Degree-day model for timing insecticide applications to control *Dioryctria amatella* (Lepidoptera: Pyralidae) in loblolly pine seed orchards

James L Hanula,[1] Gary L DeBarr[2]

Southern Research Station, Forestry Sciences Laboratory, USDA Forest Service. 320 Green Street, Athens, Georgia, United States 30602-2044

Julie C Weatherby[3]

Forest Health Protection, USDA Forest Service, 2500 Shreveport Highway. Pineville, Louisiana, United States 7 1360

Larry R Barber[2]

Forest Health Protection, USDA Forest Service, 200 Weaver Boulevard, Asheville, North Carolina, United States 28804

C Wayne Berisford

Department of Entomology, University of Georgia, 413 Biological Sciences Building, Athens. Georgia, United States 30602

The Canadian Entomologist **134**: 255 – 268 (2002)

Abstract-Because *Dioryctria amatella* (Hulst) is a key pest in loblolly pine, *Pinus taeda* L. (Pinaceac), seed orchards in the southeastern United States, improved timing of insecticide applications would be valuable for its control. To time two fenvalerate (Pydrin® 2.4 EC) applications we tested four variations of a degree-day model that was developed to predicted when various proportions of *D. amatella* eggs would hatch during the spring generation. Wc compared reductions in *Dioryctria* spp. cone damage to unsprayed checks and a standard operational spray regime of four monthly applications of fenvalerate. In addition, we examined seeds from healthy cones to determine if sprays to control *D. amatella* also reduced seed damage caused by *Leptoglossus corculus* Say (Heteroptera: Coreidae) and *Tetyra bipunctata* (Herrich-Schäffer) (Heteroptera: Scutelleridae). Trials were conducted from 1984 to 1986 in two orchards in South Carolina and one in Alabama. Degree-day accumulations (threshold = 1 1 °C) were begun on the day when the cumulative number of male *D. amatella* equaled or exceeded five captured in 15 Pherocon 1 C® traps baited with 100 μg of *Z*- 1 1 -hexadecenyl acetate. One application per year was insufficient to control *D. amatella* or reduced seed-bug damage. Two sprays based on *D. amatella* phenology significantly reduced coneworm and seed bug damage, and were as effective as four sprays applied monthly. None of the treatments reduce spring cone losses, which are primarily caused by *Dioryctria merkeli* Mutuura and Monroe. Several variations of the model performed well, but we suggest that the best, based on efficacy and ease of use, was when sprays were applied immediately alter five males were caught (degree-day = 0) and again when the model predicted 50% of the spring generation eggs had hatched.

[1] Corresponding author (e-mail: jhanula@fs.fed.us).
[2] Retired.
[3] Deceased.

Hanula JL, DeBarr GL, Weatherby JC, Barber LR, Berisford CW. 2002. Modèle d'accumulation de degrés-jours pour Ctablir le moment propice aux applications d'insecticide dans la lutte contre *Dioryctria amatella* (Lepidoptera : Pyralidae) dans les pépinières de production de graines du pin à encens. The *Canadian Entomologist* **134: 2X-268.**

Résumé—*Dioryctria amatella* (Hulst) est l'un des principaux ravageurs des pépinibres de production de graines du pin à encens, *Pinus taeda* L. (Pinaceae), dans le sud-est des États-Unis; il semble donc important de déterminer le moment le plus propice à l'application d'insecticides pour lutter contre ce parasite. Pour Ctablir le moment idéal de deux applications de fenvalérate (Pydrin® 2.4 EC), nous avons examine quatre variantes d'un modèle basé sur l'accumulation de degrés-jours pour déterminer à quel moment les diverses proportions des oeufs de *D. amatella* de la génération de printemps devraient éclore. Nous avons comparé les réductions des dommages infligés aux cônes par *Dioryctria* spp. dans des parcelles témoins non traitées et dans des parcelles soumises à un régime de yuatre traitements mensuels de fenvalérate. Nous awns, en outre, examiné les graines des cônes sains pour déterminer si les applications réduisent Cgalement les dommages causés aux graines par *Leptoglossus corculus* Say (Heteroptera : Coreidae) et par *Tetyra bipunctata* (Herrich-Schäffer) (Heteroptera : Scutelleridae). Les tests ont eu lieu de 1984 à 1986 dans deux pépinières de la Caroline du Sud et une de l'Alabama. L'accumulation des degrés-jours (seuil de 11°C) a commencé le jour où le nombre cumulatif de mâles de *D. amatella* capturés dans des pièges de 1.5 Pherocon 1C® garnis de 100 µg d'acétate de Z- 11 -hexadécényle a été égal ou supérieur à cinq. Une seule application par année ne suffisait pas à assurer le contrôle de *D. amatella,* ni à réduire les dommages causés aux graines par les punaises. Deux applications prévues en fonction de la phénologie du parasite ont réduit significativement les dommages causés par les punaises et par la pyrale et se sont avérées aussi efficaces que quatre arrosages mensuels. Aucun des traitements n'a réussi à réduire les pertes de cônes au printemps, attribuables surtout à *Dioryctriu merkeli* Mutuura et Monroe. Plusieurs variantes du modble se sont montrées fonctionnelles, mais nous croyons que la meilleure, par son efficacité et sa facilité d'utilisation, est celle basée sur les vaporisations effectuées immédiatement après la capture de cinq mâles (somme des degrés-jours = 0) et de nouveau lorsque le modèle indique que 50 % des oeufs de la génération de printemps ont éclos.

[Traduit par la Rédaction]

Introduction

Chemicals for insect control and methods for applying them change, but insecticides continue to be an important component of integrated pest management programs for insects that feed on cones and seeds in loblolly pine, *Pinus taeda* L. (Pinaceae), seed orchards. Improved timing of insecticide applications can reduce the amount and frequency of insecticide use. Impediments to better timing include the presence of multiple pests and their immigration from natural pine forests or plantations near seed orchards (Cameron 1984). Spray timing based upon degree-day accumulations have been used to time insecticide applications for the Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock) (Lepidoptera: Tortricidae), a pest of young pine plantations (Garguillo *et al.* 1983, 1984, 1985; Berisford *et al.* 1984; Fettig and Berisford 1999). The development of similar, effective methods to time insecticide applications is essential to improve seed-orchard management.

