Systemic Insecticide Injections: New, Effective Option for Protecting Pine Seed Orchard Crops from Insect Pests

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Abstract: The efficacies of systemic insecticides emamectin benzoate and fipronil were evaluated in four southeastern pine seed orchards for preventing damage and mortality to cones by cone and seed insects. Single injections of emamectin benzoate consistently reduced cone damage and mortality (70 – 95%) by coneworms in slash pine and loblolly pine orchards for two years compared to untreated checks. Fipronil performed nearly as well on most sites reducing coneworm damage by 66 – 92%. Both chemicals were moderately effective against pine seed bugs during the first year after injection; reducing damage by 3 – 37% compared to checks. No significant treatment effect was observed against seed bugs during the second year. Emamectin benzoate demonstrated some activity against slash pine flower thrips in Alabama.

Keywords: systemic injections, cone protection, coneworm, seed bug, slash pine flower thrip

INTRODUCTION

Cone and seed insects severely reduce potential seed yields in southern pine seed orchards that produce genetically improved seed for regeneration programs. Two of the most important insect pest groups include the coneworms (*Dioryctria* spp.) that attack flowers, cones and stems of pines and the seed bugs (southern pine seed bug, *Leptoglossus corculus* (Say) and shield-backed pine seed bug, *Tetyra bipunctata* (Herrich-Schaffer)), that suck the contents from developing seeds in conelets and cones (Ebel et al. 1980). Without a comprehensive insect-control program, these pests commonly destroy 50% of the potential seed crop, and losses up to 90% are not uncommon (Fatzinger et al. 1980).

Trials conducted from 1998 – 2004 at the Texas Forest Service (TFS) Magnolia Spring seed orchard showed that trunk injections of either emamectin benzoate (Syngenta Crop Protection Inc., Greensboro, NC) and fipronil (BASF Corp., Research Triangle Park, NC) were effective in reducing damage caused by coneworms and seed bugs (Grosman et al. 2002; Grosman unpublished data). New formulations of these chemicals were developed during the winter of

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2004/2005. In this report, we describe a study to evaluate the efficacy of new formulations of emamectin benzoate and fipronil, applied by the Arborjet™ Tree IV injector for control of coneworms, seed bugs and/or slash pine flower thrips, *Gnophothrips fuscus* (Morgan) (Order: Thysanoptera), in loblolly and slash pine orchards in the southeastern United States.

MATERIALS AND METHODS

The study was conducted in two loblolly pine orchards and two slash pine orchards. Loblolly pine orchard blocks were located at Plum Creek Timber Co.'s Hebron orchard near Chatham, LA (Jackson Parish) and International Paper Co.'s Bellamy orchard near Marianna, FL (Jackson Co.). Slash pine orchard blocks were located at Temple-Inland Forest Product's Forest Lake orchard near Spurger, TX (Jasper Co.) and Smurfit-Stone Container's Brewton orchard near Brewton, AL (Escambia Co.). The FL and TX orchard blocks had been sprayed for insect control in 2004, while the LA and AL orchard blocks had not been sprayed for at least three years prior to 2005.

In early spring 2005, six to eight ramets from five to six clones were selected in each orchard. The treatments were evaluated using a randomized complete block with clones as blocks (DeBarr 1978). The treatments included: 1) emamectin benzoate (Arborjet Inc.) at 5 - 10 ml (0.2 – 0.4g AI) per inch tree diameter at breast height (DBH) by Tree IV injector; 2) Fipronil (BASF) at 1.7 - 3.4 ml (0.2 – 0.4g AI) per inch tree DBH by Tree IV injector; 3) Foliar spray (standard) of Asana® XL, Capture®, Mimic® 2LVor Warrior® with Zeon Technology™ was applied to foliage 3-4 times per year at label rate beginning in April; or 4) Check (untreated).

