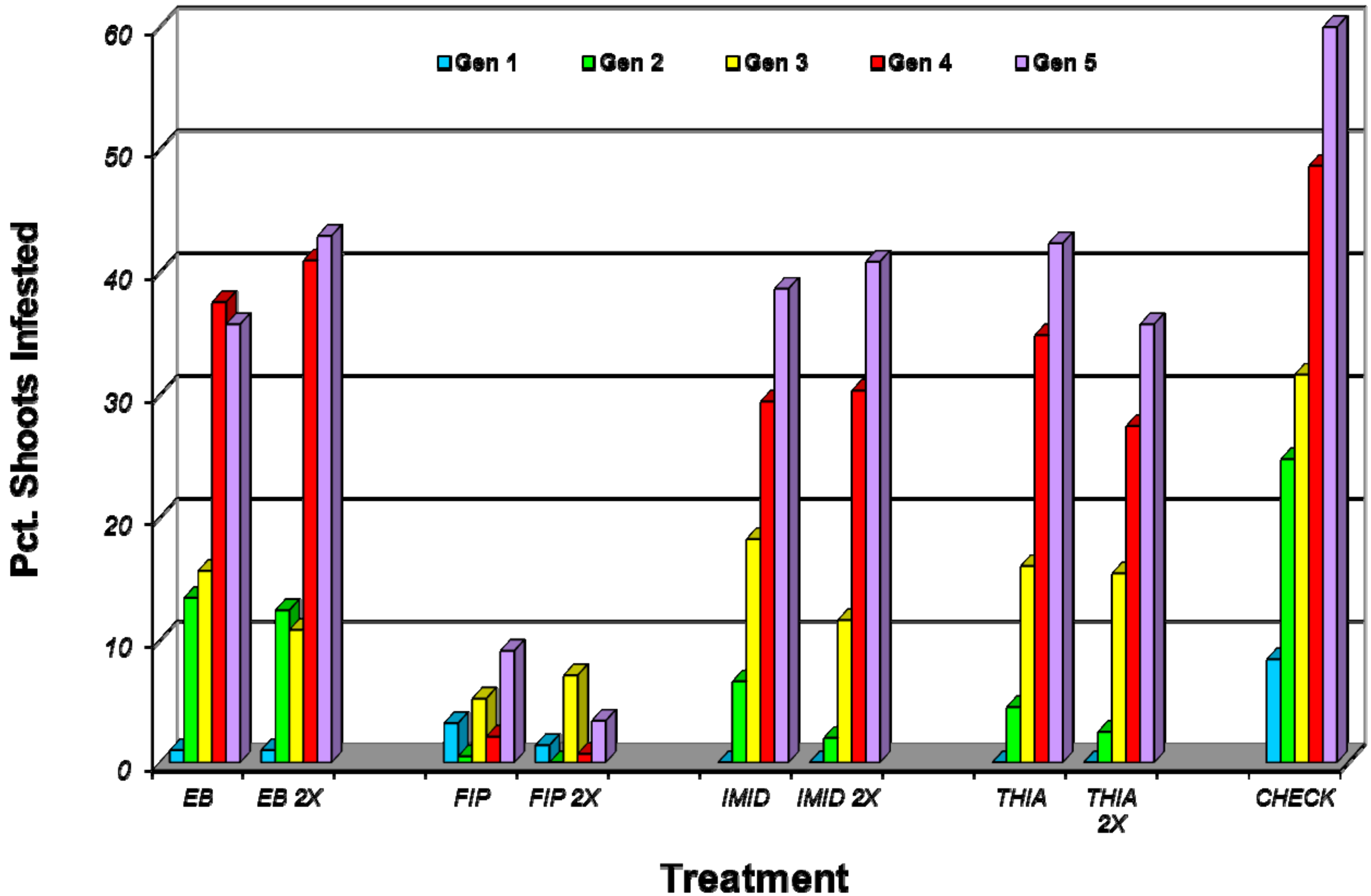

Figure 15. Effect of systemic insecticide treatments on mean percent of loblolly pine shoots (top whorl) infested by pine tip moth after each of five generations, **Plot 3**, Evans Tract, Fairchild State Forest, Cherockee Co., TX - 2002.

Table 21. Effect of systemic chemical treatments on loblolly pine growth and survival after each of 5 generations on **Plots 3**, Evans Tract, Fairchild State Forest, Cherokee Co., TX - 2002.

Treatment §	N	Mean Tree Measurements (Pct. Gain Compared to Check)						% Survival
		Height (cm)		Diameter (cm)		Volume (cm^3)		
EB (0.12% ai)	50	62.3 **bcd ***	(14)	0.99 **bc**	(18)	67.4 **ab**	(39)	100 **a**
EB (0.24% ai)	50	66.3 **bcd**	(21)	1.01 **bc**	(21)	75.2 **c**	(55)	98 **a**
FIP (0.146% ai)	50	77.9 **f**	(42)	1.25 **e**	(49)	134.8 **c**	(178)	98 **a**
FIP (0.287% ai)	50	71.2 **de**	(30)	1.15 **de**	(38)	111.3 **d**	(130)	100 **a**
IMID (0.532% ai)	50	67.3 **cd**	(23)	1.07 **cd**	(27)	92.5 **bc**	(91)	98 **a**
IMID (1.064% ai)	50	74.4 **ef**	(36)	1.15 **de**	(38)	110.5 **d**	(128)	98 **a**
THIA (0.17% ai)	50	66.3 **bcd**	(21)	1.04 **c**	(24)	90.0 **bc**	(86)	100 **a**
THIA (0.34% ai)	50	59.8 **ab**	(9)	0.92 **ab**	(19)	69.7 **bc**	(44)	100 **a**
Check	50	54.8 **a**		0.84 **a**		48.4 **a**		98 **a**

§ EB = emamectin benzoate, FIP = fipronil, IMID = imidacloprid, THIA = Thiamethoxam.

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

Nantucket Pine Tip Moth Phenology and Timing of Insecticide Applications in Arkansas, Louisiana, and Texas.

