WITHIN-CROWN DISTRIBUTION OF CONE AND SEED INSECT DAMAGE TO SLASH PINE FLOWERS, CONELETS, AND CONES

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ABSTRACT

From 76 to 87% of the total cone crop was located in the upper half of the tree crowns of slash pines, *Pinus elliottii* Engelm. var. *elliottii,* in Baker County, Florida. The east and south quadrants supported significantly larger crops than the north and west quadrants. The numbers of female strobili attacked by the slash pine flower thrips, *Gnophothrips fuscus*; coneworms, *Dioryctria* spp.; or seedworms, *Laspeyresia* spp., did not differ significantly among the quadrants. Significantly greater numbers and percentages of cones in the upper crown were infested by *Dioryctria* spp. More cones in the upper crown were infested by *Laspeyresia* spp., but the percentage of cones infested, as well as the average number of *Laspeyresia* larvae per cone, did not vary significantly between levels or among quadrants. The proportion of full, empty, and seedbug damaged seed did not differ significantly among quadrants or crown levels.

To insure early detection of insect pest problems in pine seed orchards it is essential to know where infestations are most likely to occur. Within the crowns of individual trees the host structures and insect attacks upon them are not always evenly distributed. Therefore, when collecting data on insect populations or impact in seed orchards, it may be advantageous to select sampling methods which take into account the distribution of host material and/or insect attacks within various sectors (i.e. quadrants and levels) of the crown. In addition, control measures should be directed to the area of the crown where the crop is concentrated or where the greatest losses are anticipated.

MATERIALS AND METHODS

Field layout.—Twelve slash pines, *Pinus elliottii* Engelm. var. *elliottii,* located on the Olustee Experimental Forest, Baker County, Fla., were selected on the basis of being open-grown, with well-developed crowns similar in form to seed orchard trees (Barber 1968). The trees ranged from 43 to 55 ft in total height, and 9 to 13 in. DBH. The lowest limbs were 10 to 17 ft above ground level. Three trees were chosen in each of 4 old-field stands, growing on well-drained flatwoods sites with both slash and longleaf pine, *P. palustris* Mill., present.

The tree crowns were divided into north, east, south, and west quadrants with the aid of plastic ribbon radiating out from the base of the trunk, along N. E., S. E., S. W., and N. W. compass bearings. A ribbon tied around the trunk divided the live crown into upper and lower crown levels. The locations of all female flower, conelet, and cone clusters were deter-

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mined, and each cluster was identified as to quadrant and level by a small numbered tag.

Two-foot-wide bands of aluminum placed around the trunk of each tree prevented squirrels from destroying cones.

The study was begun by tagging conelets and cones in June 1967. In 1968, all female flower clusters were tagged early in January. Each month from June 1967 through September 1968, except November and December 1967, the number of surviving conelets and cones, as well as those lost to mortality factors, was recorded.

Mortality categories.—Because only a few conelets became infected with southern cone rust, *Cronartium strobilinium* (Arthur) Hedgcock and Hahn, or were killed by attacks of coneworms, *Dioryctria* spp., insufficient data were available for analysis of within-crown distribution of these losses (DeBarr and Barber 1974). However, 2 types of conelet mortality occurred in sufficient abundance to analyze statistically.

The slash pine flower thrips, *Gnophothrips fuscus* Morgan, feeds upon female slash pine strobili from twig-bud stage until pollination. While feeding ceases once the strobili are pollinated, mortality of thrips-damaged conelets continues for several months (DeBarr 1969). Therefore, cumulative totals (January-April 1968) of the numbers of thrips-killed conelets were used in the analysis of variance. The 1967 thrips data were not analyzed because the study was begun after many of the thrips-killed conelets had fallen from the trees.

The second category of conelet mortality was damage by *Dioryctria* larvae tunneling vegetative shoots; conelets growing on infested shoots usually died. The numbers of dead conelets resulting from shoot attacks were subjected to an analysis of variance.

Coneworms, *Dioryctria* spp.; seedworms, *Laspeyresia* spp.; the leaf-footed pine seedbug, *Leptoglossus corculus* (Say); and the shieldback pine seedbug, *Tetyra bipunctata* (H.-S.), were the principal insects destroying the seed in slash pine cones. *Dioryctria* attacks were marked by loosely twisting a small piece of colored wire around the cone stalks. Thus, monthly records contained only data on infestations that occurred since the previous tally. A cumulative total of cones infested by *Dioryctria* for 1967 (June-October) and 1968 (January-October) was obtained by combining the monthly records. These yearly totals were analyzed for differences in the number or percentage of cones infested with *Dioryctria* among trees, quadrants, and crown levels.