In March (AL & TX) and April (FL & LA) 2005, at least four holes, 9 mm diameter and 5-8 cm deep, were drilled about 30 cm high at cardinal points on the tree bole. Arborplugs™ were installed in each hole. The Arborjet™ Tree IV system was used to inject a predetermined amount of product at 50 psi pressure into each tree. The chemical rate increased with tree diameter: 0.2g AI/inch DBH in trees <30 cm DBH or 0.4g AI/DBH" in trees 30-58 cm DBH. The length of time to inject each tree varied from 5-40 min and was dependent on tree species, location, soil moisture and temperature.

The foliar spray treatment (Capture®, Mimic®, or Warrior® standard) was applied at one orchard (Bellamy) to foliage beginning in April 2005 using a hydraulic sprayer at 38 L/tree. At two orchards (Forest Lake and Brewton) where hydraulic spray equipment was not available, a comparison was made between treatment efficacies on injected trees to operationally sprayed trees of similar clones in another nearby block.

Coneworm damage was evaluated by collecting all cones present from each tree in August or September 2005 and 2006. From the samples, counts were made of cones killed by coneworms in the spring (small dead cones) and the summer (large dead or green-infested cones), and of cones with other damage and healthy cones. The slash pine cones collected at the Brewton orchard also were visually inspected for damage by slash pine flower thrips. Seed bug damage was evaluated by randomly selecting a subsample of 10 healthy cones/tree; seed lots from these cones were radiographed (DeBarr 1970) to determine seed yield/cone and filled-seed yield/cone to measure the extent of seed bug damage. Data were analyzed by GLM and the Fisher's Protected LSD test using Statview statistical programs.

RESULTS AND DISCUSSION

The study site in LA (Hebron, Plum Creek) had never been treated for cone and seed insects and the site in AL (Brewton, Smurfit-Stone) had not been sprayed for several years, whereas, the study orchard blocks in TX (Forest Lake, Temple Inland) and in FL (Bellamy, International Paper) were sprayed operationally in 2004. This suggests that pressure from coneworms and seed bugs would likely be higher at the LA and AL orchards compared to the TX and FL orchards. This was confirmed for coneworms by >27% and 47% damage on check cones in LA and AL orchards, respectively (Table 1). In contrast, <12% and <11% damage from coneworms occurred on the same trees in the TX and FL orchards, respectively. Relatively high numbers of both southern and/or shield-backed pine seed bugs were observed in the trees at the FL, AL and LA orchards (personal communications with respective orchard mangers). The seed analyses confirmed these observations with >36%, 55% and >59% total seed bug damage, respectively, in check seed lots (Table 2).

Treatment Effect on Coneworm Damage: In 2005, both injection treatments (emamectin benzoate and fipronil) significantly reduced early and late coneworm damage compared to the checks in FL and TX (Table 1). Damage to cones at these sites was lower than at the LA site. At the LA site, only emamectin benzoate provided significant protection against early and late-season coneworm damage and improved percentage of healthy cones. Drought conditions at the LA orchard may have slowed the movement and dispersal of fipronil throughout the treated trees as was observed in 2003 in a similar trial in TX (Grosman, personal observation). Overall, the emamectin benzoate treatment applied by the Arborjet injector provided the greatest reductions in total coneworm damage (76 - 92%) compared to the check. In contrast, fipronil and spray treatments reduced damage 32 – 90% and 16 – 40%, respectively.

In 2006, the second year following a single injection in 2005, emamectin benzoate and fipronil injection treatments again significantly reduced early and late coneworm damage compared to the checks at all four southern orchards (AL, FL, LA and TX) (Table 1). Overall, there were no significant differences between the emamectin benzoate and fipronil treatments; the emamectin benzoate treatment provided 70 - 95% reductions in total coneworm damage compared to the check and fipronil provided a reduction of 66 – 92%. The spray applications provide only moderate protection, reducing coneworm damage by 46 – 66%.