Highlights:

- A model was developed to predict the number of tip moth generations in Arkansas (3-4), Louisiana (4-5) and east Texas (4-5).
- A model was used to predict the optimal spray period for the first 3 or 4 generations at sites in Arkansas (n = 63), Louisiana (n = 45) and east Texas (n = 42).
- Spray validation trials showed that there was 57% agreement (8 of 14) between the predicted optimal spray periods and field-determined spray dates based on insecticide efficacy.

Objectives:

The objectives of the study are to 1) develop a model of tip moth phenology at several locations within Arkansas, Louisiana, and Texas, and 2) validate spray period predictions within this region.

Cooperators: Chris Fettig, U.S. Forest Service, Davis, CA
John Nowak, U.S. Forest Service, Pineville, LA
Don Grosman, WGFPMC

Research Approach:

Spray Period Predictions: A model was developed in 2001 by collecting mean daily maximum and minimum temperatures from weather stations whose distributions were chosen to provide a complete description of the macroclimate for Arkansas (*n* = 63), Louisiana (*n* = 45), and East Texas (*n* = 42). These temperatures were then transferred to a degree-day computational program. The annual number of degree-days accumulated was used to determine the number of Nantucket pine tip moth generations occurring annually at each location. Degree-days were then accumulated continuously for each location from an assigned biofix until the appropriate degree-day spray timing value was reached for each generation. Optimal spray periods were established by dividing the calendar year into five day increments.

Validation Trials: To test the validity of spray period predictions, four loblolly pine plantations (2-3 years old) were selected as validation sites in Louisiana (L1 & L2), and Texas (T1 & T2). Insecticide applications were scheduled according to the optimal spray period predictions provided in Tables 23 and 24 for the weather station nearest to each validation site (L1 and L2: Alexandria N31º 11.4”, W92º 28.8” (approx. 29 km NW of sites); T1: Jacksonville N31º 34.8”, W95º 16.2” (approx. 16 km N of site); T2: Lufkin N31º 8.4”, W94º 45.0”; T2: (approx. 26 km SSW of site) (Tables 23 and 24). Insecticide treatments were applied to 50 trees at the midpoint of the predicted optimal spray period, the midpoint of the prior optimal spray period, and the midpoint of the following optimal spray period. Dates were the same for all generations and sites: 19, 24, 29 March (generation 1), 18, 23, 28 May (generation 2), 7, 12, 17 July (generation 3), and 16, 21, 25 August (generation 4). The study was designed as a randomized complete block (RCB) with four blocks and four treatments (including a untreated control group) for each generation. Treatments were made with hand-pump backpack sprayers applying permethrin (Pounce 3.2® EC, FMC Corporation, Philadelphia, PA) at a rate of 0.6 ml of formulated product per liter of water (0.17 kg (AI)/ha) to individual trees until the foliage was moist.

Damage Evaluation: Damage estimates were collected on each tree during the pupal stage of each generation. The total number of shoots (i.e., >10 linear cm of apical stem containing foliage) and number of tip moth infested shoots were recorded. Damage was expressed as the percentage of infested shoots. Means were initially computed on a per-site basis, and insecticide efficacy was calculated as percent control ((control group – treatment group)/control group) * 100. The early, optimal, and late spray treatments within a generation and site were compared. If the most effective treatment resulted in <50% control then that combination was excluded from analysis. The optimal spray period was considered most efficacious (i.e., optimal) among treatments within a generation when 1) efficacy was greatest, or 2) efficacy was ≥75% and damage averaged <1.5%.

Results & Discussion (modified from Fettig et al. 2003): Nantucket tip moth completes three to five generations annually in the Western Gulf region (Figs. 16 - 18). Predictions of the number of generations generally increased from northern to southern latitudes, and varied with elevation only in the Ouachita and Ozark Mountain ranges in Arkansas. Unlike portions of the southeastern United States, bivoltine (two generation) populations apparently do not exist in the Western Gulf region.

Arkansas: Nantucket pine tip moth populations in Arkansas are projected to have three or four generations annually (Fig. 16). In many cases, phenology predictions are split along the 35 °N latitude, with most locations north of that latitude having trivoltine (3 generation) populations, and locations south having four generations per year. Where three generations occur annually, the predicted first generation optimal spray period generally occurred in mid- to late April, the second in mid-June, and the third in early August (Table 22). In locations where a fourth generation occurs, the predicted first generation optimal spray period typically occurred in early April, the second in early June, the third in late July, and the fourth in early to mid-September (Table 22).

Louisiana: Most Nantucket pine tip moth populations in Louisiana were projected to complete four generations annually (Fig. 17). In general, locations north and west of Baton Rouge have four generations, while areas south and east of this location are predicted to have five generations per year (Fig. 17). Predictions for populations along the Mississippi border agree with estimates provide by Fettig and others (2000a) for adjacent locations in the western portion of that state. Where four generations occur annually, the predicted first generation optimal spray period generally occurred in mid-March to early April, the second in late May to early June, the third in mid- to late July, and the fourth in late August to early September (Table 23).

Texas: The majority of Nantucket pine tip moth populations in Texas were predicted to have four generations per year (Fig. 18). In general, populations located north of the 30 ° 30” N latitude had four generations annually, and populations south of this latitude have five generations annually. This phenology boundary agrees closely with that observed in adjacent Louisiana (Fig. 17). Daingerfield, TX (station 24, Fig. 18) is presumed to be an outlier. Five generations per year are predicted to occur at that location, but it is surrounded by multiple stations predicted to have only four generations annually. According to our knowledge, this station is not associated with any particular topographic feature that would explain its warmer temperatures relative to adjacent stations. It is unknown whether this location represents a real warm pocket or whether errors have occurred at the recording station. Where four generations occur annually, the predicted first generation optimal spray period generally occurred in late-March to early April, the second in late May to early June, the third in mid- to late July, and the fourth in mid-August to early September (Table 24).

