EVALUATION OF CANDIDATE INSECTICIDES FOR CONTROL OF THE NANTUCKET PINE TIP MOTH (LEPIDOPTERA:TORTRICIDAE)

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ABSTRACT—Initial screening in 1995 compared the efficacy of Capture®, Dimlin®, Foray®, Mimic®, Neem®, Pounce®, and Tempo® in controlling infestation by the Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock). Orthene®TTO, Tame® and a tank-mix of the two were added to the trials in 1996. All compounds tested were significantly better than the check regarding infestation of terminal and top whorl shoots by Nantucket pine tip moth. All sprays were timed for a contact-type insecticide, unless otherwise stated, following the methods of Berisford and others (1984), using degree-day accumulation triggered by male moth flight. In the Piedmont, the pyrethroids Tempo®, Capture® and Pounce® and the insect growth regulator (IGR) Mimic® performed best with Dimlin®, Neem® and Foray® being somewhat less effective. Test results from the Alabama Coastal Plain were similar with Foray® joining the top group. In 1996, Neem® and Dimlin® were dropped in favor of Orthene® and Tame® alone and in combination. All treatments in the Coastal Plain and Piedmont tests were significantly better than control plots. Only two sprays (1 of Foray® and 1 of Orthene® applied on a contact timing) failed to limit infestation in the top whorl below 10 percent. On an epidemic Virginia site, all treatments were significantly better than controls with the pyrethroids, Orthene®/Tame mixtures and Foray® plus a UV screen grouping together followed by the various tank-mixes and Foray® minus the UV screen. In 1997, Warrior®, a pyrethroid, was tested against third and fourth generation tip moth in the upper Coastal Plain of Georgia. Top whorl infestation was held below 5 percent for both generations compared to a mean of 30 percent for Pounce®. In 1998, Imidan, an organophosphate, was tested at 2 rates for control of second generation Nantucket pine tip moth on a Piedmont site near Athens, GA. Control was excellent being at or near zero percent infestation in treatment plots.

INTRODUCTION

Historically, chemical control of the Nantucket pine tip moth (NPTM) has been accomplished by calendar sprays every 2 weeks beginning in spring and continuing through fall. Timing of insecticide applications based on degree-day driven models (Garguillo and others 1985, Fettig and others 1999) has both improved effectiveness and dramatically reduced the number of sprays required to achieve satisfactory control. Initial efficacy testing was conducted with dimethoate, acephate (both organophosphates) and then with fenvalerate, a synthetic pyrethroid (Berisford and others 1984, Garguillo and others 1985). Clarke and others (1990) and DeBarr (1982) suggested that repeated spraying with fenvalerate and azinphosmethyl in a seed orchard setting induced secondary scale outbreaks that reached epidemic proportions in some cases. Some broad-spectrum insecticides are toxic to tip moth natural enemies (McCravy and others 2001) and may worsen tip moth infestations when poorly timed. Recent regulatory actions taken by the U.S. Environmental Protection Agency, most notably the review of carbamate, chlorinated hydrocarbon and organophosphate based insecticides under the Food Quality Protection Act, has reduced the number of compounds available and threatened the continued existence of several forestry-use labels, due to their minor-use designation. With this last trend in mind, we undertook to screen some new and old compounds for efficacy in controlling tip moth infestation in loblolly pine plantations.

METHODS

We began initial screening of potential tip moth control chemicals in 1995 which compared the efficacy of Capture® (FMC Corp.), Dimilin® (Uniroyal), Foray® (Abbott Labs), Mimic® (Rohm and Haas Co.), Neem® (Phero Tech Inc.), Pounce® (FMC Corp.) and Tempo® (Bayer Corp.) in controlling infestation by NPTM (table 1). Neem® and Dimlin® were dropped in favor of Orthene TTO®, Tame® and a combination of the two (Valent USA) in 1996. The 1995 and 1996 trials were conducted in the Coastal Plain of Alabama in Escambia and Monroe Counties and in the Piedmont Plateau in Oglethorpe County near Lexington, GA. A group trial was also conducted in an epidemic population of tip moth in loblolly pine in southern Virginia in Southhampton County near Emporia, VA. during the fall of 1996. In 1997, Warrior® (Zeneca Ag Products), a pyrethroid, was tested against third and fourth generation tip moth in the upper Coastal Plain in Burke County near Waynesboro, GA. In 1998, Imidan® (Gowan Co.), an organophosphate, was tested at two rates for second generation tip moth control on a Piedmont site near Athens, GA.

