Evidence of Inherent Resistance to *Dioryctria* Infestation in Slash Pine

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INTRODUCTION

Tree improvement workers are interested in developing strains of pines resistant to destructive insects. The objectives, methods, possibilities, and limitations of pest-resistance improvement in trees have been discussed thoroughly by Holst and Heimburger (1955), Schreiner (1960), and Soegaard (1964). We shall present evidence of resistance of individual slash pines, Pinus *elliottii* Engelm., to cone and stem infestation by *Dioryctria* spp. *Lepidoptera: Phycitidaei.* In these studies, mature cones were attacked by *Dioryctria abietella* (D. & S.) and D. *amatella* (Hulst), whereas stem infestation was by the latter species only.

Dioryctria larvae are very destructive to the seed crops in southern pine seed orchards and natural seed-production areas. Annually they destroy from 20 to 50 percent of the slash pine seed crop in such areas in north Florida, where chemical control is not used. Although extensive reliable data on the economic importance of stem attacks is lacking, D. *amatella* is known to cause serious damage to young plantations of either seedlings or grafted trees. Larvae bore meandering galleries in the phloem of the main stem and eventually enter the xylem, particularly in tissues infected with southern fusiform rust. The larval galleries frequently girdle young trees resulting in their death; whereas larger stems often become weakened and break during high winds. Crooked trees may also result from larvae destroying the terminal shoots.

CONE ATTACK

Evidence of inherent resistance of mature cones to infestation by *Dioryctria* coneworms

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Table 1. Record of mature cones harvested from 10 slash pines and the incidence of infestation by *Dioryctria* spp. -- Olustee, Florida, 1956-1958.

Tree Number	1956 Total cone crop	1956 Total cones infested		1957 Total cone crop	1957 Total cones infested		1958 Total cone crop	1958 Total cones infested		3-year weighted average infestation
	Number	Number	Percent	Number	Number	Percent	Number	Number	Percent	Percent
10	244	70	28.7	180	15	8.3	178	23	12.9	17.9
14	465	207	44.5	239	61	25.5	410	121	29.5	34.9
23	78	44	56.4	409	16	3.9	508	66	13.0	12.7
30	373	164	44.0	205	14	6.8	185	64	34.6	31.7
34	225	88	39.1	329	17	5.2	196	70	35.7	23.3
35	307	179	58.3	199	41	20.6	366	87	23.8	35.2
50	204	81	39.7	172	31	18.0	151	43	28.5	29.4
59	266	83	31.2	421	36	8.6	401	31	7.7	13.8
61	149	99	66.4	283	60	21.2	23	14	60.9	38.0
75	385	181	47.0	343	46	13.4	379	111	29.3	30.5
Totals	2,696	1,196		2,780	337		2,797	630		
Averages	270	120	44.4	278	34	12.1	280	63	22.5	

Table 2. Percent[1] mature slash pine cones infested by Dioryctria spp. expressed as departures from yearly averages at Olustee, Florida.

Year	Tree number									
	10	14	23	30	34	35	50	59	61	75
	Percent									
1956	-18.4	+12.1	-2.2	+5.4	-9.4	+15.2	-10.2	-14.6	+12.8	+9.2
1957	-8.1	+10.3	-5.0	-8.5	-6.2	+3.4	-0.2	+1.8	+8.5	+3.6
1958	-18.6	+10.7	-2.1	+1.4	+3.2	+1.8	-6.2	-14.6	+16.4	+8.5
	R[2]	S[3]						R	S	

1/ Adjusted for cone crop size by analysis of covariance

2/ R = apparently resistant tree

3/ S = apparently susceptible tree

was obtained in a 4-acre, 21-year-old, natural slash pine-seed production area at Olustee, Florida. The area had been thinned to 33 seed trees per acre in late 1953. For 3 consecutive years, starting in 1956, all mature cones were harvested from 10 trees, and total numbers of cones attacked by coneworms were determined (table 1).

It should be noted that our recorded data for Dioryctria cone attack represent only that portion of the second-year cones infested during the period from early June through cone harvest time (mid-September). Second-year cones attacked prior to June have usually dried up and dropped off the tree by cone harvest. Coneworms also kill many first-year cones.

RESULTS AND DISCUSSION

Correlation analysis of data in table 1 showed that the number of Dioryctria attacks on mature slash pine cones were positively correlated with the total mature cone crop. The pooled correlation coefficient (0.62), within years, was highly significant. Covariance analysis showed that the numbers of cones attacked among trees, after adjusting for the effect of cone-crop size, was highly significant.