Transition zones between phenology boundaries are not precise, and considerable deviation from temperature norms may cause slight, temporary shifts in their distribution. Recent trapping studies as far north as Lufkin, TX suggested that perhaps a fifth adult emergence may occur during warm years (D.M. Grosman, unpublished data). It is thought that these parent adults contribute little, if anything, to the subsequent generation. Kudon and others (1988) examined the possibility of a fourth generation in 1984 in the Georgia Piedmont where only trivoltine populations are thought to occur. They reported that although some additional mating and oviposition occurred, no damage was observed that could be attributed to the fourth emergence. Any such emergence would therefore likely be of minor consequence from a pest management perspective.

Validity of Predictions: Mean tip moth damage levels on unprotected trees ranged from 3% to 53% (Table 25). Overall, damage levels were considerably lower in Texas than Louisiana. There was 57% agreement (8 of 14) between the optimal spray periods and field-determined spray dates based on insecticide efficacy. At one of the Texas validation sites (T1), the optimal spray periods were most efficacious during all four generations. It is interesting to note that this site was also the closest of the four in proximity to the weather station from which our predictions were generated. Data trends suggest that insecticide applications may have been more efficacious if applied 1-2 weeks prior to the early spray date for the third and fourth generations in Louisiana (Table 25). Optimal spray period predictions were most efficacious among all treatments during the first generation at each site (Table 4).

A significant treatment effect was found during one of the four generations ($P < 0.05$; Table 26). The early, optimal, and late insecticide applications were significantly different from the control, although no significant differences were detected among their treatment means (Table 26). A lack of further significant differences was likely a result of our small sample size ($df = 3, 9$) and the large amount of variation in the data.

Management Implications: Although largely effective, improper use of various *R. frustrana* spray-timing models has led to errors in spray date predictions. These models require a detailed knowledge of tip moth biology, proper pheromone trap deployment, intensive trap monitoring, knowledge of degree-day calculations, conversions and utility, and the ability to acquire daily maximum and minimum temperatures on or near the site. Although the collection of data required to use timing models is costly and laborious to obtain, these costs can be mitigated by increased insecticide efficacy and reduced application frequency. However, scheduling problems may still arise from short-term advance notice of approaching optimal spray dates. Still, degree-day spray-timing models will provide the best overall control if workers invest the training, time and resources in learning how to properly use them.

When considering these difficulties, the optimal spray period predictions presented here are a viable alternative to using spray-timing models. Land managers applying contact insecticides, such as pyrethroids, can simply locate the nearest weather station to their pine plantation (Figs. 16 - 18), and use the optimal spray periods to time their insecticide applications accordingly (Tables 22 - 24). During extended periods of inclement weather, it is advisable to adjust spray period predictions by one period depending on the prevailing temperature deviation from normal.

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Kudon, L. H.; Berisford, C. W.; Dalusky, M. J. 1988. Refinement of a spray timing technique for the Nantucket pine tip moth (Lepidoptera: Tortricidae). Journal of Entomological Science. 23: 180-186.

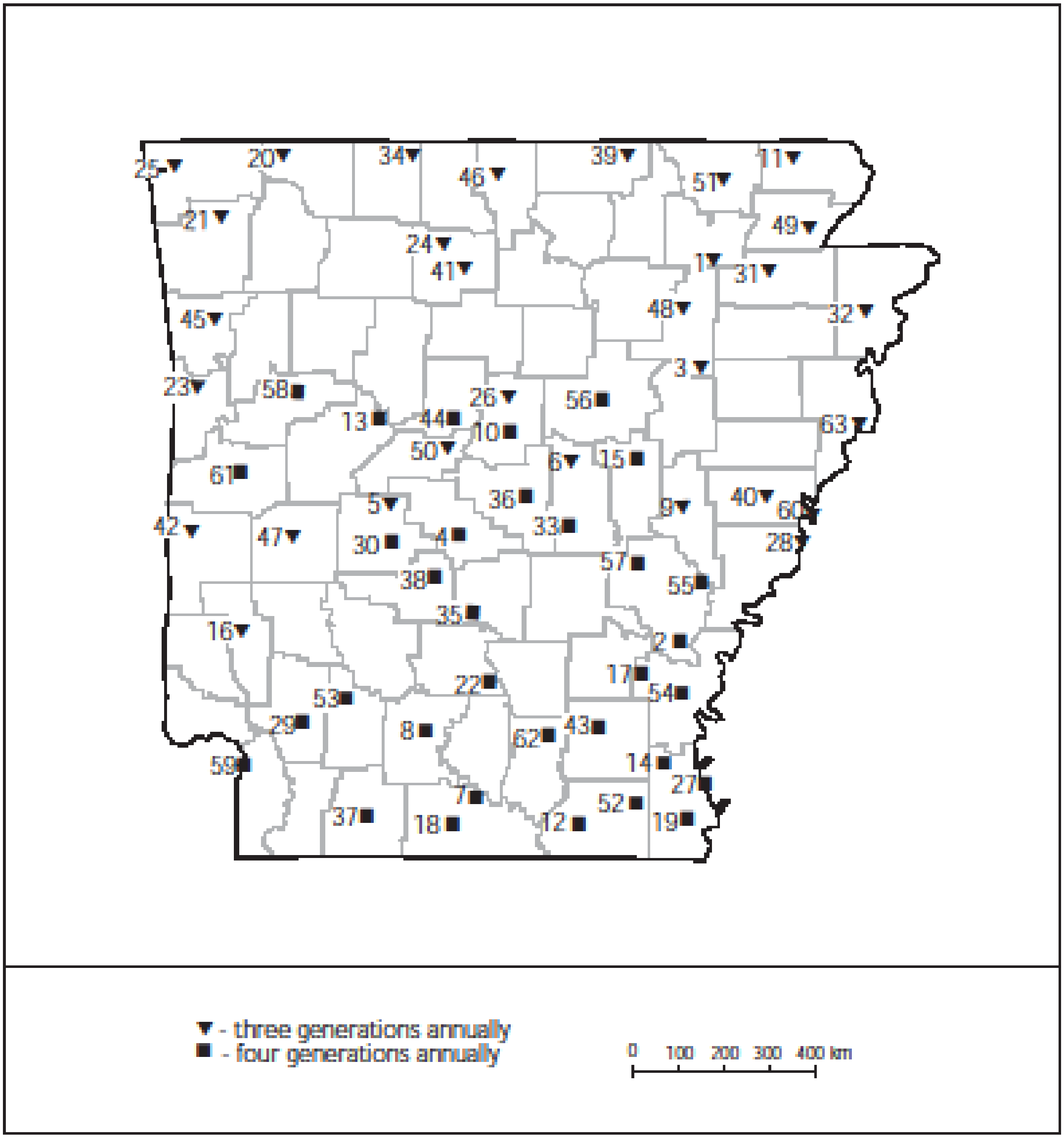

Figure 16. Nantucket pine tip moth phenology in Arkansas based on analysis of historical temperature data. Filled triangles denote three generations annually. Filled squares denote four generations annually. Numbers correspond to weather station locations in Table 22.