Univoltine cone- or seed-feeding insects or the first generation of multivoltine species are the most promising targets for such methods. Loblolly pine cones and seeds are damaged by an array of insects that include four sympatric species of coneworms, *Dioryctriu* spp. Zeller (Lepidoptera: Pyralidae), and two species of seed bugs (Ebel *et* al. 1980). Two coneworms are multivoltine, *Dioryctria amatellu* (Hulst) and *Dioryctria clarioralis* (Walker), and two are univoltine, *Dioryctriu disclusa* Heinrich and *Dioryctria merkeli* Mutuura and Monroe. Important seed-feeding insects include the multivoltine leaffooted pine seed bug, *Leptoglossus corculus* (Say) (Heteroptera: Coreidae), and the univoltine shieldbacked pine seed bug, *Tetyra bipunctata* (Herrich-Schäffer) (Heteroptera: Scutelleridae). Insecticides are often applied four to six times annually by helicopter or fixed-wing aircraft to control this complex of pests (Nord *et* al. 1985; Lowe *et al.* 1994; Mangini *et al.* 1998). Most insecticides applied to control *Dioryctriu* spp. also provide seed bug control because residues persist on pine foliage (Nord and DeBarr 1992).

Dioryctria amatella has the most complex life cycle of the four *Dioryctria* species, making it the most difficult to control. The life history *of D. amatella* appears to be similar on loblolly pine throughout its natural range (Neunzig et *al.* 1964; Ebel 1965; Brown 1969; Coulson and Franklin 1970; Merkel and Fatzinger 1971; Yates and Ebel 1975; Chatelain and Goyer 1980; McLeod and Yearian 1981, 1982; Tauer *et al. 1983;* Weatherby et *al.* 1985; Hanula *et* al. 1985). During a 3-year study conducted in northern Georgia, *85%* or more of the *D. amatella* population had only one generation per year in 2nd-year cones (Hanula *et al.* 1985). Only a small number of pupae and adults were present in midsummer and they appeared to be part of a distinct population of *D. umatellu* that relied on previously damaged cones for survival and successful completion of a second generation in cones.

Previous insecticide tests using calendar-based schedules suggest that early applications (March-June) can reduce *Dioryctriu* spp. attacks throughout the remainder of the growing season (Merkel 1964; Merkel and Yandle 1965; DeBarr and Merkel 1971; Merkel and DeBarr 197 1; DeBarr *et al.* 1972; Merkel *et al.* 1976; McLeod and Yearian 1979). Merkel and Yandle (196.5) noted that protection of 2nd-year cones following three insecticide applications (April, May, and June) continued through to September.

We hypothesized that two well-timed insecticide applications in the spring could provide consistent season long control of *D. amatellu.* We developed a degree-day model, based on *D. umatellu* development (Hanula *et ul.* 1984*a*, 1987), that predicts when various proportions of the population hatch. Four variations of the model that provided timing for two fenvalerate applications per year in loblolly pine seed orchards were compared with conventional calendar-based applications and a single application timed to coincide with peak pine pollen release. In addition, we determined if applications made for *Dioryctria* spp. control also reduced seed bug damage.

Materials and methods

Experiments were conducted in 1985 at the US Forest Service's Francis Marion Seed Orchard (Berkeley County, South Carolina, 32°58′N, 79°56′W) and at a Champion International seed orchard (Newberry County, South Carolina, 34°16′N, 81°46′W), and from 1984 to 1986 at Weyerhaeuser Company's seed orchard (Greene County, Alabama, 32°55′N, 88°05′W). Individual loblolly pine trees (10–15 m height) were sprayed with 19-30 L of 0.05% ai (wt/wt) of fenvalerate (Pydrin® 2.4 EC formulation) until the foliage was visibly wet using a hydraulic sprayer (Nord *et al.* 1984).

Seed orchards consist of trees (ramets) cloned from parent trees by grafting cuttings unto seedlings planted for root stock. Clones are replicated throughout orchards so sufficient crossing occurs between clones, and a number of clones are included in each orchard for a variety of reasons (van Buijtenen *et al.* 1971). Some clones are more susceptible to insect damage than others so we blocked our experiments by clones to remove variation, due to clonal differences in succeptiblity to coneworms, from the experimental error. Individual ramets were treatment units and all experiments were randomized complete block designs.

Nine treatments were tested in 1984 in the Alabama orchard to determine if a single application of fenvalerate was sufficient to provide season-long control. They included a control (no insecticide applied) and eight treatments of a single application of fenvalerate where the application dates differed among the eight treatments by 2 weeks. The date of earliest application was 6 April; the latest was 18 July (Table 1). Each tree was treated only once during the growing season.

Studies of *D. amatella* oviposition and egg maturation showed that females produced over 80% of their eggs within 12 d of emergence and that peak oviposition occurred at 7 d. Eggs require 87 degree-days (°d) (°C) for hatching, and egg development only occurred above the threshold temperature of 11 °C (Hanula et *al.* 1984*a*, 1987). We developed a model to predict when egg hatch would occur based on these data and predicted flight activity of females. The model was not validated by examining eggs under field conditions because no one has successfully or consistently located the oviposition sites of *D. amatella*.

Seasonal flight activity of *D. amatella* females was obtained by comparing catches in blacklight traps at three locations in each of 2 years for a total of six data sets: (*i*, ii) 1968 and 1970 Clarke County, Georgia (33°58′N, 83°23′W) (Yates and Ebel 1975); (iii, iv) 1978 and 1979 Georgetown County, South Carolina (33°23′N, 79°24′W) (GL DeBarr, LR Barber, unpublished data); (*v*, *vi*) 1982 and 1983 Putnam County, Georgia (33°48′N, 83°16′W) (Hanula *et* al. 1985). Two to 1.5 blacklight traps (Merkel and Fatzinger 1971) were operated from March through October at each site. Maximum and minimum daily temperatures were obtained from three National Weather Service stations: (i) Athens, Georgia (1968 and 1970); (ii) Georgetown, South Carolina (1978 and 1979); and (iii) Siloam, Georgia (1982 and 1983). Degree-day accumulations corresponding to 10, 25, 50, and 80% of first generation female emergences were calculated using a modified sine wave method (Allen 1976). The biofix, or beginning point for degree-day accumulations (threshold = 11 °C) for the model, was the date when the cumulative total of male moths caught in traps equaled or exceeded five. The capture of five males was chosen because it was a sufficient number to denote the beginning of the emergence of the main population and it prevented us from starting degree-day accumulations prematurely based on one or two early emerging males.

Data on female emergence were incorporated into a development model with degree-days required for egg hatch, and days to peak oviposition. We tested four variations of the model designed to predict when various percentages of the eggs would hatch. Fenvalerate applications for control of first generation *D. amatella* were timed based on the model: spray date = °d to *x*% ♀ emergence + 7 d to peak oviposition + 87°d (°C) to egg hatch, where *x* = 10, 25, 50, or 80.