All sprays were timed for a contact-type insecticide, unless stated otherwise, following the method of Garguillo and others (1985) revised by Fettig and others (1999), using degree-day accumulation triggered by male moth flight. The basic experimental design was similar for all tests regardless of location or year. Trials consisted of randomized complete blocks with 4–6 replicates of 8–10 tree plots. All compounds were applied in water with Solo ® hand-pump sprayers.

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Citation for proceedings: Berisford, C. Wayne; Grosman, Donald M., eds. 2002. The Nantucket pine tip moth: old problems, new research. Proceedings of an informal conference, the Entomological Society of America, annual meeting. 1999 December 12–16. Gen. Tech. Rep. SRS–51. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 68 p.

Table 1—Products tested for control of Nantucket pine tip moth:1995–1998

Product (formulation)	Class	Percent A.I. applied	Label rate	Active ingredients	Label status[a]
Capture (2EC)	Pyrethroid	0.025	8–12 oz/ac	Bifenthrin	None
Pounce (3.2EC)	Pyrethroid	0.024	4–8 oz/ac	Permethrin	Full
Tame (2.4EC)	Pyrethroid	0.025	8–16 oz/ac	Fenpropathrin	Partial
Tempo (2S)	Pyrethroid	0.008	6–8 oz/ac	Cyfluthrin	Partial
Warrior (1EC)	Pyrethroid	0.016 0.032	3.2–5.12 oz/ac	Lambda-cyhalothrin	24C
Imidan (70WP)	Organo-phosphate	2.0 4.0	1.33 lb/Ac	Phosmet	Partial
Orthene TTO (78%WP)	Organo-phosphate	1.1	0.05–1 lb/ac	Acephate	Partial
Foray (48B)	Bacterial	NA	0.125–1 gal per acre	*Bacillus thuringiensis*	Full
Mimic (2F)	Insect growth regulator	0.014	8.0 oz/ac (0.12lb.)	Tebufenozide	Full

[a] full= full EPA label for both pest, crop, and application technique; partial = either pest, crop, or application labeled but not all three; and 24C = special local need state label.

Water was pH adjusted to 5.5 for Orthene® and Imidan® applications on recommendations by technical representatives of the manufacturers . Pines were sprayed with a fine mist until the foliage was visibly wet but not until run-off. Mixing rates were extrapolated from existing labels or were supplied by technical reps (see table 1 for list). Frequently, in large group tests, all compounds were applied on the same date which may not have been the optimum date for a particular chemical. This was necessary due to the logistics of traveling to sites with sufficient NPTM infestation to make testing worthwhile. When NPTM damage was readily visible, the number of infested shoots in the top whorl (Fettig and Berisford 1999) were recorded for all treatments and untreated controls. Typically, the percent infestation in the terminal and top whorl shoots was analyzed via ANOVA at alpha=0.05. Means were separated with a Tukey test for all pairwise multiple comparisons or the non-parametric ANOVA on ranks with means separated by Student-Newman-Keuls method when assumptions of normality and equal variances were not met (SigmaStat Version 2.03, SPSS Inc. 1997).

Experiment 1: Spring/Summer 1995

Initial screening compared the efficacy of Capture® 2EC, Dimlin®, Foray® 48B, Mimic® 2F, Neem®, Pounce® 3.2EC and Tempo® 2S for control of second generation NPTM infestation. Testing was conducted during late spring and early summer in the Alabama Coastal Plain and in the Piedmont region of Georgia. Neem® and Dimlin® were dropped from subsequent testing in favor of Orthene® and Tame®.

Experiment 2: Spring/Summer 1996

Group testing was performed during the first generation of moths in the Alabama Coastal Plain and in the upper Coastal Plain of Georgia. An additional test was conducted for third generation control in southern Virginia on an upper Coastal Plain site experiencing an epidemic tip moth infestation. Orthene® TTO (78 percent WP), an organophosphate, and Tame® 2.4EC, a pyrethroid, alone and in combination were added to the tests this year. On the Georgia and Virginia sites, a two-spray regime of these products was also evaluated. The second application occurred ca. 8 days after the initial spray. Combination sprays of Orthene® and Tame® were dropped from testing in 1997.

Experiment 3: Spring/Summer 1997

Group testing was limited to two sprays in the Alabama Coastal Plain during the first tip moth generation. Foray®, Mimic®, Orthene® TTO, Pounce® and Tame® were selected for testing based on demonstrated efficacy and interest in continued testing by the companies involved. The two spray dates (160 and 190 degree-days centigrade) were dictated by adverse weather in the Brewton area, and they occurred before the optimum predicted pyrethroid spray date (237 degree-days centigrade). This unfortunate circumstance allows us to draw conclusions concerning timing of spray applications only as they relate to the predicted optimum pyrethroid spray date. During the third and fourth generation of moths in the upper Coastal Plain of Georgia, Warrior® 1EC (a pyrethroid new to NPTM control) was evaluated with Pounce® included as a standard for comparison.