Table 22. Location, phenology, and optimal spray period predictions at 63 weather stations located throughout the natural range of *Rhyacionia frustrana* (Comstock) for Arkansas.

			Optimal Spray Period Intervals			
No.	**Location**	**Phenology**	**1**	**2**	**3**	**4**
1	Alicia	3	Apr 16-20	June 15-19	Aug 4-8	
2	Arkansas Post	4	Apr 6-10	May 31-June 4	July 20-24	Sept 3-7
3	Beedeville	3	Apr 16-20	June 15-19	July 30-Aug 3	
4	Benton	4	Apr 6-10	June 5-9	July 30-Aug 3	Sept 13-17
5	Blakeley Mtn.	3	Apr 16-20	June 25-29	Aug 9-13	
6	Cabot	3	Apr 16-20	June 20-24	Aug 4-8	
7	Calion	4	Apr 6-10	June 5-9	July 25-29	Sept 8-12
8	Camden	4	Apr 6-10	June 5-9	July 25-29	Sept 8-12
9	Clarendon	3	Apr 16-20	June 15-19	Aug 4-8	
10	Conway	4	Apr 11-15	June 10-14	July 30-Aug 3	Sept 13-17
11	Corning	3	Apr 21-25	June 20-24	Aug 9-13	
12	Crossett	4	Apr 6-10	June 5-9	July 30-Aug 3	Sept 13-17
13	Dardanelle	4	Apr 11-15	June 10-14	July 30-Aug 3	Sept 13-17
14	Dermott	4	Apr 11-15	June 5-9	July 25-29	Sept 8-12
15	DesArc	4	Apr 16-20	June 10-14	July 30-Aug 3	Sept 13-17
16	Dierks	3	Apr 16-20	June 20-24	Aug 9-13	
17	Dumas	4	Apr 6-10	May 31-June 4	July 20-24	Aug 29-Sept 2
18	Eldorado	4	Apr 6-10	June 5-9	July 25-29	Sept 3-7
19	Eudora	4	Apr 6-10	June 5-9	July 20-24	Sept 3-7
20	Eureka Springs	3	Apr 21-25	June 25-29	Aug 14-18	
21	Fayetteville	3	Apr 26-30	June 30-July 4	Aug 24-28	
22	Fordyce	4	Apr 11-15	June 5-9	July 25-29	Sept 8-12
23	Fort Smith	3	Apr 16-20	June 20-24	Aug 9-13	
24	Gilbert	3	Apr 16-20	June 25-29	Aug 14-18	
25	Gravette	3	Apr 21-25	June 25-29	Aug 14-18	
26	Greenbrier	3	Apr 16-20	June 20-24	Aug 4-8	
27	Greenville, MS	4	Apr 6-10	May 31-June 4	July 20-24	Aug 29-Sept 2
28	Helena	3	Apr 16-20	June 15-19	Aug 4-8	
29	Hope	4	Apr 11-15	June 10-14	July30-Aug 3	Sept 13-17
30	Hot Springs	4	Apr 16-20	June 10-14	July 30-Aug 3	Sept 13-17
31	Jonesboro	3	Apr 16-20	June 15-19	July 30-Aug 3	
32	Keiser	3	Apr 21-25	June 20-24	Aug 4-8	
33	Keo	4	Apr 11-15	June 10-14	July 25-29	Sept 13-17
34	Leadhill	3	Apr 21-25	June 25-29	Aug 9-13	
35	Leola	4	Apr 11-15	June 5-9	July 25-29	Sept 13-17
36	Little Rock	4	Apr 16-20	June 10-14	July 30-Aug 3	Sept 13-17
37	Magnolia	4	Apr 1-5	May 31-June 4	July 25-29	Sept 3-7
38	Malvern	4	Apr 6-10	June 5-9	July 30-Aug 3	Sept 13-17
39	Mammoth Springs	3	Apr 21-25	June 25-29	Aug 14-18	
40	Marianna	3	Apr 16-20	June 20-24	Aug 4-8	
41	Marshall	3	Apr 26-30	June 30-July 4	Aug 19-23	
42	Mensa	3	Apr 21-25	June 25-29	Aug 14-18	
43	Monticello	4	Apr 11-15	June 10-14	July 30-Aug 3	Sept 13-17
44	Morrilton	4	Apr 11-15	June 5-9	July 25-29	Sept 8-12
45	Mountainburg	3	Apr 16-20	June 25-29	Aug 14-18	
46	Mountain Home	3	Apr 21-25	June 30-July 4	Aug 14-18	
47	Mount Ida	3	Apr 21-25	June 30-July 4	Aug 14-18	
49	Newport	3	Apr 21-25	June 20-24	Aug 4-8	