Treatment Effect on Flower Thrip Damage: Evaluation of cones from the AL site in 2006 showed low flower thrip damage levels (1.8%) on check trees (Table 1). However, the emamectin benzoate treatment appears to show some activity against this insect, reducing damage on treated trees by 56%. No other treatment affected thrip damage levels.

Treatment Effect on Seed Bug Damage: Analysis of 2005 seed lots showed that the emamectin benzoate injection significantly reduced seed bug damage and improved the number of filled

Table 1. Mean percentages (+ SE) of cones killed early and late by coneworms, damaged by slash pine flower thrip, other-damaged cones, and healthy cones on loblolly pine or slash pine protected with systemic injections of emamectin benzoate (EB) or fipronil (FIP), 2005 & 2006.

Tree Spp.	Site	Year	Treatment	Application Technique, Treatment Date(s)	N	Mean Coneworm Damage (%) Early (small dead)	Late (large dead and infested)	Total	Mean Thrip Damage (%)	Mean Other Damage (%) *	Mean Healthy (%)
Loblolly pine	LA	2005	EB	Tree IV - Apr., '05	12	1.0 ± 0.4 **a†**	1.8 ± 0.9 **a**	2.9 ± 1.2 **a**		34.3 ± 4.6 **b**	62.9 ± 5.1 **b**
			FIP	Tree IV - Apr., '05	12	11.2 ± 2.1 **b**	10.2 ± 2.8 **b**	21.3 ± 3.3 **b**		33.7 ± 4.3 **b**	44.9 ± 5.2 **a**
			Check		12	16.2 ± 3.5 **b**	15.1 ± 3.4 **b**	31.3 ± 4.9 **b**		24.9 ± 2.2 **a**	43.8 ± 5.7 **a**
		2006	EB	Tree IV - Apr., '05	12	1.2 ± 0.3 **a**	2.9 ± 0.9 **a**	4.0 + 1.1 **a**		22.5 ± 3.9 **ab**	73.4 + 4.4 **b**
			FIP	Tree IV - Apr., '05	12	6.4 ± 1.8 **b**	1.6 ± 0.7 **a**	8.0 + 2.1 **a**		27.6 ± 3.6 **b**	64.4 + 4.7 **ab**
			Check		12	14.9 ± 2.6 **c**	12.0 ± 2.8 **b**	26.9 + 4.1 **b**		16.5 ± 3.6 **a**	56.7 + 6.0 **a**
	FL	2005	EB	Tree IV - Apr., '05	12	0.1 ± 0.1 **a**	0.8 ± 0.3 **a**	0.9 ± 0.3 **a**		2.4 ± 0.5 **a**	96.7 ± 0.7 **a**
			FIP	Tree IV - Apr., '05	12	0.2 + 0.1 **a**	0.8 ± 0.3 **a**	1.0 ± 0.3 **a**		2.0 ± 0.4 **a**	96.9 ± 0.7 **a**
			Spray	Hydraulic - 5X	12	1.1 ± 0.3 **b**	2.1 ± 0.5 **b**	3.2 ± 0.6 **b**		1.4 ± 0.4 **a**	95.4 ± 0.9 **a**
			Check		12	1.8 ± 0.9 **b**	1.9 ± 0.4 **b**	3.8 ± 1.1 **b**		1.9 ± 0.6 **a**	94.3 ± 1.3 **a**
		2006	EB	Tree IV - Apr., '05	12	0.1 ± 0.1 **a**	0.7 ± 0.2 **a**	0.7 + 0.2 **a**		2.5 ± 0.5 **a**	96.7 + 0.5 **b**