Fifteen Pherocon 1C® (Zoecon Corp, Palo Alto, California), traps baited with 100 μg of Z-11-hexadecenyl acetate (Albany International Corporation, Needham, Massachusetts) impregnated on red rubber septa (Arthur H Thomas, Philadelphia, Pennsylvania) (Meyer *et al.* 1986) were installed in the test area at each orchard. Traps were placed as high as possible in the upper one third of the crown (Hanula *et* al. 1984*b*) and monitored three times per week until a cumulative total of five *D. amatella* males was caught, at which time recordings of degree-day accumulations started using an Omnidata biophenometer (Omnidata International, Logan, Utah) programed with a lower threshold of 11 °C.

Coneworm control was evaluated on X-10 clones selected in each orchard on the basis of cone production, and seven ramets, each with a minimum of 50 2nd-year cones, were selected from each clone. The following seven treatments were randomly assigned

TABLE 1. Orchard locations, insecticide treatments, spray dates, and degree-days for the *Dioryctria amatella* degree-day model tests in three *Pinus taeda* seed orchards.

Location	Treatment	Date
Greene County, Alabama, 1984	One spray	6 April (—), 24 April (—), 9 May (—), 25 May (—), 6 June (—), 20 June (—), 2 July (—), 18 July
	Unsprayed	
Berkeley County, South Carolina, 1985	Operational aerial spray:"	8 April (—), 6 May (—), 25 June (—), 29 July (—)
	Four monthly sprays†	X April (—), 6 May (—), 25 June (—), 29 July (—)
	One spray (7 d PP)‡	8 April (—)
	Unsprayed	—
Newberry County, South Carolina, 1985	Four monthly sprays	4 April (—), 30 April (0), 29 May (417), 24 June (766)
	Model variation I (5 ♂ + 50%)§	30 April (0), 5 June (538)
	2 (IO + 50%)	15 May (235), 5 June (538)
	3 (I 0 + 80%)	IS May (235), 24 June (766)
	4 (25 + 80%)	29 May (417), 24 June (766)
	Unsprayed	
Greene County, Alabama, 1985	Four monthly sprays	9 April (—), 6 May (0), 4 June (394), I July (766)
	Model variation I (5 ♂ + SO%)	6 May (0), 2 I June (625)
	2 (10 + 50%)	23 May (255), 21 June (625)
	3 (IO + 80%)	23 May (255), I July (766)
	4 (25 + 80%)	4 June (394), I July (766)
	One spray (7 d PP)	9 April (—)
	Unsprayed	
Greene County, Alabama, 1986	Four monthly sprays	2 April (—), 30 April (102), 29 May (391), 26 June (X21)
	Model variation I (5 ♂ + 50%)	16 April (0), I I June (576)
	2 (IO + 50%)	13 May (235), 11 June (576)
	3 (IO + 80%)	13 May (235), 26 June (X21)
	4 (25 + 80%)	29 May (391), 26 June (821)
	One spray (7 d PP)	3 April (—)
	Unsprayed	—

NOTE: Treatments included four variations of a degree-day model to time insecticide applications based on the proportion of *D. amatella* eggs hatched. Values in parentheses in the last column are the degree-day accumulations, above the 11°C development threshold, beginning on the date when five ♂ moths were captured.

* Included for comparison only and not part of statistical analyses; matching ramets for test clones selected in an adjacent block of the orchard sprayed operationally by helicopter.

† Four sprays made at about monthly intervals beginning at peak pollen release.

‡ Single spray applied 1–7 d after peak pollen (PP) release.

§ Cumulative total ≥5 ♂ *D. amatella* moths caught in 15 pheromone traps; percentages refer to predicted proportion of first generation *D. amatella* eggs hatched.

to individual ramets: (1) one application of fenvalerate 1-7 d after peak pollen release; (2) four applications of fenvalerate at monthly intervals starting 1-7 d after peak pollen release (standard spray schedule); (3) two fenvalerate applications, the first immediately after the cumulative catch equaled or exceeded five *D. amatella* males in the pheromone traps and the second when the model predicted egg hatch of 50% of the population (spray date = 549°d + 7 d); (4) two fenvalerate applications on dates when the model predicted egg hatch by 10% (spray date = 208°d + 7 d) and 50% of the population (spray date = 549°d + 7 d); (5) two fenvalerate applications on dates when the model predicted egg hatch of 10% (spray date = 208°d + 7 d) and 80% of the population (spray date = 797°d + 7 d); (6) two fenvalerate applications on dates when the model predicted egg hatch of 25% (spray date = 380°d + 7 d) and 80% of the population (spray date = 797°d + 7 d); and (7) control (no fenvalerate applied). Not all treatments were applied in the Newberry County seed orchard because the number of ramets/clone was limited (Table I). Only three treatments were compared statistically at the Berkeley County orchard. Damage on ramets of matching clones was evaluated in an adjacent area of the orchard that received operational aerial applications on a monthly basis. This was done to see if individual tree applications with ground-based equipment provided control comparable to standard area wide orchard sprays; however, those data were not included in statistical analyses.

Treatment efficacy was evaluated at cone harvest and was based upon the reduction in the amount of insect damage to cones and seeds. In September of each year, all cones were removed from each test tree, sorted by damage categories, and counted. Cone damage categories included (i) undamaged cones; (ii) spring-attacked, dead brown cones less than full size killed by *Dioryctria* spp.; *(iii)* summer-attacked, full size dead brown cones killed by *D. amatella*; and *(iv)* fall-attacked, mature green cones damaged by *D. amatella*. Spring-attacked included cones infested with *D. merkeli* and *D. amatella*. No cones with pitch blisters, characteristic of attacks by *D. clarioralis* (Ebel *et ml.* 1980), were observed during our tests so we attributed all the summer and fall attacks to *D. amatella*. Samples of 200 cones in each damage class were placed in cages at the Forestry Sciences Laboratory, Athens, Georgia, to rear moths for identification.

Although the model was designed to time insecticide applications for coneworms, we were interested in determining if it also reduced seed bug damage. Ten undamaged cones were randomly selected from each tree, dried at room temperature, and the seeds extracted to measure seed bug damage. Seeds were examined from four clones per orchard in 1985 and nine clones in 1986. Methods of cone handling and seed radiography are described by DeBarr (1970, 1978). Radiographs were examined for 2nd-year aborted ovules, empty seeds, seeds per cone, and filled seeds per cone (DeBarr 1970; DeBarr and Ebel 1974).

