A South-wide Rate Test of Esfenvalerate (Asana® XL) for Cone and Seed Insect Control in Southern Pine Seed Orchards

Alex C. Mangini[1], Tom D. Byram[2] and Dudley A. Huber[3]

Abstract: As many as five monthly applications may be required each year to protect southern pine seed orchards from coneworms, *Dioryctria* spp. Insecticides that control coneworms usually provide control of two other pests, the leaffooted pine seed bug, *Leptoglossus corculus*, and the shieldbacked pine seed bug, *Tetyra bipunctata*. Esfenvalerate (Asana® XL) is a pyrethroid insecticide that is effective for both coneworms and seed bugs. Aerial application of the maximum labeled rate of esfenvalerate can cause secondary outbreaks of scale insects and mealy bugs; and the honeydew they produce promotes growth of unsightly sooty mold that reduces tree vigor and growth. A South-wide study operationally evaluated the efficacy of reduced rates of esfenvalerate. Six orchards throughout the South were used in the study, five loblolly pine and one slash pine orchards. Each orchard had four treatment plots. A complete block design was used with each orchard serving as a replicate. The experimental unit was one treatment block in each orchard. The four study treatments were: Asana® XL at the labeled rate of 0.19 pounds active ingredient/acre (ai/ac), Asana® XL at 0.10 pounds ai/ac, Asana® XL 0.03 pounds ai/ac, and a control consisting of untreated trees. Aerial applications were made five times at monthly intervals (May-August). Efficacy data collected were crop survival, yields of healthy and damaged cones, and seed yield. Each treatment was surveyed for secondary insects the following year. All rates of esfenvalerate were effective in controlling seed bugs. First-year conelet survival, and percent good seed were significantly lower for the control when compared against the 0.03, 0.10 and 0.19 pound ai/ac application rates. The composite trait, good-seed per original-flower, gave the same results. However, the lower rates did not protect against coneworm damage. For the five loblolly pine seed orchards, coneworm damage at the 0.19 pound ai/ac was significantly lower than for the control or the two reduced rates. The two low rates did not result in secondary insect outbreaks. Reduced rates of esfenvalerate may be applied in combination with insecticides specific to coneworms, such as the growth regulator tebufenozide. This results in a combination of efficacy and reduced risk of secondary outbreaks.

INTRODUCTION

Cone and seed insects can severely limit production of genetically improved seeds in southern pine seed orchards. These seeds are vital for regeneration programs. Important insect pests include the pine coneworms, *Dioryctria* spp. (Ebel et al. 1980). Coneworm larvae feed in and destroy the flowers and cones of pines. Also, the leaffooted pine seed bug, *Leptoglossus corculus* (Say) and the shieldbacked pine seed bug, *Tetyra bipunctata* (Herrich-Schaffer), feed

[1] USDA Forest Service, Southern Region, Forest Health Protection, Pineville, Louisiana 71360
[2] Texas Forest Service, Texas A&M University, College Station, Texas 77843-2585
[3] University of Florida, Cooperative Forest Genetics Research Program, Gainesville, Florida 32611-0410

by sucking out the contents of developing seeds in cones and conelets causing conelet abortion and empty seeds in mature cones (Ebel et al. 1980). Without control, these insects can destroy as much as 90% of the potential seed crop (Fatzinger et al. 1980).

As many as five monthly applications may be required each year to protect southern pine seed orchards from coneworms. Insecticides that control coneworms usually provide control of the two seed bug species. Esfenvalerate (Asana® XL) is a pyrethroid insecticide that is effective for both coneworms and seed bugs (Lowe et al. 1994). However, aerial application of the maximum labeled rate of esfenvalerate can cause secondary outbreaks of scale insects and mealy bugs (Clarke et al. 1988); and the honeydew they produce promotes growth of unsightly sooty mold that reduces tree vigor and growth.

Previous ground application studies have shown that seed bugs can be controlled with much lower levels of esfenvalerate. Experience with other pesticides has shown that area treatments with aerial applications may require less pesticide than indicated in ground application studies which compare treatments on individual trees (Mangini et al. 1998). The amount of pesticide used may be reduced if lower application rates with aerial applications are shown to be effective. There is also the possibility that a lower application rate can be identified that will provide control of targeted insects while not promoting the buildup of secondary insects.