Experiment 4: Summer 1998

This test evaluated the efficacy of two rates of Imidan® 70WP (an older organophosphate) for control of second generation moths on a Georgia Piedmont site near Lexington, GA. Pounce® was included as a standard for comparison.

RESULTS AND DISCUSSION

Experiment 1 (1995):

Tip moth populations were moderate at the Coastal Plain site in Alabama with 45 percent of top whorl shoots infested on check trees. In the Georgia Piedmont, the population was somewhat lower with 33 percent of top whorl shoots infested. At this test site, the pyrethroids, Tempo®, Capture® and Pounce® and the insect growth regulator (IGR) Mimic® performed best with Dimlin®, Neem® and Foray® being somewhat less effective (table 2). Test results from the Coastal Plain site were similar with Foray® joining the group of most effective treatments. All treatments were significantly better than controls at both sites ($F=8.36$, $P<0.0001$, $n=5$, $df=7$ for Alabama Coastal Plain site; $F=10.4$, $P<0.0001$, $n=5$, $df=7$ for Georgia Piedmont site).

Experiment 2 (1996):

Tip moth populations in the Alabama Coastal Plain and Georgia upper Coastal Plain sites were low, ranging from 24 percent to 27 percent. All treatments significantly reduced damage compared to checks ($F= 6.33$, $P<0.0001$, $n=5$, $df=8$) at both sites (table 3). Capture®, Pounce®, Tempo®, Orthene®/Tame® mix, Mimic®, Foray® and Orthene® alone (timed for a systemic) performed well. Only 3 sprays (1 of Foray® and 2 of Orthene® applied on a contact timing) failed to contain infestation in the top whorl below 10 percent. We feel that tip moth pressure was not high enough to provide a rigorous test of efficacy on this site. However in Virginia, tip moth populations were at epidemic levels with infestation in the top whorl above 65 percent. Again, all treatments significantly reduced damage level below that of the check plots ($F= 11.3$, $P<0.001$, $n=4$, $df=10$) (table 4). Capture® out-performed both Orthene® applications as well as the initial Orthene®/Tame® mix. All other treatments were not significantly different although there was a trend for Capture® and Tempo® to provide more protection than the remaining treatments. Considering the high tip moth incidence and the asynchronous nature of third generation life stages, all treatments performed well.

Experiment 3 (1997):

In the Alabama Coastal Plain, populations of NPTM were again low ranging from 26 to 33 percent of top whorl shoots on check plots. Spray date 1 occurred on March 3 at 160 degree-days (centigrade), and spray date 2 on March 8 at 190 degree-days. The optimum predicted value from Fettig and others (1999) is 237 degree-days. All treatments were significantly different from untreated control plots regarding

Table 2—Mean percent top-whorl and terminal shoot infestation for group testing in 1995

	Experiment 1: AL Coastal Plain		Experiment 1: GA Piedmont	
Product	Top whorl	Terminal	Top whorl	Terminal
Capture	10.5 a[a]	10.0 a	3.8 a	5.0 a
Tempo	10.8 a	27.5 ab	2.2 a	5.0 a
Pounce	12.9 a	15.0 ab	6.6 ab	20.0 ab
Foray	13.4 a	22.5 ab	19.1 ab	38.6 b
Mimic	17.9 ab	22.5 ab	7.3 ab	15.0 ab
Neem	25.3 b	44.4 b	19.8 b	36.4 ab
Dimlin	29.0 c	40.0 b	18.0 ab	27.5 ab
Check	45.0 d	72.5 c	34.3 c	70.0 c

[a] Means in columns with different letters are significantly different; alpha = 0.05.

Table 3—Mean percent top-whorl and terminal shoot infestation for group testing in 1996

	Experiment 2: AL Coastal Plain		Experiment 2: GA Piedmont	
Product	Top whorl	Terminal	Top whorl	Terminal
Capture	4.0 a[a]	3.0 a	0.0 a	0.0 a
Tempo	1.4 a	0.0 a	1.1 a	0.0 a
Pounce	5.2 a	3.0 a	0.8 a	0.0 a
Foray	2.8 a	7.0 a	5.6 ab	3.4 a
Foray plus UV	6.6 a	3.0 a	9.6 b	20.6 b
Mimic	5.0 a	7.0 a	2.4 ab	4.0 a
Orthene	10.0 a	7.0 a	11.1 b	16.8 b
Orthene II	NA	NA	3.1 ab	10.2 b
Orthene/ tame	6.0 a	3.0 a	6.7 ab	4.0 a
Orthene/tame II	NA	NA	3.5 ab	6.6ab
Check	24.0 b	23.0 b	26.9 c	50.0 c

[a] Means in columns with different letters are significantly different at alpha = 0.05.

