Inheritance of Stem and Branch Characters
in Slash Pine and Relation to Gum Yield

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The original tree improvement program at Olustee, Florida was confined to selection and breeding for increased gum yield. Recently the program has been modified to include combining gum yield with other desirable traits (Squillace, 1965). In accordance with the revised objective, the present study was designed to determine inheritance of number of crooks per foot, degree of crook, size of branches, and crown width ratio and to determine relationships of these traits with gum yield. Data for this study were obtained from three sources:

1. Progeny plantation 0-116.--This plantation was established from 1-year-old seedlings in June 1946, at Olustee. Parents of the trees had been selected for either high, average, or low gum yield ability. Both wind- and cross-pollinated progenies were included. The plot layout consisted of 7 blocks, each containing from 2 to 6 individuals per progeny, randomly positioned in each block. Spacing was 20 by 20 feet. Twenty-six of the progeny trees were selected for either high-or average-gum yielding ability and used as ortets in establishing clones for clonal plantation NS-112, described below. Likewise, 9 high yielders were selected and used as ortets for clones in clonal orchard G-24, also described below.

2. Clonal plantation NS-112.--This plantation was established at Olustee over the period 1957 to 1959. The plot layout consisted of a split block, split plot design with each of eight randomized treatments being replicated three times. The treatments were: irrigation, fertilization, cultivation, and combinations thereof. Spacing was 20 by 20 feet. There were 24 ramets of each of 24 clones and 12 ramets of each of 2 clones in this plantation.

3. Clonal plantation G-24.--This plantation was established in 1957-58 on the Osceola National Forest, several miles northeast of Lake City, as a seed orchard. It included 26 ramets of each of 6 clones and 22 ramets of each of 3 clones. It contained 13 blocks, with 2 ramets of each clone being located in each block. Spacing was 30 by 30 feet.

MEASUREMENTS

Crown and stem form measurements were made on all ortets and ramets in the spring of 1965. The following traits were measured: total height, number of crooks, degree of crook, size of branches, and crown width. Gum-yield data for plantation 0-116 were available from standard face chipping in 1964.

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The number of crooks were counted by the same individual on all plantations. The number of crooks were then divided by total height to obtain number of crooks per foot. This procedure minimized the effect of age and total height on the number of crooks. To have real meaning, the amount or degree of crook must also be considered along with the number of crooks. Goddard and Strickland (1964) used a "crook index," which was the product of the number of crooks in the first log times the deviation of the most severe crook from a straigh line along the bole, to express this relationship. However, because of the large amount of time that would be required for obtaining such measurements, an ocular estimate of the degree of crook was used for this study. The trees were classified as straight, slightly crooked, crooked, and very crooked. These classifications were then arbitrarily assigned values ranging from one for straight to four for very crooked so they could be statistically evaluated.

Size of branches was also an ocular estimate, made by one person on all plantations. Branches were classified as small, medium, large, and extra large. These classifications were then arbitrarily assigned values ranging from one for small to four for extra large so they could be statistically evaluated. Crown widths were measured at the widest portion of the crown. Crown width ratios were obtained by dividing the crown width by total height. Fastigiate or upturned branches and forking or tendency to fork were also recorded in the ramets and ortets.

Table 1. Ortet data and clonal means for various traits studied.