The objective of this study was to test the efficacy of several rates of 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 against a control with no insecticide application using a protocol developed in previous South-wide operational efficacy tests (Lowe et al. 1994, Mangini et al. 1998).

MATERIALS AND METHODS

Initial Coordination

The Seed Orchard Pest Management Subcommittee (SOPMS) of the Southern Forest Tree Improvement Committee, was established to address the critical need for insect pest management in southern seed orchards (Lowe et al. 1994, VanBuijtenen 1981). Tests on an operational level require large areas of seed orchards to test the efficacy of aerially applied pesticides, no single organization has the necessary resources or expertise available. Consequently, the SOPMS coordinated the South-wide test of esfenvalerate.

Six companies supplied orchards for the study (Table 1). The orchards were in locations throughout the South; five were loblolly pine orchards and one orchard was slash pine. Previous experience in South-wide tests (Lowe et al. 1994, Mangini et al. 1998) indicated that careful planning and coordinated activities are essential to a successful test. Consequently, in February 2001, a meeting was held at Lyons, GA in which participating orchard managers and SOPMS members developed a study plan (Byram, T. D. 2001. Asana® XL Rate Study For Cone and Seed Insect Control in Southern Pine Seed Orchards. A Regional Cooperative Study Plan. Unpublished). A complete plan of activities was established (Table 2).

Table 1. Participating orchards used in the South-wide rate test of esfenvalerate (Asana® XL) for cone and seed insect control in southern pine seed orchards conducted in 2001.

Company	Orchard	Location	Tree Species
Florida Division of Forestry	Baker	Milton, FL	Slash
International Paper	Jay	Jay, FL	Loblolly
International Paper	Springhill	Springhill, LA	Loblolly
Mississippi Forestry Commission	Craig	Baxterville, MS	Loblolly
Temple-Inland Forest Products	Forest Lake	Jasper, TX	Loblolly
Weyerhaeuser	Lyons	Lyons, GA	Loblolly

Table 2. Timeline of activities for the South-wide rate test of esfenvalerate (Asana® XL) for cone and seed insect control in southern pine seed orchards conducted in 2001.

Times (2001-2002)	Activity	Responsible Group
February	Organizational meeting	Cooperative staff, orchard personnel, entomologists
March	Select and flag sample ramets Tag survival conelets and cones	Cooperative staff and orchard personnel
April	Apply first application	Orchard personnel
May	Apply second application	Orchard personnel
June	Apply third application	Orchard personnel
July	Apply fourth application	Orchard personnel
August	Apply fifth application	Orchard personnel
Cone Harvest (September/October)	Count survival conelets and cones Harvest ALL cones on sample ramets Separate and count damaged and undamaged cones Collect ten-cone samples from each ramet and send to respective Cooperative	Orchard personnel
Post-harvest	Examine and sort damaged cones Extract seed from ten-cone samples Radiograph and evaluate seed samples	Entomologists Cooperative staff TFS Pest Management
Summer 2002	Evaluate for secondary pest outbreaks	Orchard personnel and entomologists
2002 and later	Data analysis and report preparation	SOPMS Committee

Treatments

Three rate treatments of esfenvalerate were compared to an untreated control (Table 3). The timing of the applications was identical for all treatments. For loblolly pine seed orchards, the first application was within seven days of peak pollen flight (early April); the first application in slash pine seed orchards was made about April 1 (Lowe et al. 1994). In orchards of either species, the initial application was followed by four subsequent applications made at monthly intervals (May, June, July and August).

Table 3. Treatment rates used in the South-wide rate test of esfenvalerate (Asana® XL) for cone and seed insect control in southern pine seed orchards conducted in 2001.

Treatment[1]	Amount of Asana® XL[2]
0.19	0.287 gallons or 36.8 fluid ounces
0.10	0.152 gallons or 19.4 fluid ounces
0.03	0.046 gallons or 5.8 fluid ounces

[1] Pounds of active ingredient per acre.
[2] To mix with 10 gallons of water for each acre to be sprayed (Asana® XL contains 0.66 pounds active ingredient per gallon of formulation).