49	Paragould	3	Apr 21-25	June 20-24	Aug 4-8	
50	Perry	3	Apr 16-20	June 20-24	Aug 4-8	
51	Pocahontas	3	Apr 16-20	June 20-24	Aug 4-8	
52	Portland	4	Apr 6-10	May 31-June 4	July 20-24	Sept 3-7
53	Prescott	4	Apr 6-10	May 31-June 4	July 20-24	Sept 3-7
54	Rohwer	4	Apr 16-20	June 10-14	July 30-Aug 3	Sept 13-17
55	St. Charles	4	Apr 16-20	June 10-14	July 30-Aug 3	Sept. 13-17
56	Searcy	4	Apr 16-20	June 10-14	July 30-Aug 3	Sept. 13-17
57	Stuttgart	4	Apr 6-10	June 5-9	July 20-24	Sept 3-7
58	Subiaco	4	Apr 11-15	June 10-14	July 30-Aug 3	Sept.13-17
59	Texarkana	4	Apr 1-5	May 26-30	July 15-19	Aug 24-28
60	Tunica, MS	3	Apr 16-20	June 15-19	Aug 4-8	
61	Waldron	4	Apr 11-15	June 10-14	July 30-Aug 3	Sept 13-17
62	Warren	4	Apr 11-15	June 10-14	July 30-Aug 3	Sept 13-17
63	West Memphis	3	Apr 16-20	June 20-24	Aug 4-8	

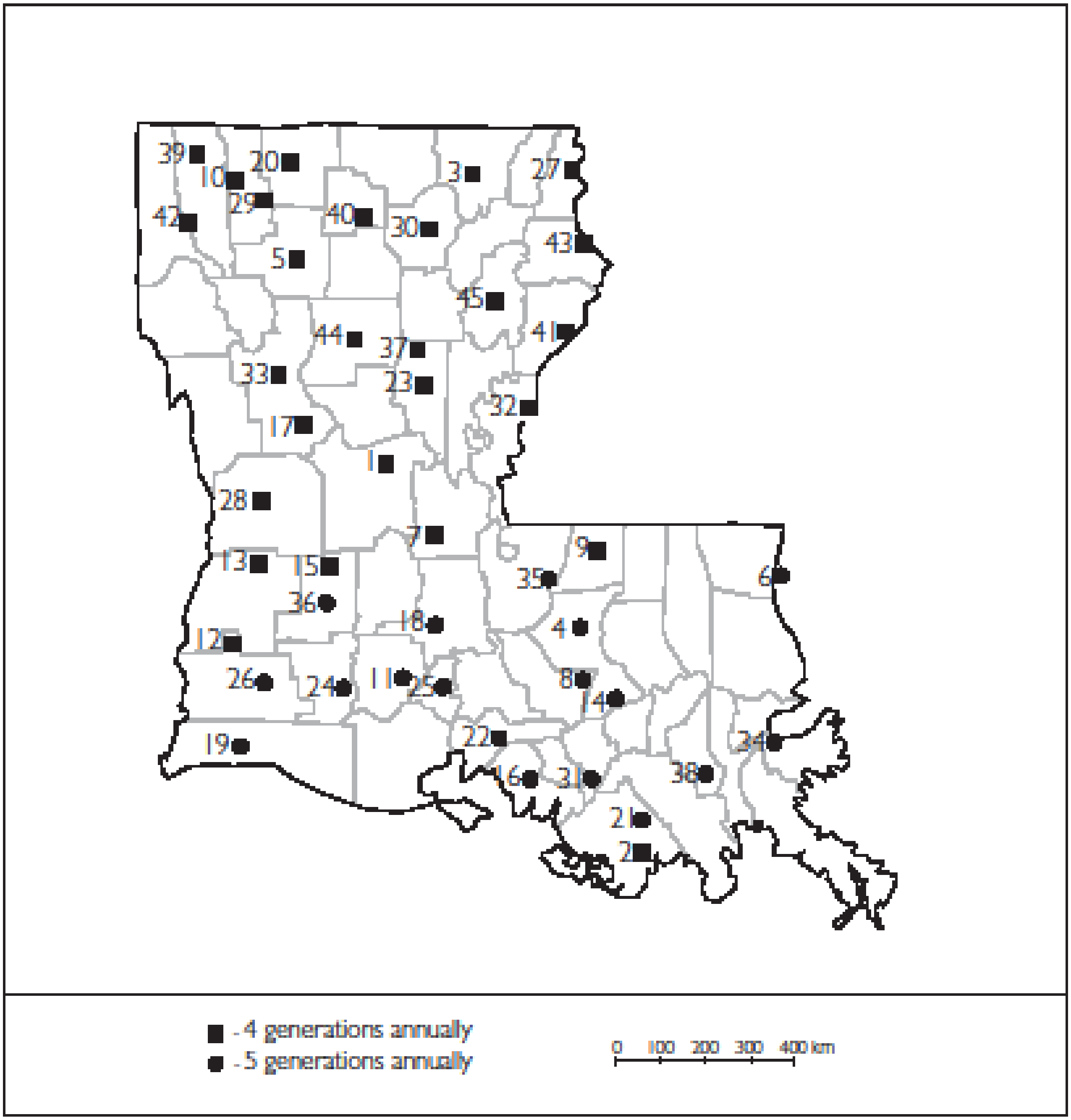

Figure 17. Nantucket pine tip moth phenology in Louisiana based on analysis of historical temperature data. Filled squares denote four generations annually. Filled circles denote five generation per year. Numbers correspond to weather station locations in Table 23.

Table 23. Location, phenology, and optimal spray period predictions at 45 weather stations located throughout the natural range of *Rhyacionia frustrana* (Comstock) for Louisiana.

