Two-year Protection of Loblolly Pine from Southern Pine Bark Beetles with Systemic Insecticide Injections

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Introduction

The southern pine beetle (SPB), *Dendroctonus frontalis* Zimmermann, is one of the more important forest pests in the southeastern U.S., Mexico and Central America (Billings et al. 2004) with local and regional outbreaks causing severe economic losses on a nearly annual basis. Other species of pine bark beetles, including the secondary pests *Ips avulsus* (Eichoff), *I. grandicollis* (Eichoff), and *I. calligraphus* (Germar), also are known to cause significant tree mortality particularly during severe drought periods in the southeastern U.S (Wilkinson & Foltz 1982). The current abundance of susceptible trees and forests underlines the need to develop new methods to protect individual trees from bark beetle attacks.

Protection of individual trees with insecticides has historically involved applications to the entire bole of the tree using ground-based hydraulic sprayers. Spray applications may result in drift (Fettig et al. 2008), which can be detrimental to natural enemies and generally require the use of large equipment which can limit the ability to reach and treat target trees.

The systemic insecticide emamectin benzoate (Syngenta Crop Science) was found to be highly effective (3+ years) against pine wood nematode, *Bursaphelenchus xylophilis* (Takai et al. 2003a and b) and coneworms, *Dioryctria* spp. (Grosman et al. 2002). Another systemic, fipronil (BASF), was efficacious against coneworms and the Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock) (Grosman, unpublished data). Injections of emamectin benzoate and fipronil were highly effective in preventing both the successful colonization of treated bolts and mortality of standing trees by *Ips* bark beetles 3 and 5 months post treatment (Grosman and Upton 2006). Given these successes, trials were initiated to determine the efficacy of emamectin benzoate and fipronil for protecting individual trees from SPB attack and associated levels of tree mortality.

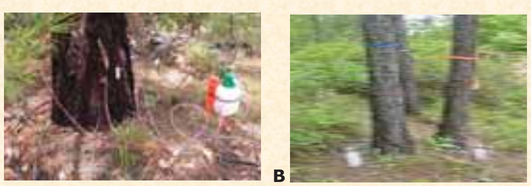
Materials & Methods

Thirty-five 3-tree (loblolly pine, *Pinus taeda* L.) groups were established the DeSoto (MS) and Talladega (AL) National Forests. Three treatments, emamectin benzoate (EB) (0.16 g AI / cm dia., Syngenta Crop Protection), fipronil (FIP) (0.16 g AI / cm dia., BASF), and an untreated control were randomly assigned to one tree in each group. The control group was used to assess bark beetle pressure (based on mortality of untreated, baited trees) during 2005-2006 (MS) and 2006-2007 (AL).

The two systemic insecticides (EB and FIP) were injected with the Arborjet Tree IV™ microinfusion system (Arborjet Inc., Woburn, MA.) into 4 cardinal points 0.3 m above ground to each study tree (Fig. 1). Injected trees were allowed about 5 weeks time to translocate chemicals prior to being challenged by baiting (SPB tree baits, Synergy Semiochemical Corp., Burnaby, BC, Canada). **Note:** Due to low SPB populations in MS, the target bark beetle species in MS was switched in 2006 from SPB to *Ips* spp. The remaining study trees were treated with Vapam + DMSO (Strom et al. 2004) and baited with *Ips* lures (Synergy Semiochemical Corp., Burnaby, BC, Canada).

Treatments were considered to have sufficient beetle pressure if ≥60% of the untreated control trees died from bark beetle attack. Insecticide treatments were considered efficacious when <20% of the trees died as a result of bark beetle attack (Shea et al. 1984; Figure 2 & 3).

In 2006, a 1 m bolt section was taken from 5 m height from all MS and AL trees that had been killed. In the laboratory, two 10 cm X 50 cm bark samples (total = 1000 cm²) were removed from each bolt to determine the cause of tree mortality and to confirm the presence of SPB or *Ips* engraver beetles and success of attacks (Table 1, Fig. 4).