			FIP	Tree IV - Apr., '05	12	0.4 + 0.1 **a**	2.1 ± 0.5 **ab**	2.5 + 0.6 **ab**		2.4 ± 0.4 **a**	95.1 + 0.8 **b**
			Spray	Hydraulic - 5X	12	1.2 ± 0.2 **b**	2.8 ± 0.8 **b**	4.0 + 0.9 **b**		1.5 ± 0.2 **a**	94.5 + 0.9 **b**
			Check		12	6.1 ± 1.7 **c**	5.7 ± 0.9 **c**	11.8 + 2.2 **c**		1.8 ± 0.3 **a**	86.5 + 2.2 **a**
Slash pine	TX	2005	EB	Tree IV - Mar. - Apr., '05	10	0.1 ± 0.1 **a**	0.4 ± 0.3 **a**	0.5 ± 0.4 **a**		5.6 ± 1.3 **a**	93.9 ± 1.5 **a**
			FIP	Tree IV - Mar. - Apr., '05	10	0.2 ± 0.1 **a**	0.4 ± 0.3 **a**	0.6 ± 0.3 **a**		4.4 ± 1.3 **a**	95.0 ± 1.2 **a**
			Spray	Aerial - 5X	10	0.0 ± 0.0 **a**	3.6 ± 0.9 **b**	3.6 ± 0.9 **b**		3.0 ± 0.5 **a**	93.4 ± 1.3 **a**
			Check		10	0.5 ± 0.2 **b**	5.5 ± 1.5 **b**	6.0 ± 1.5 **b**		3.3 ± 0.9 **a**	90.7 ± 2.2 **a**
		2006	EB	Tree IV - Mar. - Apr., '05	10	0.0 ± 0.0 **a**	0.5 ± 0.1 **a**	0.5 + 0.1 **a**		4.7 ± 0.7 **a**	94.8 + 0.8 **b**
			FIP	Tree IV - Mar. - Apr., '05	10	0.0 ± 0.0 **a**	0.9 ± 0.5 **a**	0.9 + 0.5 **a**		4.6 ± 1.3 **a**	94.5 + 1.8 **b**
			Spray	Aerial - 5X	10	0.4 ± 0.1 **b**	5.4 ± 1.2 **b**	5.8 + 1.2 **b**		4.8 ± 1.0 **a**	89.4 + 1.7 **a**
			Check		10	0.4 ± 0.2 **b**	10.6 ± 3.5 **b**	11.0 + 3.5 **b**		2.7 ± 0.8 **a**	86.2 + 3.9 **a**
	AL	2005	EB	Tree IV - Mar. - Apr., '05	10	**No data available due to hurricane damage to cone crop**					
			FIP	Tree IV - Mar. - Apr., '05	10						
			Spray	Aerial - 5X	10						
			Check		10						
		2006	EB	Tree IV - Mar. - Apr., '05	10	2.8 ± 0.4 **a**	11.6 ± 0.7 **a**	14.4 + 0.8 **a**	0.8 ± 0.3 **a**	0.3 ± 0.1 **a**	85.3 + 0.9 **c**
			FIP	Tree IV - Mar. - Apr., '05	10	4.2 ± 0.3 **ab**	11.7 ± 0.7 **ab**	16.0 + 0.8 **a**	1.1 ± 0.2 **ab**	0.5 ± 0.2 **a**	83.6 + 0.8 **c**
			Spray	Aerial - 5X	10	5.1 ± 0.6 **b**	20.4 ± 1.0 **b**	25.5 + 1.4 **b**	1.6 ± 0.3 **b**	2.3 ± 0.4 **b**	71.5 + 1.6 **b**
			Check		10	10.9 ± 0.6 **c**	36.6 ± 1.8 **c**	47.4 + 1.7 **c**	1.8 ± 0.4 **b**	1.9 ± 0.4 **b**	50.6 + 1.7 **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 2. Seed bug damage, seed extracted, and seed quality (Mean + SE) from second-year cones of loblolly pine and slash pine protected with systemic injections of emamectin benzoate (EB) or fiprinil (FIP) or foliar sprays (Spray), 2005 & 2006.