			Optimal Spray Period Intervals			
No.	**Location**	**Phenology**	**1**	**2**	**3**	**4**
1	Alexandria	4	March 22-26	May 21-25	July 10-14	Aug 19-23
2	Ashland	4	Apr 1-5	May 31-June 4	July 20-24	Sept 3-7
3	Bastrop	4	Apr 1-5	May 26-30	July 15-19	Aug 24-28
4	Baton Rouge	5	-	-	-	-
5	Bienville	4	Apr 1-5	May 31-June 4	July 20-24	Aug 29-Sept 2
6	Bogalusa	5	-	-	-	-
7	Bunkie	4	Mar 22-26	May 21-25	July 10-14	Aug 19-23
8	Carville	5	-	-	-	-
9	Clinton	4	Mar 17-21	May 16-20	July 10-14	Aug 19-23
10	Cotton Valley	4	Apr 6-10	June 5-9	July 25-29	Sept 3-7
11	Crowley	5	-	-	-	-
12	DeQuincy	4	Mar 17-21	May 21-25	July 10-14	Aug 19-23
13	DeRidder	4	Mar 22-26	May 21-25	July 10-14	Aug 19-23
14	Donaldsville	5	-	-	-	-
15	Elizabeth	4	Mar 17-21	May 21-25	July 10-14	Aug 19-23
16	Franklin	5	-	-	-	-
17	Gorum Fort	4	Mar 17-21	May 21-25	July 10-14	Aug 19-23
18	Grand Coteau	5	-	-	-	-
19	Hackberry	5	-	-	-	-
20	Homer	4	Apr 6-10	June 5-9	July 25-29	Sept 3-7
21	Houma	5	-	-	-	-
22	Jeanerette	5	-	-	-	-
23	Jena	4	Mar 27-31	May 26-30	July 15-19	Aug 24-28
24	Jennings	5	-	-	-	-
25	Lafeyette	5	-	-	-	-
26	Lake Charles	5	-	-	-	-
27	Lake Providence	4	Apr 6-10	May 31-June 4	July 20-24	Aug 29-Sept 2
28	Leesville	4	Mar 22-26	May 21-25	July 15-19	Aug 24-28
29	Minden	4	Apr 1-5	May 31-June 4	July 20-24	Aug 29-Sept 2
30	Monroe	4	Apr 1-5	May 31-June 4	July 15-19	Aug 29-Sept 2
31	Morgan City	5	-	-	-	-
32	Nantchez, MS	4	Mar 17-21	May 21-25	July 10-14	Aug 24-28
33	Natchitoches	4	Mar 27-31	May 21-25	July 10-14	Aug 19-23
34	New Orleans	5	-	-	-	-
35	New Roads	5	-	-	-	-
36	Oberlin	5	-	-	-	-
37	Olla	4	Mar 22-26	May 26-30	July 15-19	Aug 29-Sept 2
38	Paradis	5	-	-	-	-
39	Plain Dealing	4	Apr 6-10	June 5-9	July 25-29	Sept 8-12
40	Ruston	4	Apr 1-5	May 31-June 4	July 20-24	Sept 3-7
41	St. Joseph	4	Apr 1-5	May 26-30	July 15-19	Aug 29-Sept 2
42	Shreveport	4	Mar 27-31	May 26-30	July 15-19	Aug 29-Sept 2
43	Tallulah	4	Apr 1-5	May 31-June 4	July 20-24	Aug 29-Sept 2
44	Winnfield	4	Mar 22-26	May 26-30	July 15-19	Aug 29-Sept 2
45	Winnsboro	4	Apr 1-5	May 26-30	July 15-19	Aug 29-Sept 2

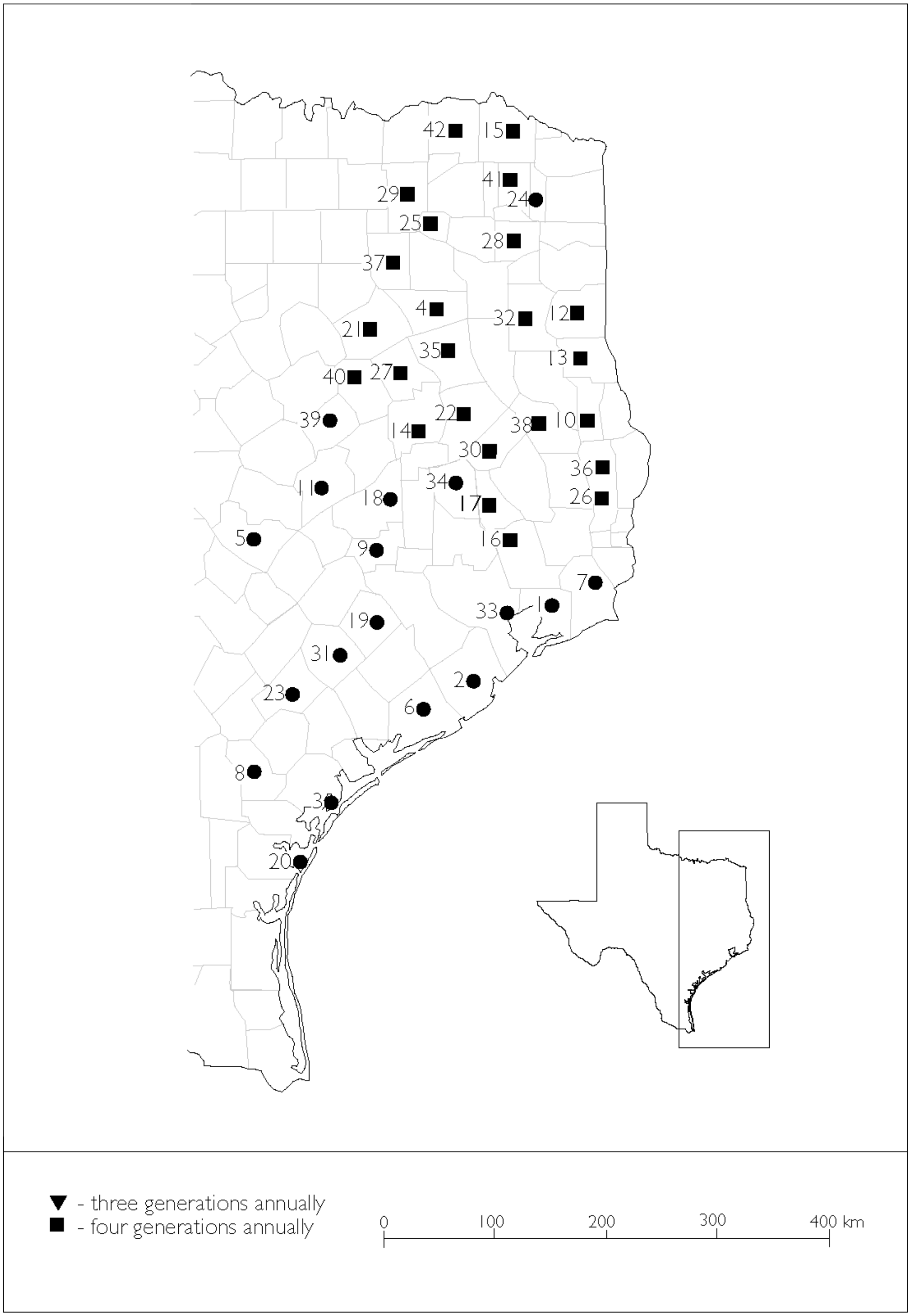

Figure 18. Nantucket pine tip moth phenology in Texas based on analysis of historical temperature data. Filled squares denote four generations annually. Filled circles denote five generation per year. Numbers correspond to weather station locations in Table 24.