In September of 1967 and 1968, all cones undamaged by *Dioryctria* spp. were collected by quadrant and level to provide data on the incidence of seedworm, *Laspeyresia* spp., infestation. Following seed extraction, the cones were bisected with a cone cutter (DeBarr and Proveaux 1969) and the number of larval galleries per cone axis recorded. Analyses of variance were used to examine the quadrant and level variation in number and proportion of cones infested by *Laspeyresia,* as well as the mean number of *Laspeyresia* larvae per cone. Seed condition was determined by a radiographic procedure (DeBarr 1970). These data were also subjected to analyses of variance.

Data analysis.—The data were summarized with a PL/I computer program. The mortality percentages for each category were based upon the total number of conelets or cones present in each octant on the first observation date each year. Analyses of variance to test for statistically significant differences in the distribution of conelets and cones, and for losses in each mortality category among trees, quadrants, and levels were run, utilizing Statistical Analysis System (SAS) programs. Duncan's New Multiple Range test (DNMRt) was used to determine the statistical significance of quadrant differences.

Where sufficient data were available, an analysis of variance was run on the mortality for a single month. In some analyses, missing plots made it necessary to combine data from upper and lower crown levels into quadrant totals, or calculate level totals by combining the quadrant data for each level. These quadrant or level totals were then used in a simplified analysis of variance.

Results and Discussion

Among-tree variation of insect attacks.—Analyses of variance of infestation or strobili mortality showed significant differences among trees for the following factors: conelets killed by thrips ($p=0.01$), conelets indirectly killed by *Dioryctria* shoot attacks ($p=0.01$), and cones infested with *Dioryctria* ($p=0.001$) or *Laspeyresia* ($p=0.0001$). These differences may reflect local environmental effects, but apparent differences in inherent susceptibility of individual trees to *Dioryctria, Laspeyresia,* and thrips (DeBarr *et al.* 1972, Merkel *et al.* 1965, Merkel 1967a) have been reported.

Highly significant differences ($p=0.01$) in the proportion of full, seedbug-damaged, and empty seed occurred among trees in 1967 and 1968. DeBarr *et al.* (1972) previously reported clonal differences in susceptibility of slash pines to seedbug damage. Furthermore, the amount of self-pollination varies from tree to tree, and this affects the proportion of empty vs. full seeds per cone (Franklin 1969).

Within-crown distribution of female strobili.—In the analyses of variance of numbers of conelets or cones present at several different times during female strobili development, all F-tests showed highly significant differences ($p=0.0001$) among trees and between the upper and lower crown levels. From 76 to 87% of the total conelet or cone crops were found in the upper crown (Table 1). Cone production is generally greatest in the upper crowns of conifers, as reported for Douglas fir, *Pseudotsuga menziesii* (Mirb.) Franco, (Kozak *et al.* 1963, Winjum and Johnson 1964); red pine, *Pinus resinosa* Ait., (Hard 1964); longleaf pine, *P. palustris* Mill., (Coyne 1968); and shortleaf pine, *P. echinata* Mill., (Coulson and Franklin 1968).

The numbers of conelets differed significantly ($p=0.05$) among the quadrants in both years. Numbers of cones differed significantly ($p=0.05$) among quadrants in 1967, but not in 1968. The DNMRt showed that in 3 out of 4 tests, the east and south quadrants supported significantly larger ($p=0.05$) crops than the north and west quadrants (Table 2). Our findings substantiate the report of a strong non-random east over west distribution of cone initiation on slash pine trees observed by Goddard and Strickland (1965) in a clonal seed orchard at Gainesville, Florida. Later, Smith and Stanley (1969) also found a preponderance of cone initiation on the east crown face for open-grown trees in 3 slash pine stands near Gainesville. They postulated that this distribution was related to the intensity of morning sunshine received on the east crown face during the period (July and August) when flower primordia are initiated. Similarly, branches in the south quadrant

TABLE 1. PERCENTAGE OF TOTAL CONELETS AND CONES BY QUADRANTS AND LEVELS WITHIN THE CROWNS OF 12 SLASH PINES. BAKER CO., FLA.

Cone Crop	Date	Stage of ♀ Strobili Development	No.	Quadrants				Levels	
				S	E	N	W	Upper	Lower
1967	June 1967	Cones	1928	29	31	21	19	76	24
1967	Sept. 1967	Cones	1523	32	27	20	21	76	24
1968	June 1967	Conelets	3820	32	27	20	21	84	16
1968	Jan. 1968	Cones	2829	30	26	21	23	87	13
1968	Sept. 1968	Cones	2103	30	28	22	20	85	15
1969	Jan. 1968	Conelets	5119	30	27	22	21	86	14
1969	Sept. 1968	Conelets	3689	29	29	22	20	87	13

TABLE 2. Mean number of conelets or cones per quadrant on 12 slash pines—Baker Co., Fla.—1967 and 1968.