All proportion data were arcsine square-root transformed to satisfy the assumptions of normality and homogeneity of variance where appropriate. Data were summarized and analyzed using the GLM procedure of the Statistical Analysis System (SAS Institute Inc 1990). The 1984 Greene County and 1985 Berkeley County trials were analyzed separately because they differed in treatments tested (Table 1). The 1985 Newberry County, and the 1985 and 1986 Greene County trials had the same treatments, so the data were pooled and analyzed to test for interactions between site and treatment. Model effects tested included site, clone within site, treatment, and site x treatment interaction. The site x treatment interaction was significant for 8 of the 10 variables at $\alpha = 0.05$ and all had a significant interaction at $\alpha = 0.08$ (Table 2), so we analyzed the data from each site separately as a randomized complete block design with treatments blocked by clone. The same treatments were applied to the same clones at the Greene County orchard in 1985 and 1986, so the results of the 2 years were summed and analyzed together. Fisher's least significant difference (LSD) was used to determine differences among treatments because of its consistency (Saville 1990).

TABLE 2. Significance levels for analyses of variance showing the effects of study site, tree clone, treatment, and site x treatment interaction on seed- and cone-quality variables in *Pinus taeda* seed orchards.

	Sources of variation							
	Site		Clone within site		Treatment		Site x treatment	
Variables	F	$P > F$	F	$P > F$	F	$P > F$	F	$P > F$
Seed								
No. of filled seeds/cone	59.30	<0.001	12.82	<0.001	10.7x	<0.001	1.92	0.049
Total no. of seeds/cone	1 X.30	<0.001	1 s.49	<0.001	7.78	<0.001	2.24	0.020
Percent filled seeds	1 x3.34	<0.001	7.60	<0.001	10.47	<0.001	3.60	<0.001
Percent empty seeds	142.61	<0.001	14.35	<0.001	4.7s	<0.001	2.9 1	0.003
Percent seed hug damaged	89.60	4.00 I	3.34	<0.001	6.31	<0.001	2.07	0.032
Cone								
Percent spring attacks	50.65	<0.001	4.90	<0.001	2.28	0.040	1 .x7	0.049
Percent summer attacks	6.63	0.002	3.77	<0.001	4.23	0.00 1	1.69	0.082
Percent fall attacks	7.54	0.001	3.37	<0.001	0.78	0.588	1.78	0.064
Percent *D. amatella* total	8.01	<0.001	4.58	<0.001	3.98	0.001	2.2x	0.014

NOTE: Proportion data were arcsine square-root transformed.

Results

The average ± SE number of cones harvested was 288 ± 26 cones/tree for the Berkeley County degree-day test and 265 ± 24 cones/tree for the Newberry County degree-day test. Cone yields at the Greene County site averaged 479 ± 40 cones/tree in 1984, 379 ± 34 cones/tree in 1985, and 95 1 ± 66 cones/tree in 1986. In analyses of pooled data there were significant effects due to site, clone within site, treatment, and significant site x treatment interaction for almost all of the cone-infestation, seed-quality, and seed-yield variables that we measured (Table 2).

Greene County single spray test

None of the single fenvalerate applications timed 2 weeks apart reduced *D. amatella* damage in 1984. *Dioryctria* spp. infestation averaged 4.3 ± 1.3% on the control trees and there were no differences among treatments ($F_{8,24} = 1.77$, $P = 0.1237$). Seed bug damaged seed detected on radiographs averaged 2.6 ± 1.2% on the control trees and did not differ among treatments ($F_{8,24} = 1.25$, $P = 0.2872$), but differences were observed among the number of 2nd-year aborted ovules ($F_{8,24} = 2.83$, $P = 0.0103$). Abortion of 2nd-year ovules (mean ± SE) was lower on trees sprayed on 6 April (0.39 ± 0.24%), 20 April (0.10 ± 0.05%), 18 May (0. 15 ± 0.13%), and 1 June (0.28 ± 0.08%) than on control trees (2.21 ± 0.9%). Abortion of 2nd-year ovules is caused by seed bug feeding during the spring before the seedcoat has hardened (DeBarr and Ebel 1974).

Berkeley County timed spray test

The first *D. amatella* moth was trapped on 28 May, but a cumulative catch of five moths did not occur until 17 June, 6 weeks after the model was initiated at the Newberry County site. Because it was so late in the growing season, treatments based on the degree-day model were not made at the Berkeley County site.

TABLE 3. Mean ± SE percentages of cones damaged by *Dioryctria* spp. on trees (n = 10) sprayed with insecticide in a *Pinus taeda* seed orchard, Berkeley County, South Carolina.

	Percent cones infested by			
		D. amatella		
Treatment	*Dioryctria* spp. spring attacks	Summer attacks	Fall attacks	Total attacks
Operational aerial spray*	11.1±2.2	5.1±2.0	2.3±0.6	7.5±2.4
Four monthly sprays†	11.5±2.5*a*	4.8±1.3*a*	1.3±0.4*a*	6.2±1.6*a*
One spray (7 d PP)‡	16.4±2.5*a*	13.5±3.2*b*	3.6±1.0*b*	17.2±3.9*b*
Unsprayed	13.8±3.0*a*	17.0±4.2*b*	3.0±0.5*b*	20.0±4.3*b*
$P > F$	0.3262	0.0008	0.0289	0.0005
$F_{2,18}$	1.2	11.2	4.4	12.5

NOTE: Proportion data were arcsine square-root transformed. Means within each column followed by the same letter are not significantly different (Fisher's LSD, $P > 0.05$).

* Included for comparison only and not part of statistical analyses; matching ramets for test clones selected in an adjacent block of the orchard sprayed operationally by helicopter.

† Four sprays made at about monthly intervals beginning at peak pollen release.

‡ Single spray applied 1–7 d after peak pollen (PP) release.

TABLE 4. Mean ± SE percentages of cones damaged by *Dioryctria* spp. on trees (n = 8) sprayed with insecticide in a *Pinus taeda* seed orchard, Berkeley County, South Carolina.