Ortet (clone) number	Parent-age	Ortet data					Clonal data			
		Gum yield (coded, x 1/10)	Crooks per foot	Index of degree of crook	Index of size of branches	Crown width ratio	Crooks per foot	Index of degree of crook	Index of size of branches	Crown width ratio
		Grams	Number				Number			
			0-116				NS-112			
8-8-1	1x2	488	.189	4	3	.321	.310	3.75	3.00	.700
4-2-7	1x2	626	.140	3	2	.442	.288	2.88	2.88	.671
2-5-6	1x2	749	.179	4	2	.339	.274	3.18	2.45	.740
6-9-6	1x2	852	.135	3	2	.365	.301	2.95	2.62	.583
3-3-5	1x7	745	.167	3	3	.389	.322	3.59	3.18	.728
2-1-4	1x7	1,123	.167	3	3	.407	.477	3.32	3.18	.620
1-3-7	1xW	539	.170	2	1	.340	.270	2.96	2.83	.706
1-6-4	2xW	378	.125	3	1	.268	.219	2.47	1.67	.591
7-5-4	2xW	609	.111	4	1	.278	.233	2.63	2.67	.666
4-7-5	2xW	628	.189	3	2	.358	.288	3.04	2.25	.673
3-8-3	2xW	852	.145	2	2	.327	.268	3.08	3.00	.658
1-1-4	3x2	314	.161	3	2	.357	.245	3.00	2.63	.695
7-7-1	3x6	460	.154	3	3	.423	.235	2.45	2.70	.638
7-4-3	3xW	466	.128	2	2	.340	.232	2.71	2.75	.644
2-3-4	4x1	678	.057	1	1	.358	.204	2.22	2.48	.623
6-4-7	4x1	749	.143	2	2	.306	.216	2.21	1.96	.530
6-9-7	4x1	975	.170	3	3	.340	.238	2.63	3.17	.619
3-8-7	4x1	1,092	.094	2	3	.396	.266	3.17	3.75	.727
4-3-2	4xW	619	.188	3	2	.354	.264	2.63	2.79	.590
6-2-3	4xW	851	.094	2	3	.340	.218	2.63	2.79	.581
2-9-1	6x3	276	.111	2	2	.378	.230	2.21	2.25	.644
7-9-5	8xW	609	.250	2	2	.375	.290	2.92	2.33	.722
3-9-6	10x7	684	.080	3	1	.340	.240	2.63	2.58	.660
2-7-3	10x7	693	.135	3	1	.346	.256	2.88	2.50	.667
4-7-3	10x7	796	.160	4	2	.380	.283	3.25	2.88	.715
4-10-5	25xW	356	.163	2	2	.395	.295	3.46	3.04	.732
			0-116				G-24			
1-7-5	1x2	685	.113	2	2	.340	.209	2.38	2.31	.445
2-6-2	1x2	785	.192	3	2	.346	.238	2.73	2.35	.471
8-9-2	2x1	604	.160	2	2	.340	.158	2.10	1.95	.400
3-8-7	4x1	1,092	.094	2	3	.396	.167	2.12	3.04	.471
4-3-4	4x1	1,186	.148	2	2	.370	.146	1.81	2.31	.423
7-1-7	4x1	1,348	.152	2	3	.413	.140	1.82	2.55	.447
8-9-3	4x2	820	.100	2	1	.280	.118	1.65	1.31	.315
8-10-3	4x2	833	.075	2	2	.283	.131	1.82	1.82	.394
8-7-3	4x2	1,128	.153	3	2	.305	.097	1.58	1.85	.345

STATISTICAL PROCEDURES

Analyses were computed for the traits shown in Table 1. Correlations were computed between identical traits in the ortets and clones, using clonal means for the latter. In addition, regressions were computed between gum yield of ortets and the four measures of crown and stem form, in both the ortets and clones. NS-112 and G-24 data were pooled in these analyses.

Analyses of variance were run on both NS-112 and G-24 data. One block of NS-112 was not used in this analysis because of missing trees, which reduced the number of ramets to 16 for each of the 24 clones. In G-24, 26 ramets of each of 6 clones were used in the analysis.

RESULTS AND CONCLUSIONS

Clone-ortet correlations were significant for all traits studied, with size of branches being highly significant. The following tabulation presents the pooled correlation coefficients (r) and regression coefficients (b).

Trait	r	b
Number of crooks per foot	0.424*	0.5415
Degree of crook	.396*	.2086
Size of branches	.635**	.4069
Crown width ratio	.435*	.5761

 *Significant at 5-percent level.
**Significant at 1-percent level.

The results suggest that all of these traits are inherited to a moderately strong degree.

Tendency toward fastigiate or upturned branching habit also seems to be inherited. Clones from ortets having fastigiate branches usually, but not always, had relatively large numbers of fastigiate ramets. Clones from fastigiate ortets had an average of 48 percent fastigiate ramets, while clones from non-fastigiate ortets had an average of only 4 percent fastigiate ramets.

Tendency to fork appeared to be more affected by environmental factors than did fastigiate branching. When the ortets were classified as having a tendency to fork, 34 percent of their ramets had a tendency to fork. When the ortets were classified as not having a tendency to fork, 17 percent of their ramets had a tendency to fork. There does not appear to be any correlation between fastigiate branching and tendency to fork. A more refined study is needed to determine heritability of fastigiate branching and forking.