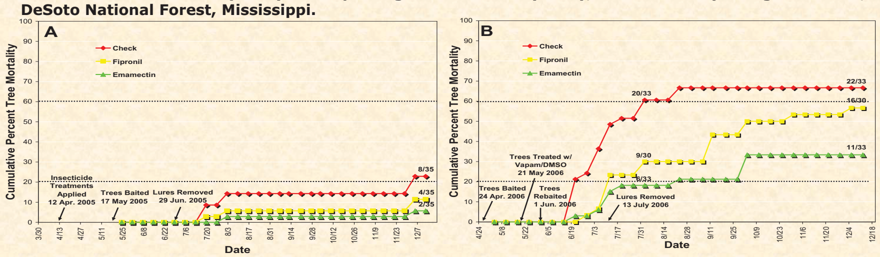


A B

Fig. 1. Tree injections using Arborjet's Tree IV™ in Mississippi, 2005 (A) and Alabama, 2006 (B).

Results

Figure 2. Cumulative first- (A) and second-year (B) mortality of emamectin benzoate- and fipronil-treated and untreated loblolly pine, *Pinus taeda* L., after attack by southern pine beetle, *Dendroctonus frontalis* (2005) and *Ips* engraver beetles (2006), Chickasawhay Ranger District, DeSoto National Forest, Mississippi.



The dashed line at 60% cumulative mortality is the level of control tree mortality considered necessary for a valid test (Shea et al. 1984); the dashed line at 20% cumulative mortality is the maximum allowable mortality for treatments to be considered efficacious.

Figure 3. Cumulative first- (A, 2006) and second-year (B, 2007) mortality of emamectin benzoate- and fipronil-treated and untreated loblolly pine, *Pinus taeda* L., after attack by southern pine beetle, *Dendroctonus frontalis*, Oakmulgee Ranger District, Talladega National Forest, Alabama.

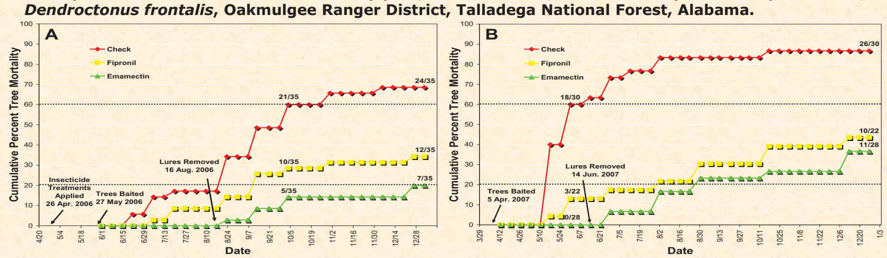


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Table 1. Effects of emamectin benzoate (EB) and fipronil (FIP) injection treatments on mean (+ SE) success of bark beetle adult attack, brood development and emergence, and success of cerambycid larvae in logs taken from faded study trees in Mississippi and Alabama - 2006.