	Percent cones infested by			
		D. amatella		
Treatment	*Dioryctria* spp. spring attacks	Summer attacks	Fall attacks	Total attacks
Four monthly sprays*	9.3±3.6*a*	7.9±1.7*a*	7.5±2.5*a*	15.4±3.4*abc*
Variation 1 (5 ♂ + 50%)†	13.1±2.2*ab*	6.9±1.8*a*	3.9±0.6*a*	10.8±2.1*a*
2 (10% + 50%)	20.0±4.1*b*	9.7±2.6*ab*	7.7±1.3*a*	17.4±3.4*bc*
3 (10% + 80%)	14.1±3.5*ab*	8.1±2.1*a*	6.3±1.3*a*	14.5±2.9*abc*
4 (25% + 80%)	13.8±2.7*ab*	6.9±2.0*a*	5.8±1.7*a*	12.7±3.5*ab*
Unsprayed	20.7±5.2*b*	13.3±2.6*b*	6.4±2.1*a*	19.7±3.0*c*
$P > F$	0.0224	0.0401	0.4230	0.0546
$F_{5,35}$	3.05	2.64	1.02	2.43

NOTE: Treatments included four variations of a degree-day model to time insecticide applications based on the predicted proportions of *D. amatella* eggs hatched. Proportion data were arcsine square-root transformed and means within each column followed by the same letter are not significantly different (Fisher's LSD, $P > 0.05$).

* Four sprays made at about monthly intervals beginning at peak pollen release.

† Cumulative total ≥5 ♂ *D. amatella* moths caught in 15 pheromone traps; percentages refer to predicted proportion of first generation *D. amatella* eggs hatched.

The proportion of spring-attacked cones ranged from 11.5 to 16.4% and did not differ significantly among the three treatments (Table 3). Trees sprayed monthly had significantly less *D. amatella* damage than those sprayed once or never sprayed. The monthly aerial applications and the ground applications using a hydraulic sprayer appeared to give similar protection from coneworms although they could not be compared statistically. In addition, the mean ± SE numbers of filled seed per cone were 87.3 ± 5.7 for individual trees sprayed monthly from the ground and 126.1 ± 3.9 for trees protected by monthly aerial applications.

TABLE 5. Mean ± SE seed quality and yield per cone for trees (n = 4) sprayed with insecticide in a *Pinus taeda* seed orchard, Newherry County, South Carolina.

	Seed quality			Seed yields	
Treatment	Percent filled seed	Percent empty seed	Percent seed bug damaged*	No. of seeds/cone	No. of filled seeds/cone
Four monthly sprays†	87.3±3.1*a*	8.8±1.6*a*	3.9±1.5*a*	103.4±11.1*a*	91.3±12.5*a*
Variation 1 (5 ♂ + 50%)‡	79.8±3.6*a*	3.9±3.3*a*	4.3±1.0*a*	97.4±10.0*a*	77.5±8.3*a*
2 (10% + 50%)	88.1±2.8*a*	9.6±2. IN	2.1±0.8*a*	101.1±6.2*a*	89.6±8.0*a*
3 (10% + 80%)	85.9±4.3*a*	111 ±4.0*a*	2.9±0.7*a*	98.8±10.1*a*	86.0±12.1*a*
4 (25% + 80%)	74.1±11.3*ab*	17.3±5.8*ab*	8.2±5.3*ab*	77.8±15.9*a*	63.0±17.8*ab*
Unsprayed	58.3±9.6*b*	27.9±6.0*b*	13.8±6.0*b*	54.5±16.0*a*	35.9±14.4*b*
$P > F$	0.0448	0.051	0.042X	0.0626	0.0422
$F_{5,75}$	3.00	2.88	3.05	2.58	2.02

NOTE: Treatments included four variations of a degree-day model to time insecticide applications based on the predicted proportions of *D. amatella* eggs hatched. Proportion data were arcsine square-root transformedand means within each column followed by the same letter are not significantly different (Fisher LSD, $P > 0.05$).

* Seed bug-damaged seeds and 2nd-year aborted ovules identifiable on radiographs.

† Four sprays made at about monthly intervals beginning at peak pollen release.

‡ Cumulative total ≥5 ♂ *D. amatella* moths caught in 15 pheromone traps; percentages refer to predicted proportion of first generation *D. amatella* eggs hatched.

Newberry County timed spray test

The first monthly fenvalerate application was made on 4 April, 2 days after peak pollen release. Degree-day accumulations were started on 30 April (Table 1). Only trees sprayed monthly had significantly fewer spring attacked cones than unsprayed trees (Table 4). Twenty-five *D. amatella* and 8 *D. merkeli* adults (3: 1) emerged from 200 spring-attacked cones. Trees sprayed according to model variations 1, 3, and 4, and trees sprayed monthly all had significantly fewer summer-attacked cones than unsprayed trees, and model variations 1 and 4 resulted in less total *D. amatella* damage. Seventy-four *D. amatella* and 1 *D. merkeli* (74: 1) emerged from 200 summer-attacked cones. None of the treatments significantly reduced fall attacks. A sample of 200 of these cones produced *30 D. amatella* and no *D. tnerkeli.*

Fenvalcrate applied to control *D. amatella* also significantly increased seed quality and yield when compared with unprotected trees (Table 5). The number of tilled seeds per cone on trees sprayed with insecticide applications timed with three of the four variations of the degree-day model was higher than that of unsprayed trees. Model variations 1, 2, and 3 produced significantly higher seed quality and more filled seeds per cone than the unsprayed controls. All three provided protection similar to 4 monthly fenvalerate applications.

Greene County timed spray tests

In 198.5, the first monthly fenvalerate application was made on 9 April. The first moth was trapped on 22 April, but degree-day accumulations were not started until 6 May, when a cumulative catch of five *D. amatella* occurred (Table I). In 1986, the first monthly application timed with peak pollen release was made a week earlier than the previous year (Table 1). Degree-day accumulations were started on 16 April, about 3 weeks earlier than the previous year. None of the treatments significantly reduced

TABLE 6. Mean ± SE percentages of cones damaged by *Dioryctria* spp. on trees (n = 9) sprayed with insecticide in a *Pinus taeda* seed orchard, Greene County, Alabama (1985 and 1986).