Inheritance of the four major traits studied was also demonstrated by analysis of variance of clonal data (Table 2). Clonal effect was highly significant for the four traits studied in both NS-112 and G-24. Broad sense heritability estimates for the four traits follow:

Trait	NS-112	G-24
Number of crooks per foot	0.29	0.47
Degree of crook	.30	.38
Size of branches	.31	.48
Crown width ratio	.40	.47

Mergen (1955) previously examined sweep in progeny plantation 0-116 of the present study. He found the progenies of parent trees with large sweep had a high percentage of undesirable trees. The number of undesirable trees in the progeny of one tree (parent tree No. 3), was highly significantly greater than in the progeny from the other trees.

Heritability of stem crook was demonstrated for loblolly pine by Goddard and Strickland (1964), who reported an intraclass correlation of 0.48 from progeny data.

Barber (1964) reported a narrow sense heritability of 0.16 to 0.19 for crown width in his study of slash pine. Squillace and Bengtson (1961) reported two estimates of narrow sense heritability for crown width, 12 percent and 24 to 48 percent, in slash pine.

Table 2. Analyses of variance and estimates of broad sense heritability (r_I) obtained from clonal data.

Source of variance	Degrees of freedom	Number of crooks per foot — Mean squares	r_I	Degree of crook — Mean squares	r_I	Size of branches — Mean squares	r_I	Crown width ratio — Mean squares	r_I
				NS-112					
Irrigation (I)	1	.2493*		25.010*		1.628		0.199	
Blocks (B)	1	.0370		.667		.211		.013	
Error 1 (IxB)	1	.0015		.011		1.966		.018	
Fertilization (F)	1	.0006		.010		2.190		.005	
Cultivation (Cu)	1	.0001		1.760		6.773**		.060*	
FxCu	1	.0154		.168		.066		.001	
IxF	1	.0006		.043		.586		.006	
IxCu	1	.0184		.668		.315		.001	
IxFxCu	1	.0023		.091		.752		.004	
Error 2	6	.0042		.561		.453		.006	
Clones (C1)	23	.0173**	0.29	2.450**	0.30	2.428**	0.31	.054**	0.40
C1xI	23	.0038		.282		.296		.003	
C1xF	23	.0025		.228		.304		.004	
C1xCu	23	.0021		.239		.377		.004	
C1xFxCu	23	.0021		.286		.310		.005	
C1xIxF	23	.0011		.389		.178		.005	
C1xIxCu	23	.0020		.275		.353		.005	
C1xIxFxCu	23	.0025		.413		.204		.009**	
Error 3	182	.0023		.318		.293		.004	
				G-24					
Clones (C1)	5	.0751**	0.47	5.299**	0.38	8.677**	0.48	.115**	0.47
Block (B)	12	.0043		.231		.728		.005	
C1xB (error)	60	.0040		.408		.433		.007	
Within plots	78	.0022		.217		.258		.003	

* Significant at the 5-percent level.
** Significant at the 1-percent level.

Some effects of cultural treatments were found. Trees in irrigated plots had an average of .27 crooks per foot and an index of degree of crook of 3.1, while those in non-irrigated plots averaged .22 and 2.6 respectively. Both differences were signficant at the 5-percent level. Trees in cultivated plots had an average size-of-branches index of 2.8 and a crown width ratio of .67, while those in non-cultivated plots average 2.6 and .65, respectively. Reasons for these effects are unknown.

Gum yield was not significantly related to any of the crown or stem characters studied. [?] Thus, high yielding ortets and their clones were found to have as good crown and stem form as low yielding ortets and their clones. This important finding suggests that high gum yield and good form can readily be combined, in a selection and breeding program.

2/ Crown width ratio studied here should not be confused with crown length ratio, which has previously been shown to be related to gum yield by Bengtson and Schopmeyer, 1959, and others.

SUMMARY

Ortet data were obtained from a 19-year-old progeny plantation (0-116), and ramet data were obtained from two clonal plantations, NS-112 and G-24. Stem and branch characters studied included numbers of crooks per foot, degree of crook, size of branches and crown width ratio. Ramet characteristics were significantly correlated with ortet characteristics for all traits studied. Gum yields of ortets were not significantly correlated to traits studied. Estimates of broad sense heritability, obtained from analysis of variance of clonal plantations NS-112 and G-24, respectively, were as follows: number of crooks per foot, 0.29 and 0.47; degree of crook, 0.30 and 0.38; size of branches, 0.31 and 0.48; crown width ratio 0.40 and 0.47.

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