Aerial Application Methods

The insecticide treatments were applied with either a fixed- or rotary-winged aircraft. To standardize the applications among orchards, each applicator conformed to the following application standards: effective swath width of 60 ft, five gal/ac of tank mix applied on each of two passes for a total of 10 gal /ac/treatment, spray droplet size of 350 microns volume mean diameter, and release height of 10-20 ft above the tops of the trees. A 30 ft row spacing in the orchards was assumed. Entomologist members of SOPMS were assigned to specific orchards to provide assistance with equipment calibration and spray deposition evaluation.

Field Layout

In each orchard four treatment plots were laid out in the test area. Each plot was at least five rows wide and comprised at least five acres in area. A buffer of at least four rows of ramets separated the treatment blocks.

A randomized complete block design was used with the experimental unit consisting of one treatment plot. Each seed 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 in each orchard. These same six clones were sampled in each plot within an orchard; however, clones differed among orchards. Treatments were randomly assigned to the plots within each orchard.

Efficacy Data Collection

Basic efficacy data included crop survival, yields of healthy and damaged cones, and seed yields for each sample tree. Each orchard/treatment block was surveyed during 2001 and in the following year for the presence and extent of secondary pests (scale insects and mealybugs).

Crop Survival. Orchard personnel counted and tagged a sample of at least 50 healthy conelets (2001 flower crop) and 50 healthy cones (2000 flower crop) from the south side of each sample ramet. These counts were made within one month of peak pollen flight in loblolly pine seed orchards and during April in the slash pine orchards. The tagged conelets and cones were recounted in the fall just prior to cone harvest, to estimate crop survival (Lowe et al. 1994, Mangini et al. 1998).

Cone Yields and Damage. At harvest, all cones were collected from each ramet. Orchard personnel sorted the cones into healthy and damaged categories according to Nord et al. (1984). Each cone was examined carefully for holes, insect frass, discolored patches of scales, and dead tips. Cones with no visible damage were counted as healthy. Questionable cones were placed with damaged cones. The number of healthy and damaged cones were recorded for each sample ramet in the field. Damaged cones from each ramet were placed in an individual cloth bags and placed in cold storage (at least 45º C or below) until examination by entomologist. The entomologist made a second examination of the damaged/questionable cones and sorted them into damage categories including coneworm damage. The initial counts were adjusted for any cones deemed healthy at the second inspection.

Seed Analysis. Ten healthy cones were picked at random from each sample ramet at harvest. The ten-cone samples were placed in cloth bags and labeled by orchard, block, clone, ramet and treatment. These ten-cone samples were subjected to standard after-ripening procedures to ensure proper cone opening (Lowe et al. 1994, Mangini et al. 1998). Seeds (including second-year aborted ovules) were extracted. The aborted ovules were counted and removed. Counts of total, filled, empty and seed bug-damaged seed were determined from radiographs of the seeds from each ramet (Bramlett et al. 1977).

Secondary Pests. A critical part of the study was to estimate treatment effect on secondary homopteran pests. Ramets (including controls) were visually inspected for homopteran (scale insects and mealybugs) populations by Dr. Stephen R. Clarke (USDA Forest Service). Dr. Clarke inspected sample ramets in each orchard in March or April 2001, before the initial pesticide application; he made second inspection in the fall (September or October) of 2001 and a final evaluation in June 2002. When present, the relative population levels of the following insects were determined using the infestation scoring system of Cameron (1989): pine tortoise scale, *Toumeyella parvicornis* (Cockerell); striped pine scale, *T. pini* (King); wooly pine scale, *Pseudophillippia quaintancii* (Cockerell); mealybug, *Oracella acuta* (Lobdell); and the pine needle scale, *Chionaspis heterophyllae* (Colley).

Table 4. ANOVA and EMS for the South-wide rate test of esfenvalerate (Asana® XL) for cone and seed insect control in southern pine seed orchards. The ANOVA assumes the treatments are fixed and that orchards, clones and ramets within clones are random effects.