	Percent cones infested by			
		D. amatella		
Treatment	*Dioryctria* spp. spring attacks	Summer attacks	Fall attacks	Total attacks
Four monthly sprays*	13.0±3.4*a*	5.1±1.1*a*	3.4±0.7*a*	X.521 .8*a*
Variation 1 (5 ♂ + 50%)[†]	12.9±2.1*a*	5.1±0.7*a*	3.7±0.5*a*	8.8±1.0*a*
2 (10% + 50%)	2.2±2.2*a*	5.7±1.3*abc*	4.3±1.2*a*	10.0±2.4*ab*
3 (10% + 80%)	2.8±1.5*a*	8.2±1.4*bc*	5.2±0.8*ab*	13.4±2.0*bc*
4 (25% + 80%)	4.9±2.6*a*	5.6±0.5*ab*	3.8±0.6*a*	9.3±0.9*ab*
One spray (7 day PP)[‡]	4.7±1.0*a*	8.1±1.3*bc*	6.7±1.0*b*	14.8±2.2*c*
Unsprayed	7.0±2.4*a*	8.5±1.5*c*	5.0±0.7*ab*	13.6±1.8*bc*
$P > F$	0.60	0.05	0.01	0.02
$F_{6,48}$	0.77	2.30	3.03	2.83

NOTE: Treatments included four variations of a degree-day model to time insecticide applications based on the predicted proportions of *D. amatella* eggs hatched. Means within each column followed by the same letter are not significantly different (Fisher's LSD, $P > 0.05$).

* Four sprays made at about monthly intervals beginning at peak pollen release.

† Cumulative total ≥5 ♂ *D. amatella* moths caught in 15 pheromone traps; percentages refer to predicted proportion of first generation *D. amatella* eggs hatched.

‡ Single spray applied 1–7 days after peak pollen (PP) release.

spring attacks by *Dioryctria* spp. (Table 6). Eighty-seven *D. merkeli* and 22 *D. amatella* adults were reared from 200 of these cones. Trees sprayed according to model variations 1 and 4, and trees sprayed monthly had significantly fewer summer attacks by *D. amutella* than unsprayed trees, but none of the treatments significantly reduced spring or fall attacks. Forty-eight *D. amatella* and only 2 *D. merkeli* adults were reared from 200 summer-attacked cones, and 82 *D. amatella* and no *D. merkeli* emerged from the same number of fall-attacked cones. Total *D.amatella* damage was reduced below that on unsprayed trees by fenvalerate applied according to model variation 1 and by 4 monthly applications. Levels of attacks on trees sprayed only once at peak pollen release were similar to those on unsprayed trees.

Treatments to control *D. umutellu* also had significantly higher seed yield and quality as a result of reduced seed bug damage (Table 7). All treatments timed with our degree-day model significantly increased seed yield and reduced seed bug damage compared with unsprayed trees; however, only model variation 1 resulted in seed yields similar to those from trees protected by 4 monthly applications of fenvalerate.

Discussion

Our field tests arc the first to show that two biologically timed applications of fenvalerate can protect cones from *D. amatella* comparable to the conventional practice of four applications at monthly intervals. Merkel and Yandle (1965) found that three calender-based sprays were necessary for control of cone- and seed-feeding insects in Florida. Haverty *et ul.* (1986) tested calender-based single and multiple sprays of fenvalerate for control *of Dioryctriu abietivorella* (Groté). They found that a single treatment with insecticide was effective in controlling this insect, but two applications were required to reduce seed bug damage enough to improve seed yield. Likewise, we found that two applications timed based on *D. amatella* phenology reduced seed bug

TABLE 7. Mean ± SE seed quality and yield per cone for trees (n = 9) sprayed with insecticide at several different spray schedules in a *Pinus taeda* seed orchard, Greene County, Alabama, test (1985 and 1986).

	Seed quality			Seed yields	
Treatment	Percent tilled seed	Percent empty seed	Percent seed bug damaged*	No. of seeds/cone	No. of filled seeds/cone
Four monthly sprays'	78.3±5.0a	18.5±4.0abc	2.2±1.1a	85.6±11.5a	66.9±10.6a
Variation 1 (5 ♂ + 50%)‡	80.0±3.8a	17.0±3.8ab	1.5±0.9a	76.5±10.1ab	61.3±9.2ab
2 (10% + 50%)	79.7±4.1a	15.8±3.3ab	2.5±1.0a	70.2±8.8bc	56.6±8.7bc
3 (10% + 80%)	81.0±5.1a	15.0±3.6a	2.7±1.6a	67.4±10.9bc	55.1±10.2bc
4 (25% + 80%)	79.4±4.6a	14.4±2.9a	3.2±1.2ab	63.7±10.4cd	50.8±9.7c
One spray (7 day PP)§	69.9±6.8b	21.8±4.5c	4.8±1.6b	68.7±9.0bc	48.2±9.0c
Unsprayed	67.2±7.6b	19.1±4.5bc	7.6±2.2c	55.1±6.7d	36.4±6.2d
$P > F$	6.22	3.44	8.39	7.49	X.48
$F_{6,48}$	0.000 1	0.007	0.000 1	0.0001	0.000 1

NOTE: Treatments included four variations of a degree-day model to time insecticide applications based on the proportion of *D. amatella* eggs hatched. Proportion data were arcsine square-root transformed and means within each column followed by the same letter are not significantly different (Fisher's LSD, $P > 0.05$).

* Seed bug damaged seeds and 2nd-year aborted ovules identifiable on radiographs.

† Four sprays made at about monthly intervals beginning at peak pollen release.

‡ Cumulative total ≥5 ♂ *D. amatella* moths caught in 15 pheromone traps; percentages refer to predicted proportion of first generation *D. amatella* eggs hatched.

§ Single spray applied 1-7 days after peak pollen (PP) release.

damage to levels similar to those achieved with current calender-based control practices.

Unlike *D. abietivorella* (Haverty *et al.* 1986), one application of fenvalerate per year was not enough to control *D. amatella* regardless of the timing, probably because of the prolonged spring emergence of females and their protracted period of oviposition. Furthermore, throughout our trials, fenvalerate sprays applied 1-7 d after peak pollination, targeted to control *D. disclusa*, were ineffective in preventing early cone mortality. The failure of fenvalerate applications timed based on *D. amatella* biology to reduce spring attacks suggests that most of those cones probably had been killed by *D. merkeli*. Although we reared both *D. amatella* and *D. merkeli* from these cones, we suspect that the majority of spring-attacked cones were the result of *D. merkeli*. It is likely that many *D. merkeli* adults emerged before our cone harvest in mid-September because *D. merkeli* begins emerging earlier than *D. amatella* in the fall and their emergence ends by late September (Yates and Ebel 1975). *Diorytria amatella* also oviposits on previously damaged cones (Hanula et al. 1985), so spring-attacked cones may have initially been damaged by *D. merkeli* larvae. *Dioryctria merkeli* overwinters as an early instar larva and initiates feeding in small secondary shoots (GL DeBarr, personal observation). Spring feeding behavior of *D. merkeli* has not been studied, but our results suggest that it remains protected from contact with fenvalerate residues. Optimum timing of sprays to prevent *D. merkeli* damage is unknown, but clearly they must occur before peak pollen release, possibly during the previous fall. Regardless of the insects causing early spring attacks, it is clear from our results that spring applications of insecticide were not effective in reducing the damage. More work is needed to determine which insects cause this early spring cone damage and to improve its control because half of the total coneworm damage we observed occurred in early spring when cones were still relatively small.