Tree Spp.	Site	Year	Treatment	Application Technique, Treatment Date(s)	N	Mean Seed Bug Damage (%): Early (2nd Yr Abort)	Mean Seed Bug Damage (%): Late	Mean Seed Bug Damage (%): Total	Mean No. Seeds per Cone	Mean No. Filled Seed per Cone
Loblolly pine	LA	2005	EB	Tree IV - Apr., '05	12	5.6 ± 1.2 **a**†	38.0 ± 4.1 **a**	43.5 ± 4.5 **a**	125.6 ± 7.8 **a**	63.5 ± 6.3 **b**
			FIP	Tree IV - Apr., '05	12	13.2 ± 2.9 **b**	36.8 ± 3.3 **a**	50.0 ± 5.1 **ab**	114.8 ± 8.0 **a**	52.4 ± 6.6 **ab**
			Check		12	17.0 ± 4.0 **b**	41.7 ± 2.4 **a**	58.7 ± 5.1 **b**	119.8 ± 8.1 **a**	46.7 ± 7.9 **a**
		2006	EB	Tree IV - Apr., '05	12	44.0 ± 6.4 **a**	32.2 ± 3.4 **a**	76.2 ± 3.6 **a**	117.6 ± 6.7 **b**	16.6 ± 3.3 **b**
			FIP	Tree IV - Apr., '05	12	56.5 ± 4.7 **a**	23.1 ± 3.3 **a**	79.6 ± 2.7 **a**	79.2 ± 8.3 **a**	9.7 ± 1.7 **ab**
			Check		12	49.3 ± 5.1 **a**	28.9 ± 3.8 **a**	78.2 ± 3.1 **a**	77.6 ± 11.6 **a**	9.2 ± 2.8 **a**
	FL	2005	EB	Tree IV - Apr., '05	12	1.6 ± 0.2 **a**	21.1 ± 3.3 **a**	22.7 ± 3.3 **ab**	103.7 ± 5.7 **a**	78.2 ± 6.3 **bc**
			FIP	Tree IV - Apr., '05	12	4.4 + 0.9 **b**	21.8 ± 4.2 **a**	26.2 ± 4.2 **b**	94.9 ± 7.8 **a**	68.4 ± 7.8 **ab**
			Spray	Hydraulic - 5X	12	2.7 ± 0.6 **ab**	14.6 ± 1.0 **a**	17.3 ± 1.2 **a**	106.3 ± 9.0 **a**	85.3 ± 7.5 **a**
			Check		12	4.7 ± 1.7 **b**	31.2 ± 4.0 **b**	36.0 ± 4.6 **c**	96.0 ± 6.7 **a**	60.7 ± 7.8 **c**
		2006	EB	Tree IV - Apr., '05	12	4.6 ± 1.0 **ab**	27.0 ± 3.9 **b**	31.5 ± 3.6 **b**	77.8 ± 6.0 **ab**	48.6 ± 4.3 **b**
			FIP	Tree IV - Apr., '05	12	6.5 + 1.8 **bc**	26.4 ± 2.5 **b**	33.0 ± 3.1 **b**	84.1 ± 5.6 **b**	50.5 ± 4.5 **b**
			Spray	Hydraulic - 5X	12	1.9 ± 0.4 **a**	12.9 ± 1.7 **a**	14.8 ± 1.4 **a**	106.1 ± 4.5 **c**	87.0 ± 4.8 **c**
			Check		12	10.7 ± 2.9 **c**	27.9 ± 2.6 **b**	38.6 ± 2.6 **b**	72.1 ± 5.9 **a**	38.3 ± 2.9 **a**
Slash pine	TX	2005	EB	Tree IV - Mar. - Apr., '05	10	1.2 ± 0.3 **b**	8.2 ± 1.1 **a**	9.5 ± 1.3 **a**	161.9 ± 5.5 **bc**	145.4 ± 5.9 **a**
			FIP	Tree IV - Mar. - Apr., '05	10	1.7 ± 0.3 **c**	9.3 ± 1.3 **a**	11.0 ± 1.5 **a**	145.4 ± 5.2 **ab**	129.0 ± 5.2 **a**
			Spray	Aerial - 5X	10	1.7 ± 0.3 **c**	10.6 ± 1.9 **a**	12.3 ± 2.2 **a**	173.5 ± 2.9 **c**	151.5 ± 4.4 **a**
			Check		10	0.0 ± 0.0 **a**	11.3 ± 1.7 **a**	11.3 ± 1.7 **a**	137.5 ± 11.1 **a**	123.0 ± 11.3 **a**
		2006	EB	Tree IV - Mar. - Apr., '05	10	1.7 ± 0.5 **b**	10.9 ± 1.7 **a**	12.6 ± 2.2 **a**	142.7 ± 8.5 **ab**	124.5 ± 8.4 **ab**
			FIP	Tree IV - Mar. - Apr., '05	10	1.6 ± 0.7 **b**	10.5 ± 1.7 **a**	12.1 ± 2.2 **a**	150.6 ± 5.1 **bc**	131.6 ± 5.8 **b**