Further analysis showed that percent cones infested was also related to the size of the mature cone crop per tree. The within-years pooled correlation coefficient (-0.51) was negative but still highly significant. As in the case of numbers of cones attacked, covariance analysis of percent infestation (transformed to arcsin angles) showed highly significant tree effects.

It is difficult to explain the biological significance of the negative relationship between percent infestation and size of mature cone crop. Hansberry and Richardson (1935) found a similar relationship between the percent apples infested with codling moth larvae and the total apple crop per tree.

The apparent resistance and susceptibility of certain trees to cone attack by Dioryctria spp. is shown in table 2. The data in table 2 were computed by adjusting the percent cones infested for cone crop size by covariance analysis and expressing the adjusted percent as a departure from the yearly average percent infestation for all trees. On this basis, trees 10 and 59 showed fairly consistent below-average coneworm attack for 3 consecutive years and might be judged relatively resistant. Conversely, trees 14 and 61 demonstrated consistent susceptibility to attack.

Although inherited resistance of cones to Dioryctria attack is not proven by these data, it is strongly suggested. Progeny tests are needed to verify or nullify this hypothesis.

Table 3. Degree of stem attack by Dioryctria amatella in 4-year-old planted slash pines (Progeny Planting G-48-A), Olustee, Florida--1964.

Progeny	Trees infested	Progeny	Trees infested
	Percent[1]		Percent[1]
G-1 x G-196	10.0	G-148 x W	2.5
G-1 x G-202	27.5	G-151 x W	7.5
G-10 x W	5.0	G-153 x W	10.0
G-11 x W	10.0	G-155 x W	7.5
G-27 x W	7.5	G-156 x W	10.0
G-29 x W	.0	G-157 x W	5.0
G-105 x W	5.0	G-159 x W	7.5
G-107 x W	15.0	G-160 x W	15.0
G-108 x W	12.5	G-162 x W	5.0
G-109 x W	10.0	G-163 x W	.0
G-123 x W	.0	G-164 x W	2.5
G-126 x W	5.0	G-165 x W	5.0
G-129 x W	5.0	G-166 x W	5.0
G-31 x W	7.5	G-167 x W	7.5
G-133 x W	25.0	G-168 x W	7.5
G-134 x W	2.5	[2] CBC	5.0
G-137 x W	10.0	[2] 19-SPAC	5.0
G-146 x W	5.0	[2] NF-SPAC	12.5
		Average	7.8

1/ Based on 40 trees per progeny; each tree was classified as infested if it had at least one active pitch mass on the main stem.

2/ Control lot.

STEM ATTACK

Evidence of inherent differences among trees in susceptibility to stem attack by Dioryctria amatella was obtained in three plantations at Olustee, Florida. These plantations are briefly

Table 4. Degree of stem attack by Dioryctria amatella in slash pine progeny planting G-48-B, Olustee, Florida--1964.

Progeny	Trees infested
	Percent 1/
G-1 x G-195	20.0
G-1 x G-196	15.0
G-1 x G-197	22.5
G-1 x G-198	5.0
G-1 x G-199	32.5
G-1 x G-200	2.5
G-1 x G-201	32.5
G-1 x G-202	32.5
G-1 x G-203	15.0
Average	19.7

1/ Based on 40 trees per progeny.

described below:

1. Progeny Plantation G-48-A.--This is a 4-year-old progeny test of selections for either high gum yield or rapid growth rate. It includes 36 progenies, most of which were wind-pollinated (table 3). The design is a randomized block type, with 40 trees per progeny planted in 4-tree row-plots in each of 10 replications.

2. Progeny Plantation G-48-B.--This is also a progeny test, similar to G-48-A, excepting that there were nine progenies in all. The progenies all had a common female parent but different male parents (table 4). The plantation is located adjacent to G-48-A.

3. Clonal Plantation NS-112.--This plantation includes 24 7-year-old ramets of each of 26 trees (table 5). There are three ramets in each of eight blocks. The ortets of the clones are located in a progeny test and hence are of known parentage.

The numbers of trees with stems attacked by Dioryctria amatella in these plantations were recorded in the spring of 1964.