Source of Variation	Degrees of Freedom[1]	Expected Mean Squares
Orchards (O)	o – 1	$\sigma^2_\varepsilon + rt\sigma^2_{C(O)} + rct\sigma^2_O$
Clones within Orchards (C)	o (c – 1)	$\sigma^2_\varepsilon + rt\sigma^2_{C(O)}$
Treatments (T)	t – 1	$\sigma^2_\varepsilon + r\sigma^2_{C(O)T} + cr\sigma^2_{OT} + cro\sigma^2_T$
O x T	(o – 1)(t – 1)	$\sigma^2_\varepsilon + r\sigma^2_{C(O)T} + cr\sigma^2_{OT}$
C(O) x T	o(c – 1)(t – 1)	$\sigma^2_\varepsilon + r\sigma^2_{C(O)T}$
Sampling Error	otc(r – 1)	σ^2_ε
Total	otcr – 1	

[1] The letters o, c, t, r equal the number of orchards, clones within orchard, treatment and ramets within clones, respectively.

Data Analysis. Efficacy was evaluated by comparing treatment differences for crop survival, yields of healthy and damaged cones, and seed quality by analyses of variance (Table 3) using SAS software options PROC GLM or PROC MIXED (Littell et al. 2002). When necessary data were appropriately transformed (Zar 1999) prior to analysis.

RESULTS AND DISCUSSION

Crop Survival

Cone (2000 Crop) Survival. There were no differences among the treatments for survival of the cones (2000 crop) across all orchards (five loblolly pine orchards and the single slash pine orchard) (Figure 1.). The Baker Orchard (slash pine) had high survival (~99%) as did the Forest Lake Orchard (loblolly pine) orchard. When these two orchards were excluded, the analysis of variance still failed to show any differences among treatments and the control.

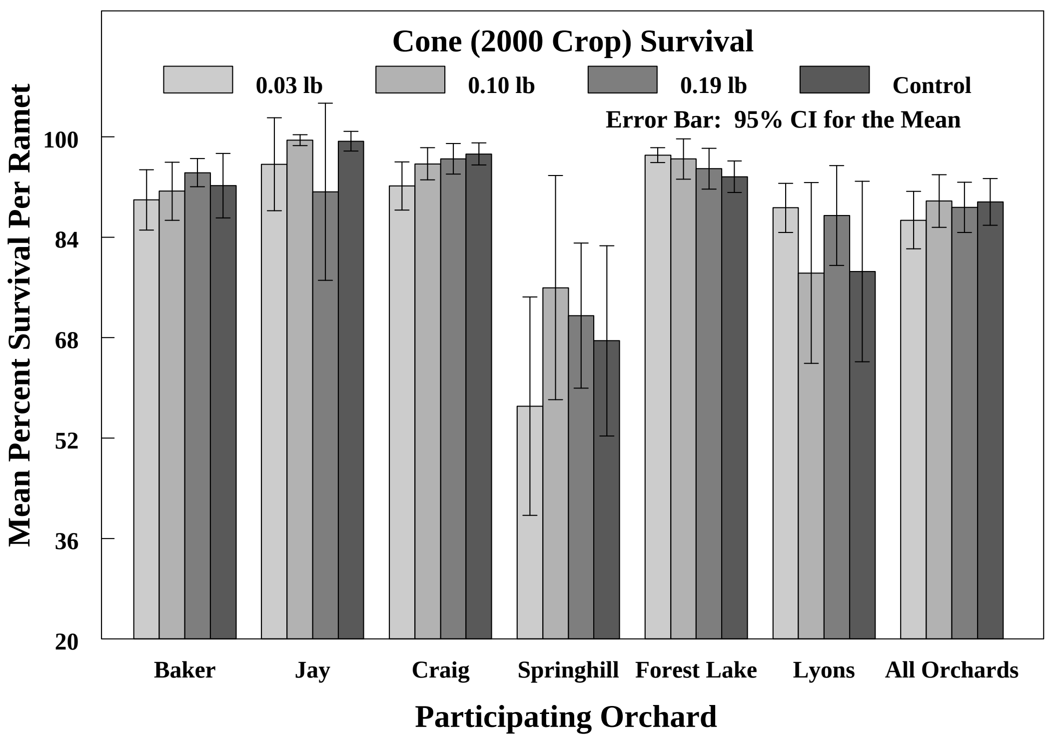

Figure 1. Mean percent survival per ramet of the cones (2000 crop) harvested in fall 2001 at the participating orchards the South-wide rate test of esfenvalerate (Asana® XL) for cone and seed insect control in southern pine seed orchards conducted in 2001. Estimate based on sample of 50 tagged cones per ramet. Loss factors include coneworm mortality and damage and loss due to other factors such as pitch canker. CI = confidence interval.