			Spray	Aerial - 5X	10	0.3 ± 0.1 **a**	11.1 ± 2.4 **a**	11.4 ± 2.4 **a**	148.5 ± 3.8 **ab**	131.4 ± 5.8 **b**
			Check		10	0.3 ± 0.1 **a**	13.5 ± 1.8 **a**	13.8 ± 1.9 **a**	133.4 ± 3.3 **a**	112.1 ± 4.4 **a**
	AL	2005	EB	Tree IV - Mar. - Apr., '05	10	**No data available due to hurricane damage to cone crop**				
			FIP	Tree IV - Mar. - Apr., '05	10					
			Spray	Aerial - 5X	10					
			Check		10					
		2006	EB	Tree IV - Mar. - Apr., '05	10	15.2 ± 3.4 **b**	33.5 ± 6.2 **b**	48.7 ± 7.3 **b**	142.7 ± 8.5 **ab**	124.5 ± 8.4 **ab**
			FIP	Tree IV - Mar. - Apr., '05	10	18.5 ± 5.7 **b**	29.4 ± 4.8 **b**	48.0 ± 5.9 **b**	150.6 ± 5.1 **bc**	131.6 ± 5.8 **b**
			Spray	Aerial - 5X	10	3.4 ± 0.5 **a**	13.0 ± 2.0 **a**	16.4 ± 2.2 **a**	148.5 ± 3.8 **ab**	131.4 ± 5.8 **b**
			Check		10	19.0 ± 6.5 **b**	36.5 ± 4.3 **b**	55.5 ± 6.2 **b**	133.4 ± 3.3 **a**	112.1 ± 4.4 **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.

(healthy) seed compared to checks at two of three sites and was comparable to the spray treatment in efficacy (Table 2). Fipronil was only effective at one site. Overall, reductions in seed bug damage ranged from 16 – 37% for emamectin benzoate and from 3 – 27% for fipronil.

In 2006, analysis of seed lots from the TX, LA, AL and FL sites showed reduced activity of both emamectin benzoate and fipronil against seed bugs. Neither injection treatment was able to significantly reduce seed bug damage compared to the check at any of the orchards (Table 2). In contrast, spray applications were able to significantly reduce seed bug damage at two of three orchards.

CONCLUSIONS

The results obtained in 2005 and 2006 confirm that the new emamectin benzoate and fipronil formulations can protect cones against coneworms through the first and second year and will often improve survival of second-year cones. At the same time, these results confirm that emamectin benzoate and fipronil are only marginally effective against pine seed bug and generally will not reduce seed bug damage past the treatment (first) year. These results mirror those obtained in previous TX trials (Grosman et al. 2002, Grosman, unpublished data).

The 2006 results at the AL (Brewton) orchard show for the first time that emamectin benzoate has some activity against thrips. Additional research is needed to evaluate chemical activity under higher insect population levels.

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