Table 4—Mean percent top-whorl and terminal shoot infestation for group testing in 1996

	Experiment 2: VA Coastal Plain
Product	Top whorl shoots
Capture	13.8 a[a]
Tempo	18.3 ab
Pounce	23.5 ab
Foray	31.0 ab
Foray plus UV	24.2 ab
Mimic	24.0 ab
Orthene	35.7 b
Orthene II	32.5 b
Orthene/Tame	35.0 b
Orthene/Tame II	27.3 ab
Check	64.5 c

[a] Means in columns with different letters are significantly different at alpha=0.05

top whorl infested shoots (F=19.2, P<0.001, n=4, df=5) (table 5). Infestation levels were held below 10 percent in top whorl shoots except for a Tame® application on spray date 2. Orthene®, Mimic®, and Foray® all of which are thought to have optimum spray dates occurring after the predicted pyrethroid date, showed good residual efficacy based on their early application dates. Mild temperatures during the early spring and reduced UV incidence due to the oblique angle of the sun may contribute to this apparent increase in residual efficacy. Applications made later in the year may not demonstrate this phenomena. In efficacy tests conducted in the upper Coastal Plain of Georgia during the third generation of NPTM, Warrior®-treated plots had less than 2 percent infestation in top whorl shoots compared to 4 percent for Pounce® and 26 percent for the untreated controls (F=51.2,P<0.001, n= 4, df=2) (fig. 1). Fourth generation control was excellent given the strongly asynchronous nature of tip moth brood at this time of year, plus the fact that the application rate for Warrior® was inadvertently cut in half (fig. 2). Infestation level was held to 4 percent in top whorl shoots compared with 18 percent for Pounce® and 35 percent for untreated controls (F=18.7, P<0.001, n=5, df=2).

Table 5—Mean percent top-whorl and terminal shoot infestation for group testing in 1997

	Experiment 3: AL Coastal Plain			
	Spray date 1		Spray date 2	
Product	Top whorl	Terminal	Top whorl	Terminal
Orthene	0.7 a[a]	4.1 a	1.0 a	0.0 a
Pounce	3.2 ab	13.7 a	4.7 ab	6.8 a
Mimic	4.2 ab	6.2 a	6.3 ab	2.0 a
Foray	7.3 b	32.5 b	10.0 bc	9.3 a
Tame	7.5 b	6.6 a	14.7 c	17.5 b
Check	26.3 c	51.1 c	32.5 d	36.7 c

[a] Means in columns with different letters are significantly different at alpha = 0.05.

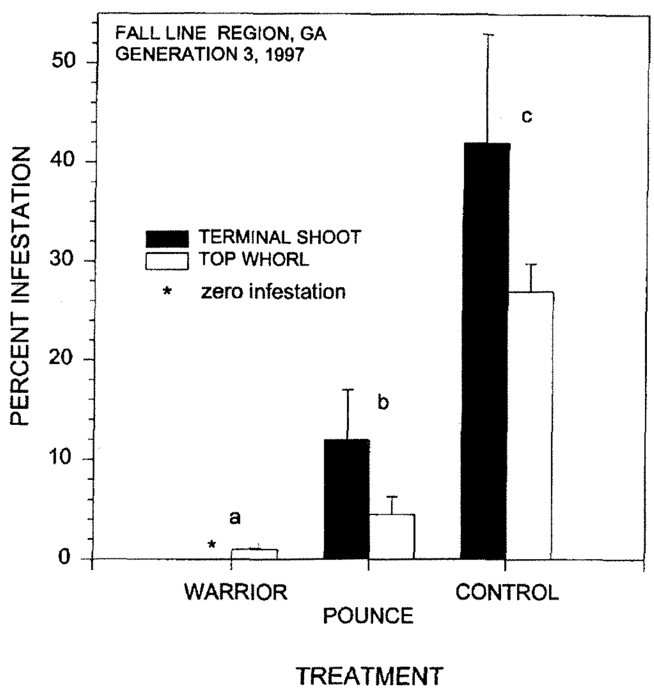

Figure 1—Mean percent infested shoots for Warrior and Pounce treated pines on a Georgia upper Coastal Plain site in summer of 1997.