Conelet (2001 Crop) Survival. Survival of conelets in the control was significantly less than that in the Asana® XL treatments across all orchards (Figure 2). When conelet survival was weighted by the number of flowers per ramet, the analysis of variance (mixed model) was significant (F = 6.45, p>F = 0.0051). The resulting least-squares mean (Littell et al. 2002) were 0.03 lb = 0.8562, 0.10 lb = 0.8740, 0.19 lb = 0.8555 and control = 0.7767. There were no significant differences in survival counts among the three treatments; however, the average conelet survival of the three treatments was significantly different from and greater than that of the control.

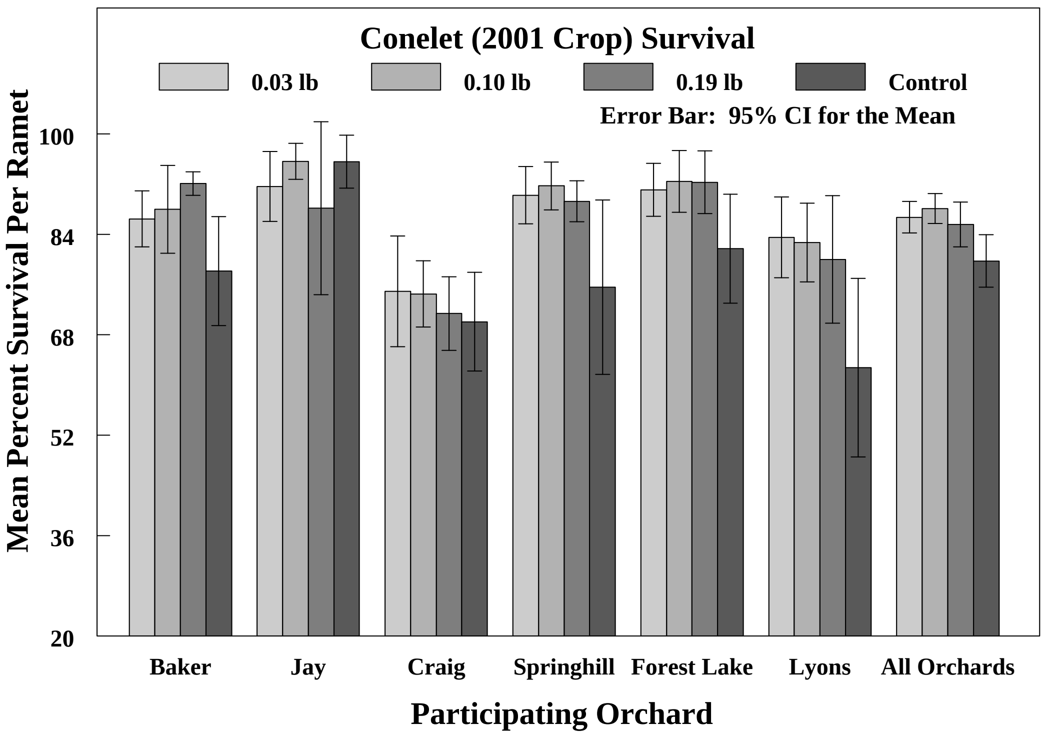

Figure 2. Mean percent survival per ramet of the conelets (2001 crop) harvested in fall 2001 at the participating orchards the South-wide rate test of esfenvalerate (Asana® XL) for cone and seed insect control in southern pine seed orchards conducted in 2001. Estimate based on sample of 50 tagged cones per ramet. Loss factors include coneworm mortality and damage and loss due to conelet abortion and unknown factors. CI = confidence interval.

Cone Yields and Damage

Healthy Cones. The number of healthy cones showed no significant effect of treatment (Table 5). However, the labeled rate of Asana® XL (0.19 lb) did result in the largest number of healthy cones. The other treatments had least-squares mean values (mixed model) about equal to that of the control (0.03 lb = 0.717, 0.10 lb = 0.722, 0.19 lb = 0.766, control = 0.717).