RESULTS AND DISCUSSION

Progeny Test G-48-A.--Percentage trees infested in this plantation varied from 0 for several progenies (G-29 x W, G-123 x W, and G-163 x W) to as high as 27.5 for progeny G-1 x G-202 (table 3). An analysis of variance of the number of trees infested per plot, showed that differences among progenies were significant at the 1-percent level. The intraclass correlation coefficient (r_I) for progenies was .09 (Snedecor, 1956, P. 282).

Progeny Test G-48-B.--In this plantation, where all progenies had a common female parent, infestation was high in seven progenies and low in two (table 4). An analysis similar to that conducted in G-48-A showed that differences among progenies were highly significant and r_I for progenies was .20.

Clonal Plantation NS-112.-- Percentage of trees infested varied from 0 for clones 1-6-4, 1-1-4, 6-4-7, and 2-9-1 to as high as 42 for clone 1-3-7 (table 5). An analysis of variance was run on the percentage of trees infested per block. (In this analysis clones 8-8-1 and 3-8-7 were omitted because they were represented on only four of the blocks.) Differences between clones were highly significant and r_I for clones was .31.

Note that some groups of clones are full-sibs, having two common parents, and others are half-sibs, having one common parent. In some of these families variation among clones was high. For example, among the 4 clones

Table 5. Degree of stem attack by Dioryctria amatella in slash pine clonal plantation NS-112, Olustee, Florida--1964.

Clone number	Parentage	Ramets per clone	Ramets infested
		Number	Percent
2-5-6	G-1 x G-2	22	4
4-2-7	G-1 x G-2	24	4
6-9-6	G-1 x G-2	21	14
8-8-1	G-1 x G-2	12	30
2-1-4	G-1 x G-7	22	36
3-3-5	G-1 x G-7	24	25
1-3-7	G-1 x W	24	42
1-6-4	G-2 x W	24	0
3-8-3	G-2 x W	24	38
4-7-5	G-2 x W	24	4
7-5-4	G-2 x W	24	12
1-1-4	G-3 x G-2	24	0
7-7-1	G-3 x G-6	20	5
7-4-3	G-3 x W	24	8
2-3-4	G-4 x G-1	23	4
3-8-7	G-4 x G-1	12	36
6-4-7	G-4 x G-1	24	0
6-9-7	G-4 x G-1	24	25
4-3-2	G-4 x W	24	17
6-2-3	G-4 x W	24	4
2-9-1	G-6 x G-3	24	0
7-9-5	G-8 x W	24	4
2-7-3	G-10 x G-7	24	21
3-9-6	G-10 x G-7	24	8
4-7-3	G-10 x G-7	24	8
4-10-5	G-25 x W	24	4
Average			13.6

of the mating G-1 x G-2 stem attack varied from 4 to 30 percent. In other families, such as G-1 x G-7 and the G-3 half-sibs, consistency prevailed.

The results suggest that inherent differences occur among individual slash pines in susceptibility to stem attack by Dioryctria amatella. This conclusion is based mainly on the fact that significant differences due to clones or progenies were found in all plantations. However, further evidence is apparent in the degree of infestation of progenies of G-1, which are represented in all plantations. Although progenies of this tree varied considerably within plantations, the plantation averages were consistently high, as indicated in the following tabulation:

Average stem attack by D. amatella

Plantation	Progenies having G-1 as a parent	Progenies not having G-1 as a parent
	Percent	Percent
G-48-A	18.8	7.2
G-48-B	19.7	---
NS-112	20.0	8.9

Thus, G-1 seems to be relatively susceptible. Among other parents involved in plantation NS-112, G-7 also seems to be relatively susceptible, while G-3 is relatively resistant.

Note also that G-1 x G-196 and G-1 x G-202 were represented in both plantation G-48-A and G-48-B. In both plantations the latter cross had more stem attacks than the former.

SUMMARY AND CONCLUSIONS

Cone infestation by Dioryctria amatella and D. abietella were studied on 10 mature slash pines over a period of 3 years. Covariance analysis revealed that some trees experienced either consistently low or consistently high cone attack from year to year independent of the total mature cone crop per tree. This suggests that inherent differences in resistance to cone worm attack exist in slash pine.

Stem infestation of young trees by Dioryetria amatella was studied in a clonal plantation and two progeny tests. Large differences in the degree of infestation occurred among clones or progenies, suggesting some degree of genetic control over this trait also.

Results point to the possibility of selection and breeding for resistance to Dioryctria spp.

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