Fenvalerate applications based on *D. amatella* phenology were effective in reducing cone infestations in the summer, but neither timed sprays or the standard practice of monthly fenvalerate applications reduced fall attacks by *D. amatella* in the Newberry County and Greene County tests. It is unclear whether or not it would be possible to achieve greater reductions in this late-season damage because of the prolonged emergence of low numbers of *D. amatella* adults that occurs in the summer (Yates and Ebel 1975).

Our results show that model variation 1 was the best for reducing both *D. amatella* and seed bug damage to the same levels currently achieved with operational spray regimes requiring twice as many fenvalerate applications. Although other variations of the model performed almost as well, variation 1 was the easiest to use because the first spray was applied when cumulative pheromone trap catches reached five males and the second when the model predicted 50% egg hatch for the population. Thus, degree-day accumulations were only required for one of the two sprays. The results of this study should improve the efficiency and cost-effectiveness of seed production in loblolly pine seed orchards.

In addition, comparison of cone protection following large-scale aerial applications to single-tree applications with a hydraulic sprayer suggests that the latter provides an effective method of testing insecticide efficacy and timing. Percentages of infested cones were similar for both techniques suggesting that individual tree applications by ground equipment is a simple method of testing insecticide treatments to be used later in operational aerial applications.

Acknowledgments

We dedicate this paper to the memory of our friend and colleague Julie C Weatherby. We thank M Cody, T Coffee, M Dalusky, A Hilton, D Leonard, and H Wallace for their assistance in spraying trees and collecting field data. 0 Buckles, US Forest Service; A Platt, Champion Paper Company; and B Wallace, Weyerhaeuser Company, graciously allowed access to their seed orchards and assisted in monitoring pollen release, pheromone traps, and temperature recorders. We thank CJ Fettig and DM Grosman for helpful reviews of an earlier draft of the manuscript. This research was funded by the Georgia Forestry Commission and the US Department of Agriculture Forest Service, Forest Pest Management and Southern Research Station.

References

Allen JC. 1976. A modified sine wave method for calculating degree-days. *Environmental Entomology* **5**: 388–96

Berisford CW, Garguillo PM, Canalos CG. 1984. Optimum timing for insecticidal control of the Nantucket pine tip moth, Lepidoptera: Tortricidae. *Journal of Economic Entomology* **77**: 174–7

Brown IL. 1969. Insects and other arthropods associated with cone-shoot complex of loblolly and shortleaf pines in Arkansas. MS thesis, University of Arkansas, Fayetteville

Cameron RS. 1984. Timing of insecticide applications in southern pine seed orchards. pp 147–56 *in* HO Yates III (Ed), Proceedings of the Cone and Seed Insects Working Party Conference, Athens, Georgia, 31 July – 6 August 1983. Asheville, North Carolina: Southeastern Forest Experiment Station

Chatelain MP, Goyer RA. 1980. Seasonal attack periods of cone-feeding insects of loblolly pine cones. *Annals of the Entomological Society of America* **73**: 49–53

Coulson RN, Franklin RT. 1970. The occurrence of *Dioryctria amatella* and other insects in *Cronartium fusiforme* cankers. *The Canadian Entomologist* **102**: 353–7

DeBarr GL. 1970. Characteristics and radiographic detection of seedbug damage to slash pine seed. *Florida Entomologist* 53: 109–77

DeBarr GL. 1978. Southwide tests of carbofuran for seedbug control in pine seed orchards. *United States Department of Agriculture Forest Service Research Paper* SE-185 [Asheville, North Carolina: Southeastern Forest Experiment Station]

DeBarr GL, Ebel BH. 1974. Conelet abortion and seed damage of shortleaf and loblolly pines by a seedbug, *Leptoglossus corculus* (Hemiptera: Coreidae). *Forest Science* 20: 165–70

DeBarr GL, Merkel EP. 1971. Mist blower spraying of longleaf pine for cone and seed insect control. *United States Department of Agriculture Forest Service Research Paper* SE-76 [Asheville, North Carolina: Southeastern Forest Experiment Station]

DeBarr GL, Merkel EP, O'Gwynn CH, Zoerb MH Jr. 1972. Differences in insect infestation in slash pine seed orchards due to phorate treatment and clonal variation. *Forest Science* **18:** 56–64

Ebel BH. 1965. The *Dioryctria* coneworms of north Florida pines (Lepidoptera: Pyralidae). *Annals of the Entomological Society of America* **58:** 623-30

Ebel BH, Flavell TH, Drake LE, Yates HO III, DeBarr GL. 1980. Seed and cone insects of southern pines. *United States Department of Agriculture Forest Service General Technical Report* **SE-8 (revised)** [Asheville, North Carolina: Southeastern Forest Experiment Station]

Fettig CJ, Berisford CW. 1999. Nantucket pine tip moth phenology in eastern North Carolina and Virginia: implications for effective timing of insecticide applications. *Southern Journal of Applied Forestry* 23: 30–8

Garguillo PM. Berisford CW, Canalos CG, Richmond JA. 1983. How to time dimethoate sprays against the Nantucket pine tip moth. *Georgia Forestry Commission Research Paper* 44 [Macon: Georgia Forestry Commission]

Garguillo PM, Berisford CW, Canalos CG, Richmond JA, Cade SC. 1984. Mathematical descriptions of *Rhyacionia frustrana* (Lepidoptera: Tortricidae) cumulative catches in pheromone traps, cumulative eggs hatching, and their use in timing of chemical control. *Environmental Entomology* **3:** 168 I-S

Garguillo PM, Berisford CW, Godbee JW. 1985. Prediction of optimal timing for chemical control of the Nantucket pine tip moth. *Rhyacionia frustrana*, (Comstock) (Lepidoptera: Tortricidae) in the southeastern coastal plain. *Journal of Economic Entomology* **78:** 148–54

Hanula JL, DeBarr GL, Berisford CW. 1984*a*. Oviposition behavior and temperature effects on egg development of the southern pine coneworm, *Dioryctria amatella* (Lepidoptera: Pyralidae). *Environmental Entomology* 13: 1624–6