Table 24. Location, phenology, and optimal spray period predictions at 42 weather stations located throughout the natural range of *Rhyacionia frustrana* (Comstock) in Texas.

			Optimal Spray Period Intervals			
No.	**Location**	**Phenology**	**1**	**2**	**3**	**4**
1	Anahuac	5	-	-	-	-
2	Angleton	5	-	-	-	-
3	Aransas	5	-	-	-	-
4	Athens	4	Mar 22-26	May 21-25	July 10-14	Aug 19-23
5	Austin	5	-	-	-	-
6	Bay City	5	-	-	-	-
7	Beaumont	5	-	-	-	-
8	Beeville	5	-	-	-	-
9	Brenham	5	-	-	-	-
10	Broaddus	4	Mar 27-31	May 26-30	July 15-19	Aug 24-28
11	Cameron	5	-	-	-	-
12	Carthage	4	Mar 27-31	May 26-30	July 15-19	Aug 29-Sept 2
13	Center	4	Mar 27-31	May 26-30	July 20-24	Aug 29-Sept 2
14	Centerville	4	Mar 22-26	May 26-30	July 15-19	Aug 24-28
15	Clarksville	4	Apr 11-15	June 10-16	July 30-Aug 3	Sept 8-12
16	Cleveland	4	Mar 17-21	May 21-25	July 10-14	Aug 19-23
17	Coldspring	4	Mar 22-26	May 21-25	July 10-14	Aug 24-28
18	College Station	5	-	-	-	-
19	Columbus	5	-	-	-	-
20	Corpus Christi	5	-	-	-	-
21	Corsicana	4	Apr 1-5	May 31-June 4	July 15-19	Aug 24-28
22	Crockett	4	Mar 27-31	May 26-30	July 15-19	Aug 24-28
23	Cuero	5	-	-	-	-
24	Daingerfield	5	-	-	-	-
25	Emory	4	Apr 6-10	June 5-9	July 20-24	Sept 3-7
26	Evadale	4	Mar 17-21	May 21-25	July 10-14	Aug 24-28
27	Fairfield	4	Mar 22-26	May 21-25	July 10-14	Aug 14-18
28	Gilmer	4	Apr 6-10	June 5-9	July 25-29	Sept 3-7
29	Greenville	4	Apr 11-15	June 5-9	July 25-29	Sept 8-12
30	Groveton	4	Mar 17-21	May 21-25	July 10-14	Aug 19-23
31	Hallettsville	5	-	-	-	-
32	Henderson	4	Apr 1-5	May 31-June 4	July 20-24	Aug 29-Sept 2
33	Houston	5	-	-	-	-
34	Huntsville	5	-	-	-	-
35	Jacksonville	4	Mar 22-26	May 21-25	July 10-14	Aug 19-23
36	Jasper	4	Mar 22-26	May 21-25	July 15-19	Aug 24-28
37	Kaufman	4	Mar 27-31	May 31-June 4	July 20-24	Aug 29-Sept 2
38	Lufkin	4	Mar 22-26	May 21-25	July 10-14	Aug 19-23
39	Marlin	5	-	-	-	-
40	Mexia	4	Mar 27-31	May 26-30	July 15-19	Aug 24-28
41	Mt. Pleasant	4	Apr 6-10	June 5-9	July 25-29	Sept 3-7
42	Paris	4	Apr 11-15	June 5-9	July 20-24	Sept 3-7

Table 25. Mean percent damage (± S.E.) of loblolly pines (n = 50) treated with permethrin to control *R. frustrana* at four sites in Texas (T1, T2) and Louisiana (L1, L2), 2002. Means in bold denote the most efficacious treatment within each generation based on the criteria reported in this publication.

		Spray Period		
Site Generation	**Early**	**Optimal**	**Late**	**Control**
T1				
1	0.27 ± 0.19	**0.17 ± 0.17**	0.0 ± 0.0	8.50 ± 1.29
2	0.24 ± 0.14	**0.78 ± 0.49**	0.50 ± 0.22	12.15 ± 1.43
3	2.98 ± 0.56	**1.52 ± 0.34**	4.75 ± 0.53	5.63 ± 0.58
4	0.57 ± 0.21	**1.14 ± 0.35**	0.67 ± 0.20	10.89 ± 0.89
T2				
1	0.43 ± 0.31	**0.44 ± 0.44**	0.20 ± 0.20	3.41 ± 0.89
2	**1.30 ± 0.52**	2.30 ± 1.15	5.67 ± 1.15	7.37 ± 1.69
3	**0.23 ± 0.14**	1.35 ± 0.43	4.31 ± 0.88	3.72 ± 0.78
4	1.91 ± 0.83	1.83 ± 0.61	**0.54 ± 0.19**	6.40 ± 0.91
L1				
1	3.89 ± 1.48	**1.77 ± 0.77**	2.45 ± 1.11	18.97 ± 3.04
2	16.47 ± 2.56	**11.56 ± 2.91**	39.81 ± 3.74	34.62 ± 3.92
3	14.15 ± 2.76	34.00 ± 3.80	39.90 ± 3.46	26.09 ± 2.88
4	**19.90 ± 2.71**	32.00 ± 3.25	34.75 ± 3.08	50.22 ± 3.79
L2				
1	1.71 ± 0.83	**1.00 ± 0.59**	1.19 ± 0.98	14.88 ± 2.26
2	**7.38 ± 2.02**	13.31 ± 2.88	17.41 ± 2.96	24.61 ± 3.55
3	**15.73 ± 2.84**	29.78 ± 2.98	32.44 ± 4.07	40.48 ± 2.74
4	26.93 ± 2.44	29.94 ± 3.04	31.80 ± 4.04	53.47 ± 3.20

Table 26. Mean percent damage (± S.E.) of loblolly pine plantations treated with permethrin to control *R. frustrana* infestations at four sites in Texas and Louisiana, 2002. Means followed by the same letter within a row are not significantly different (RCBD; $P > 0.05$, Tukey's test).