Cone Crop	Time	Stage of ♀ Strobili Development	Mean Number of Conelets and Cones Per Quadrant*			
1967	June 1967	Cones	49 E	46 S	34 N	31 W
1968	June 1967	Conelets	101 S	84 E	68 W	65 N
	Jan. 1968	Cones	71 S	61 E	54 W	50 N
1969	Jan. 1968	Conelets	127 S	116 E	95 N	89 W

*Any 2 quadrant means not underscored by the same line are significantly different ($p = 0.05$).

are reportedly the most prolific flower producers on other species of conifers, including red pine (Mattson 1972), Douglas fir (Winjum and Johnson 1964), and shortleaf pine (Coulson and Franklin 1968).

Within-crown distribution of insect attacks by quadrant.—There were no statistically significant differences in the numbers of female strobili attacked by thrips, *Dioryctria,* or *Laspeyresia* among the quadrants. Neither did the proportion of the strobili per quadrant damaged or destroyed by *Dioryctria, Laspeyresia* (Table 3), or seedbugs (Table 4) differ significantly.

TABLE 3. QUADRANT AND LEVEL MEANS FOR *Dioryctria* AND *Laspeyresia* INFESTATIONS—12 SLASH PINES—BAKER CO., FLA.

Year	Crown Level or Quadrant	*Laspeyresia* spp.			*Dioryctria* spp.	
		Cones Infested*		Larvae/Cone	Cones Infested**	
		Number	Percent	Number	Number	Percent
1967	Lower	12.6	30.4	0.44	16.3	26.8
	Upper	25.6	35.3	0.50	36.4	30.0
	East	11.6	32.8	0.50	16.6	29.2
	North	9.6	33.3	0.50	11.3	25.0
	South	10.9	37.8	0.49	18.4	31.4
	West	9.6	29.6	0.41	10.7	21.9
1968	Lower	11.5	27.3	0.31	1.5	4.9
	Upper	34.5	23.0	0.30	22.8	12.1
	East	15.0	28.6	0.36	6.3	7.8
	North	13.8	25.9	0.36	5.3	7.4
	South	10.9	20.6	0.23	7.4	8.5
	West	13.6	23.6	0.29	5.9	10.4

*Based upon the number of *Dioryctria*-free cones collected in Sept.
**Based upon the number of cones present at the first observation date of each year.

Analyses of variance of *Dioryctria* cone attacks run on individual monthly data gave results similar to the analyses based upon yearly totals (accumulated cone mortality June—September 1967 and January—September 1968). While tree differences were again significant, there were no significant differences in *Dioryctria* infestation among quadrants.

Our observations agree with previous reports on the distribution of insects in the crowns of other host species. Coulson and Franklin (1968) found that insects (primarily *Dioryctria*) infesting the conelets and cones of shortleaf pine congregated in the upper crown and that the south side (which had the most cones) did not harbor a disproportionate number of insects. Yates and Ebel (1972) found no significant differences in conelet mortality caused by the Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock), among quadrants. Coyne (1968) reported that the longleaf pine seedworm, *Laspeyresia ingens* Heinrich, also did not favor any particular crown direction on longleaf pine.

TABLE 4. QUADRANT AND LEVEL MEANS FOR SEED QUALITY—12 SLASH PINES—BAKER CO., FLA.

Crown Level or Quadrant	Seed Condition*					
	1967			1968		
	Full	Seedbug Damaged	Empty	Full	Seedbug Damaged	Empty
Lower	79.8	10.1	10.1	79.3	12.6	8.1
Upper	84.1	7.0	8.9	80.1	10.0	9.9
East	82.7	8.5	8.8	77.9	11.8	10.3
North	77.4	9.2	13.4	80.1	9.3	10.6
South	83.8	8.3	7.9	83.2	8.1	8.7
West	87.2	6.4	6.4	79.9	10.6	9.5

*All figures are percents.

Within-crown distribution of insect attacks by crown level.—Yates and Ebel (1972) reported that the Nantucket pine tip moth killed a significantly greater percentage of the shortleaf pine conelets in the upper crown than in the lower crown. In our study, there were no significant differences between crown levels for the percentages of conelets killed by thrips. The proportion of full, seedbug-damaged, and empty seeds also did not differ significantly between crown levels in either 1967 or 1968 (Table 4).

A significantly greater number and percentage of cones ($p = 0.001$) were infested by *Dioryctria* in the upper tree crown (Table 3).

Significantly greater numbers of cones ($p = 0.001$) were infested with *Laspeyresia* in the upper tree crown, but the percentage of infested cones, as well as the mean number of *Laspeyresia* larvae per cone, did not differ significantly between crown levels (Table 3). Abrahamson and Kraft (1965) found the highest population densities of the eastern pine seedworm, *L. toreuta* Grote, on the lower 10 ft of the tree crowns of jack pine, *Pinus banksiana* Lamb. Coyne (1968) also observed that *L. ingens* favors cones in the lower crown of longleaf pine for oviposition. The slash pine seedworm, *L. anaranjada* Miller, is the predominant species infesting slash pine cones (Merkel 1967b), with occasional attacks by *L. ingens*. Perhaps *L. ingens* prefers the lower tree crown, while *L. anaranjada* seeks oviposition sites in the upper crown.

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