Hanula JL, DeBarr GL, Harris WM, Berisford CW. 1984*b*. Factors affecting catches of male coneworms, *Dioryctria* spp., (Lepidoptera: Pyralidae), in pheromone traps in southern pine seed orchards. *Journal of Economic Entomology* **77:** 1449–53

Hanula JL, DeBarr CL, Berisford CW. 1985. Adult activity of *Dioryctria amatella* (Lepidoptera: Pyralidae) in relation to development of immature stages in loblolly pine cones. *Environmental Entomology* 14: X42-S

Hanula JL, DeBarr GL, Berisford CW. 1987. Threshold temperature and degree-day estimates for development of immature southern pine coneworms (Lepidoptera: Pyralidae) at constant and fluctuating temperatures. *Journal of Economic Entomology* **80**: **6 2 - 4**

Haverty MI. Shea PJ, Stipe LE. 1986. Single and multiple applications of fenvalerate to protect western white pine cones from *Dioryctria abietivorella* (Lepidoptera: Pyralidae). *Journal of Economic Entomology* **79**: 158–6 1

Lowe WJ, Barber LR. Cameron RS, DeBarr GL, Hodge CR, Jett JR, McConnell JL, Mangini AC, Nord JC, Taylor JW. 1994. A southwide test of bifenthrin (Capture") for cone and seed insect control in seed orchards. *Southern Journal of Applied Forestry* **18: 72-S**

Mangini AC, Barber LR, Cameron RS. DeBarr GL, Hodge GR, Jett JR, Lowe WL, McConnell JL, Nord JC, Taylor JW. 1998. A southwide rate test of azinphosmethyl (Guthion®) for cone and seed insect control in loblolly pine seed orchards. *Southern Journal of Applied Forestry* **22:** 1 Oh- IO

McLeod PJ. Yearian WC. 1979. Insect control tactics in loblolly pine seed orchards. *Arkansas Farm Research* **28: 4**

McLeod PJ. Yearian WC. 1981. Insects associated with pine seed production in Arkansas. *University of Arkansas Experiment Station Bulletin* X.50 [Fayetteville: University of Arkansas]

McLeod PJ, Yearian WC. 1982. *Dioryctria* coneworm adult activity in a loblolly pine seed orchard in Arkansas. *Journal of the Georgia Entomological Society* **17:** 513–7

Merkel EP. 1964. Hydraulic spray application of insecticides for control of slash pine seed and cone insects. *United States Department of Agriculture Forest Service Research Note* **SE-9** [Asheville, North Carolina: Southeastern Forest Experiment Station]

Merkel EP, DeBarr GL. 1971. Trunk implantations of dicrotophos for cone-insect control in slash pine seed production stands. *Journal of Economic Entomology* **64:** 1295–8

Merkel EP, Fatzinger CW. 1971 Periodic abundance of pine cone-infesting Lepidoptera in black light traps and sleeve cages in north Florida. *Florida Entomologist* 54: 53–61

Merkel EP, Yandle DO. 1965. Mist blower applications of insecticides for cone and seed insect control on slash pine. *United States Department of Agriculture Forest* Service *Research Note* SE-52 [Asheville, North Carolina: Southeastern Forest Experiment Station]

Merkcl EP, DeBarr GL, O'Gwynn CH. 1976. Mist blower application of Guthion for cone insect control in slash pine seed orchards. *United States Department of Agriculture Forest Service Research Paper* **SE-**148 [Asheville, North Carolina: Southeastern Forest Experiment Station]

Meyer WL, DeBarr GL, Hanula JL, Kovalev B, Cameron RS, Berisford CW, Roelofs WL. 19X6. Z-l l-hexadecenyl acetate, a sex pheromone for the southern pine coneworm, *Dioryctria amatella* (Lepidoptera: Pyralidae). *Environmental Entomology* **15: 3** 16-20

Neunzig HH, Cashatt ED, Matuza GA. 1964. Observations on the biology of four species of *Dioryctria* in North Carolina (Lepidoptera: Phycitidae). *Annals of the Entomological Society of America 57:* 317-21

Nord JC, DeBarr GL. 1992. Persistence of insecticides in a loblolly pine seed orchard for control of the leaf-footed pine seed bug, *Leptoglossus corculus* (Say) (Hemiptera: Coreidae). *The Canadian Entomologist* **124: 6** 17-29

Nord JC, DeBarr GL, Overgaard NA, Neel WW, Cameron RS, Godbee JF. 1984. High-volume applications of azinphosmethyl, fenvalerate, permethrin, and phosmet for control of coneworms (Lepidoptera: Pyralidae) and seed bugs (Hemiptera: C oreidae and Pentatomidae) in southern pine seed orchards. *Journal of Economic Entomology 77:* 15X9-95

Nord JC. DeBarr GL, Barber LR, Weatherby JC, and Overgaard NA. 1985. Low-volume applications of azinphosmethyl, fenvalerate, and permethrin for control of coneworms (Lepidoptcra: Pyralidae) and seed bugs (Hemiptera: Coreidae and Pentatomidae) in southern pine seed orchards. *Journal of Economic Entomology* **78: 445-50**

SAS Institute Inc. 1990. *SAS/STAT® user's guide, version* 6, *4th edition.* Cary, North Carolina: SAS Institute Inc

Saville, DJ. 1990. Multiple comparison procedures: the practical solution. *American Statistician 44:* 174-80

Tauer CG, Eikenhary RD, LeHar GM. 1983. Light trapping cone and seed insects (Lepidoptera: Pyralidae) of pine in southeastern Oklahoma. *Environmental Entomology* 12: 753-7

van Buijtenen JP, Donovan GA, Long EM, Robinson JF, Woessner, RA. 1971. Introduction to practical forest tree improvement. *Texas Forest Service Circular 207*

Weatherhy JC, DeBarr GL. Barber LR. 1985. Monitoring coneworms with pheromone traps: a valuable pest detection procedure for use in southern pine seed orchards. pp 20X-20 in RC Schmidtling. MM Griggs. (Eds), Proceedings of the 18th Southern Forest Tree Improvement, Long Beach, Mississippi, 21–23 May 1985. Sponsored publication No. 40 of the Southern Forest Tree Improvement Committee, National Technical Information Services, Sprinlield, Virginia

Yates HO III, Ebel BH. 1975. Light-trapping and identifying *Dioryctria* that damage pine cones in northeastern Georgia (Lepidoptera: Phycitidae). *Journal of the Georgia Entomological Society* **10: 7X-X6**

(Received: 23 April 2001; accepted: 18 January 2002)