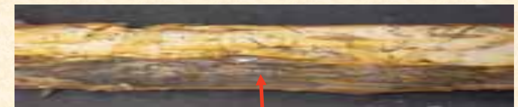
Site	Treatment	N	No. of Bark Beetle Attacks per 1000 cm²	Ranking (Many or All = 1.0, Around Half = 0.5, Few or None = 0.0): Bark Beetle Galleries (Length > 2.5 cm) Present	Ranking: Bark Beetle Brood Present	Ranking: Bark Beetle Emergence Holes Present	No. of Cerambycid Egg Niches per 1000 cm²	No. of Cerambycid Larval Galleries per 1000 cm²
			Ips Engraver Beetles					
MS	EB	11	9.3 ± 1.5 **a**†	0.00 ± 0.00 **a**	0.00 ± 0.00 **a**	0.00 ± 0.00 **a**	22.8 ± 4.5 **a**	0.5 ± 0.5 **a**
	FIP	16	9.8 ± 1.0 **a**	0.22 ± 0.04 **b**	0.06 ± 0.04 **a**	0.06 ± 0.04 **a**	20.3 ± 1.9 **a**	1.9 ± 0.9 **a**
	Check	22	9.5 ± 0.7 **a**	1.00 ± 0.00 **c**	1.00 ± 0.00 **b**	1.00 ± 0.00 **b**	16.9 ± 2.3 **a**	11.3 ± 0.7 **b**
			Southern Pine Beetle					
AL	EB	7	11.0 ± 1.8 **a**	0.00 ± 0.00 **a**	0.00 ± 0.00 **a**	0.00 ± 0.00 **a**	17.8 ± 5.1 **b**	0.4 ± 0.4 **a**
	FIP	12	11.8 ± 1.8 **a**	0.45 ± 0.11 **b**	0.46 ± 0.11 **b**	0.36 ± 0.12 **b**	11.5 ± 1.5 **a**	4.8 ± 1.3 **b**
	Check	24	12.3 ± 1.0 **a**	1.00 ± 0.00 **c**	1.00 ± 0.00 **c**	1.00 ± 0.00 **c**	8.9 ± 0.8 **a**	10.6 ± 5.2 **c**

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

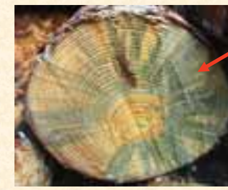
A B C

Fig. 4. Bolts collected from EB- (A), FIP-injected (B) and untreated (C) study trees in Mississippi showing success of *Ips* spp. attack and colonization in 2006.

Evaluation of bolts collected from faded (dead) trees in 2006 indicated that a similar number of *Ips* engraver beetles (MS) and *D. frontalis* (AL) attacked the study trees regardless of treatment (Table 1). However, the success of the *Ips* and *D. frontalis* in constructing galleries (> 2.5 cm) or producing brood was significantly less for both injection treatments compared to the checks. Similarly, the number of cerambycid egg niches was similar for all treatments, but there were significantly fewer larval galleries in the injected logs. All logs were infected with blue stain fungi (Fig. 5A & B).



A



B

Fig 5. Blue stain fungi infection of phloem (A) and xylem (B) tissue from *D. frontalis* attacked tree from Alabama, 2006.

Conclusions

Based on the established criteria of when 60% mortality of check trees occurred, EB injections successfully prevented mortality of standing pines from pine bark beetles at both sites for two years after treatment. This is the first published report documenting that a systemic insecticide is capable of protecting individual pines from a *Dendroctonus* species. FIP was only efficacious the second year in Alabama against SPB infestation.

The experimental design utilized (Shea et al. 1984) in these trials provided an extreme test of the ability of the tested systemics to protect individual trees. Tree injections would be most applicable for high value trees in urban or recreation areas. These trees rarely would face the beetle pressure created by baiting. The success of EB at both sites and FIP in the second year in AL under this type of challenge indicates these two insecticides have utility in tree protection.

It is important to note that although the efficacy evaluation was made once 60% of check trees had been killed, tree mortality continued long after the baits had been removed and the check mortality threshold had been reached. The evaluations of the tree bolts indicated that gallery construction and girdling by the bark beetles were not responsible for a majority of the deaths of treated trees. All dead study trees were infected with blue stain fungi. Most bark beetles have complex associations with fungi species, including non-staining *Ceratocystiopsis* spp. (carried in the SPB mycangium) and staining *Ophiostoma* and *Ceratocystis* spp. (carried on the external body surface) (Paine et al. 1997). As the beetle bores into the phloem tissue under the bark, spores of the staining fungi, largely *O. minus*, are inoculated and serve to help beetle colonization by reducing host resistance. The fungi on their own can disrupt water transport and cause tree death (Nelson and Beal 1929). As the bark beetles were largely unsuccessful in their gallery construction in treated trees (particularly with EB), it appears likely that the numerous blue stain fungi infections were the primary cause of their mortality.

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