	Spray Period			
Generation	**Early**	**Optimal**	**Late**	**Control**
1	1.58 ± 0.84 a	0.85 ± 0.35 a	0.96 ± 0.56 a	11.40 ± 3.44 b
2	6.35 ± 3.72 a	6.99 ± 3.18 a	15.80 ± 8.74 a	19.70 ± 6.16 a
3	8.27 ± 3.90 a	16.70 ± 8.83 a	20.40 ± 9.26 a	19.20 ± 8.83 a
4	12.30 ± 6.57 a	16.20 ± 8.52 a	16.90 ± 9.45 a	30.20 ± 12.50 a

Predicting Infestation Levels of the Nantucket Pine Tip Moth Using Pheromone Traps

Highlights:

- A model was developed to predict the number of tip moth generations in Arkansas (3-4), Louisiana (4-5) and east Texas (4-5).
- A model was used to predict the optimal sprat period for the first 3 or 4 generations at sites in Arkansas (n = 63), Louisiana (n = 45) and east Texas (n = 42).
- Spray validation trials showed that there was 57% agreement (8 of 14) between the predicted optimal spray periods and field-determined spray dates based on insecticide efficacy.

Objectives:

The objectives of the study were to: 1) develop regression models using pine tip moth trap catch prior to the spray date of each generation to predict subsequent tip moth damage, 2) compare two trap types, the Pherocon 1C wing trap and the Pherocon III Delta trap, for their effectiveness for predicting tip moth populations, 3) identify factors which may facilitate risk rating of stands for tip moth damage, and 4) determine whether pheromone trap catches between sites within a region are more similar to each other than to trap catches from sites in more distant regions.

Cooperators:

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Wayne Brewer, Auburn University, Auburn, AL
John Nowak, U.S. Forest Service, Pineville, LA
Don Grosman, WGFPMC, Lufkin, TX

Research Approach:

<u>Site Selection</u> - Cooperators selected 2 to 6 one-year old plantations (those entering their second year in the field). Plantation sizes were between 25-100 acres. Attempts were made to pick sites that are “clumped” together within an area (county), preferably in groups of two or three, but each site should be at least three miles apart from another. The “clumps” should be situated as far away from each other as possible.

<u>Trap types</u> - Two trap types, Pherocon IC wing trap and the Pherocon III Delta trap (orange), were used in the study. Four traps of each type were deployed at each site, alternating by trap type, i.e., Delta-Wing-Delta-Wing-Delta-Wing-Delta-Wing. Traps were placed at least 200 feet from each other and 100 feet from the plantation edge, ideally along an access road. Traps were hung at the average terminal height for trees in the immediate vicinity. Lures were replaced every month.

<u>Trap Data Collection:</u> Traps were deployed before first adult emergence begins in December or early January and checked weekly. Trapping and counting moths were continue until the predicted spray date for each generation in an area is reached. This was determined using Chris Fettig’s spray timing publications; Fettig et al. 2000 for sites in states east of Louisiana and Arkansas and Fettig’s unpublished data for sites in Arkansas, Louisiana and Texas.

Damage Estimates: Tip moth damage were evaluated four weeks after peak emergence of each generation by selecting six trees near, but not adjacent to, each the eight traps (48 trees total). Each tree was flagged and top whorl damage estimates were made on each tree for each tip moth generation. When counting the number of shoots and damaged shoots in the top whorl, a "shoot" was defined as being at least one inch long and terminating in a bud.

Tree Measurements: Supplementary information on tree heights and total number of shoots per tree was collected when traps were first installed on site and when final damage estimates were made for the last generation at the end of the year. The height of each tree was measured and the total number of shoots per tree were counted by selecting three trees near, but not adjacent to, each trap in the stand (24 trees total).

Data Analysis: For each tip moth generation, linear regression was used to evaluate the relationships between top whorl damage and trap catch up to the spray date and one, two, three weeks etc. prior to spray date for the spring generation. Initial tree height may be used as a covariate in a multivariate model. Spatial statistics may be used to compare similarities between adjacent sites or site clusters.

Results (provided by Chris Asaro): Twenty-seven sites (Georgia = 20, South Carolina = 2, Louisiana = 3, Texas = 2) were monitored and used to develop a prediction model in 2002. A preliminary look at the data suggests that Delta traps are not useful for prediction of tip moth populations, although they are useful for monitoring tip moth phenology. Wing traps, however, show considerable promise in being able to predict tip moth populations for the first three generations. Regression models for wing traps may be significantly improved if tree heights are included as a covariate in a multiple linear regression model. This is so because damage estimates based on percent of infested shoots are meaningless relative to actual moth populations unless tree height (and corresponding number of shoots per tree) is estimated (i.e. 50% infested shoots on a small tree will yield fewer moths than 50% infested shoots on a larger tree, and trap catches will reflect this difference even though damage estimates are the same). Therefore, average tree height for each stand will be included in the analysis. Prediction models for the fourth generation will be forthcoming. The prediction models presented thus far are adequate for predicting and distinguishing populations that are very low or relatively high. However, intermediate populations will not likely be so easily classified based on trap catch. Furthermore, from time to time tip moth populations will crash or explode between generations in an unpredictable fashion, probably due to a reduction or influx of parasitoids following the trapping period. Our data suggest that this occurs approximately 20% of the time. Due to our limited knowledge of parasitoid behavior and population dynamics, this problem is not likely to be circumvented in the near future. Despite these problems, however, the ability to predict low and high tip moth populations with 80% success will still be a valuable tool in tip moth management.