Coneworm-infested Cones. There were no significant differences for treatments versus control when all orchards were included in the analysis (Table 5). Two of the orchards (Springhill and Forest Lake) were heavily infested with coneworms. When these two orchards were analyzed exclusively, the resulting analysis of variance revealed significant differences (F=7.33, p>F=0.0680). However, these differences were between the 0.03 and 0.10 lb rates versus the 0.19 lb rate and not between the treatments and the control. The least-squares mean values (mixed model) for this analysis were 0.03 lb = 0.3807, 0.10 lb = 0.3458, 0.19 lb = 0.2325, and control = 0.2969.

Table 5. Cone quality and yield of loblolly and slash pine seed from the South-wide rate test of esfenvalerate (Asana® XL) for cone and seed insect control in southern pine seed orchards conducted in 2001. Estimates are based on whole-tree picks of the 2000 cone crop from each study ramet.

	Average Whole-tree Counts per Ramet[1]				
Treatment[2]	Coneworm	Healthy	Total	Percent Coneworm	Percent Healthy
0.03	58.4±25.6[3]	546.7±250.5	653.6±257.5	73.3±6.4	17.8±5.1
0.10	60.2±26.5	495.8±189.6	608.5±195.8	74.7±6.0	15.7±5.0
0.19	41.4±14.3	517.8±201.8	607.0±210.3	80.1±5.6	12.3±4.3
Control	57.6±20.0	407.3±159.2	517.3±170.4	74.1±5.9	17.1±4.4

[1]Averaged across all six orchards in the study.
[2]Pounds of active ingredient per acre of Asana® XL.
[3]Mean value ± 95% confidence interval about mean.

Seed Analysis

Based on quality estimates from radiography of seeds, all rates of esfenvalerate were effective in controlling seed bugs. Percent good seed was significantly lower for the control when compared against the 0.03, 0.10 and 0.19 lb rates (Table 6). The composite trait, good-seed per original-flower, gave similar results. The slash pine at the Baker Orchard did not have good control at the two lowest treatment rates.

Secondary Pests

Examinations of sample trees in spring before the first application indicated small numbers of secondary pests. Populations of mealybug, *O. acuta,* and the striped pine scale, *T. pini*, were sparse at all loblolly pine orchards. After the treatments, only the Craig and Forest Lake Orchards had noticeably larger numbers of these two pests. For example, at Forest Lake, on March 29, 2001, there were no *T. pini* present. However, on September 26, 2001, the sampling revealed 191 live striped pine scale on the samples from the 0.19 lb treatment and 260 on the 0.10 lb treatment sample. Similarly, at Craig, *T. pini* numbers were high in June but declined sharply by October. Examinations done in 2002 revealed sparse populations of these species.

Table 6. Percent seed bug damage to loblolly and slash pine seed from the South-wide rate test of esfenvalerate (Asana® XL) for cone and seed insect control in southern pine seed orchards conducted in 2001. Damage estimates are based on radiographic analysis of mature seed from a ten-cone sample of the 2001 cone crop taken from each study ramet.

	Participating Company[1]-Site-Tree Species						
Treatment[2]	IP-Jay-Loblolly	IP-Springhill-Loblolly	MFC-Craig-Loblolly	TI-Forest Lake-Loblolly	WEY-Lyons-Loblolly	All Loblolly Orchards	FDF-Baker-Slash
0.03	15.4±3.8**a** [3]	28.7±4.3**a**	12.1±2.8**b**	24.0±5.9**a**	26.5±6.1**ab**	21.2±2.2**a**	18.6±5.7**a**
0.10	16.6±3.9**a**	29.8±5.2**a**	9.3±2.0**a**	31.4±6.2**ab**	23.2±5.0**a**	22.2±2.3**a**	19.8±3.2**a**
0.19	16.6±3.8**a**	29.1±3.6**a**	10.6±1.9**ab**	26.7±5.8**ab**	21.7±5.1**a**	20.8±2.0**a**	14.6±1.8**a**
Control	19.2±4.1**a**	39.9±4.2**b**	12.7±2.4**b**	36.0±5.4**b**	32.5±4.8**b**	28.0±2.3**b**	20.6±1.4**a**

[1] IP = International Paper, MFC = Mississippi Forestry Commission, TI = Temple-Inland Forest Products, WEY = Weyerhaeuser Company, FDF = Florida Division of Forestry.
[2] Pounds of active ingredient (Asana® XL) per acre applied monthly April – August 2001.
[3] Mean ± Standard error of the mean. Means followed by the same letter in each column are not significantly different at the 5% level (Fisher's Protected LSD).