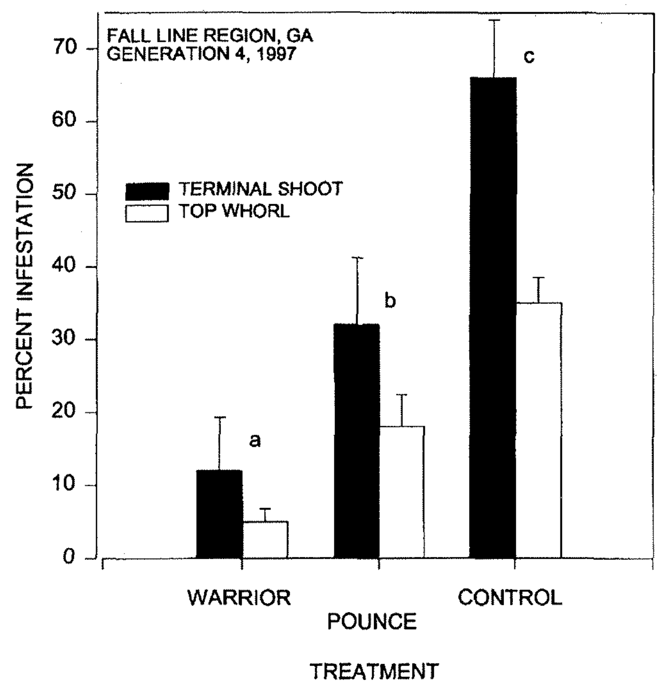

Figure 2—Mean percent infested shoots for Warrior and Pounce treated pines on a Georgia upper Coastal Plain site in late summer of 1997.

Experiment 4 (1998):
The site in the Georgia Piedmont near Lexington experienced moderate to heavy tip moth infestation in 1998 with the untreated control plots having near 50 percent infestation in the top whorl shoots (fig. 3). Both rates of Imidan® provided excellent control, being significantly better than both Pounce® and untreated control plots (H=15.9,P=0.001, n=5, df=3;). The low dosage rate of Imidan® in this trial was very efficacious, and the results warrant additional testing of this product at lower rates.

CONCLUSIONS

There are several chemical control options in a variety of chemical classes for reducing damage by NPTM. Simple but adequate timing models are available for most commercial pine growing regions and can probably be extrapolated to areas not specifically covered by recent and current research. Resistance management should be easily accomplished by timing sprays and rotating chemicals when necessary. Forestry benefits greatly from agricultural testing of new products. Target specificity and toxicological data are generally available 5–10 years before a new product is considered for forestry use. Given this, we do not foresee a lack of products in the near future for inclusion in a NPTM management program. The real challenge lies in assessing the need to spray, and maximizing application efficacy once the decision is made to use an insecticide.

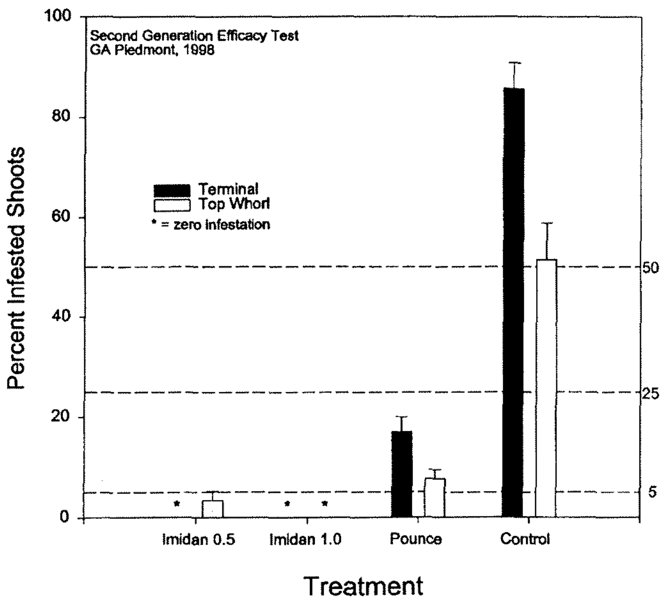

Figure 3—Mean percent infested shoots for two rates of Imidan and one of Pounce treated pines on a Georgia Piedmont site in summer of 1998.

ACKNOWLEDGEMENTS

We would like to thank International Paper Company personnel, in particular Scott Cameron and Jimmy Seckinger, for their invaluable assistance in locating sites for spray testing.

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