Implications

It is apparent that the reduced rates of Asana® XL were not effective against coneworms. The fact that cone (2000 crop) survival and number of healthy and coneworm-infested cones at the 0.03 and 0.10 lb rates were not significantly different from the control numbers indicates that these rates did not control coneworms. This is consistent with Nord et al. (1984) who show decreased cone damage with increasing pyrethroid dosage.

However, these reduced rates (0.03 lb and 0.10 lb) were effective in controlling seed bug populations. Again, the present study is consistent with past work. Seed bugs are controlled by lower rates of pesticides than those required for control of coneworms (Byram et al. 2003). Consequently, reduced rates of esfenvalerate may be applied in combination with insecticides specific to coneworms, such as the growth regulator tebufenozide. This results in a combination of efficacy and reduced risk of secondary outbreaks.

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LITERATURE CITED

Bramlett, D.L., E.W. Belcher, Jr., G.L. DeBarr, G.D. Hertel, R.P. Karfalt, C.W. Lantz, T. Miller, K.D. Ware and H.O. Yates III. 1977. Cone analysis of southern pines. A guidebook. USDA For. Serv. Gen. Tech. Rep. SE-13. 28p.

Byram, T.D., A.C. Mangini, and S.E. McKeand. 2003. Cone and seed insect pest research: The role of the southwide studies. Proc. 27th South. For. Tree Improv. Conf., pp. 116-125.

Cameron, R. S. 1989. Promising new pesticides for cone and seed insect control in the Southern United States. pp. 193-202 in Proc. Cone and Seed Insects Working Party Conf. IUFRO. For. Canada. Pac. For. Cent., Victoria, BC, Canada.

Clarke, S.R., G.L. DeBarr, and C. W. Berisford. 1988. Differential susceptibility of *Toumeyella pini* (King) (Homoptera: Coccidae) to pyrethroid and organophosphate insecticides: A factor in outbreaks in Southern pine seed orchards. J. Econ. Entomol. 81(5): 1443-1445.

Ebel, B.H., T.H. Flavell, L.E. Drake, H.O. Yates III, and G.L. DeBarr. 1980. Seed and cone insects of southern pines. USDA For. Serv. Gen. Tech. Rep. SE-8. 43p.

Fatzinger, C.W., G.D. Hertel, E.P. Merkel, W.D. Pepper, and R.S. Cameron. 1980. Identification and sequential occurrences of mortality factors affecting seed yields of southern pine seed orchards. USDA For. Serv. Res. Pap. SE-216. 43p.

Littell, R.S., W.W. Stroup and R.J. Freund. 2002. SAS® for linear models. 4th ed. SAS Institute Inc. Cary, NC 466 p.

Lowe, W.J., L.R. Barber, R.S. Cameron, G.L. DeBarr, G.R. Hodge, J.B. Jett, J.L. McConnell, A. Mangini, J. Nord and J.W. Taylor. 1994. A southwide test of bifenthrin (Capture®) for cone and seed insect control in seed orchards. South. J. Appl. For. 18(2): 72-75.

Mangini, A.C., L.R. Barber, R.S. Cameron, G.L. DeBarr, G.R. Hodge, J.B. Jett, W.L. Lowe, J.L. McConnell, J. Nord, and J. W. Taylor. 1998. A southwide rate test of azinphosmethyl (Guthion®) for cone and seed insect control in loblolly pine seed orchards. South. J. Appl. For. 22(2): 106-110.

Nord, J.C., G.L. DeBarr, N.A. Overgaard, W.W. Neel, R.S. Cameron, and J. F. Godbee. 1984. High volume applications of azinphosmethyl, fenvalerate, permethrin, and phosmet for control of coneworms (Lepidoptera: Pyralidae) and seed bugs (Hemiptera: Coreidae and Pentatomidae) in southern pine seed orchards. J. Econ. Entomol. 77: 1589-1595.

VanBuijtenen, J.P. 1981. Insecticides for seed orchards – a case study in applied research. South. J. Appl. For. 5: 33- 37.

Zar, J.H. 1999. Biostatistical analysis. 4th ed. Prentice-Hall. New York. 663 p.