Combining Superior Growth and Timber Quality with High Gum Yield in Slash Pine[1/]

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Until recently, the tree improvement work of the Naval Stores and Timber Production Laboratory at Olustee, Florida, was concentrated on the development of a high-gum-yielding strain of slash pine. Our success with this effort is well known. However, recent research results show that combining high gum yield with other desirable traits such as rapid growth, straight stems, and small branch size is feasible. In this report I shall give the basis for this statement and then briefly describe the development of seed-production areas and clonal orchards designed to capitalize on the research findings.

BASIS FOR COMBINING DESIRABLE TRAITS

In many plant breeding efforts, the task of attaining appreciable genetic gains for a number of traits in a single strain is difficult and time-consuming. Most breeders are aware of the problems frequently encountered, such as adverse genetic correlations, the reduction in genetic gains (when selecting from a limited population) as each new trait is added, the impracticability of screening all available trees, and the effects of unfavorable gene action. However, in our present effort to combine gum yield with other traits, these problems are not insurmountable, as indicated by the following recent research findings.

1. Gum-yielding ability in slash pine varies greatly among individual trees growing under comparable conditions. This is true even if the effect of stem diameter is discounted. The point is well illustrated in Figure 1, which is based upon microchip yields of 363 20-year-old trees growing in a plantation near Lake City, Florida. The sample includes all trees 2.6 inches d.b.h. and larger in nine systematically selected one-tenth-acre plots. Note that the distribution has a long tail toward the right, a feature also reported by Goddard and Peters (1965). The best 5 percent of the trees yielded an average of about 2.0 times as much as the average tree. The best 10 percent yielded 1.8 times as much as the average tree. The unusually high variation suggests that satisfactory selection differentials for gum yield can be attained, even within relatively small populations of trees selected for other desirable traits.

2. Heritability of gum yield is strong, with narrow sense estimates varying from 45 to 90 percent and broad sense estimates Varying from 67 to 90 percent (Mergen, et al., 1955; Squillace and Bengtson, 1961; Squillace and Dorman, 1961; and Goddard and Peters, 1965). This feature assures relatively high genetic gains in gum yield even if selection differentials need to be reduced because of restricted population size.

3. Gum-yielding ability and growth rate seem to be genetically correlated to at least a moderate degree. This means that the two traits are probably affected by common genes (pleiotropy) and that, since the correlation is positive, a genetic improvement in one will cause simultaneous improvement in the other. Evidence for the relationship was obtained from two studies conducted with slash pine at Olustee.

In our 19-year-old progeny plantation, gum yield was found to be strongly correlated with d.b.h. A covariance analysis showed that, although some of this relation was due to environmental causes, a large part was due to genetic causes. The data suggest that if, through breeding for gum yield alone, we double gum-yielding ability, an increase of about 6 percent in stem diameter growth (or about 12 percent in volume growth) is attained simultaneously.

[1/] The seed-production area discussed in this report was installed in cooperation with the Osceola National Forest. In this effort special thanks are due to Forest Supervisor R.J. Riebold and District Ranger Wm. V. Cranston.

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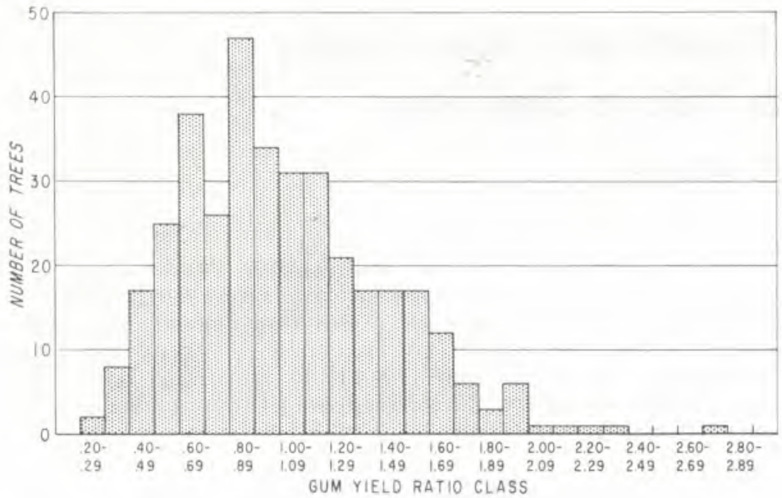

Figure 1 -- Frequency distribution of gum yield ratios (yield of tree/average yield of trees of same d.b.h.) of 20-year-old planted slash pines. Basis, 363 trees.

Table 1. Classification of 363 unselected slash pines in a 20-year-old plantation according to 1) stem straightness and gum yield and 2) branch thickness and gum yield.

Item	High yielders	Medium yielders	Low yielders
	- - - - - - -	Percent	- - - - - - - - -
Stem Straightness			
Straight	3	5	3
Slightly crooked	84	83	86
Very crooked	13	12	11
Branch thickness			
Fine	10	11	15
Medium	75	69	61
Thick	15	20	24

In the other study, reported by Gansel, average heights of 7-year-old clones were found to be correlated with the gum-yielding ability of their ortets to a moderately strong degree (r = .41, significant at the 5 percent level). These results are in harmony with Sulgin's (1964) report that *Pinus nigra* var. *caramanica* trees with high resin yield have high rates of photosynthesis. This fortunate relationship will, of course, facilitate breeding work designed to combine gum yield and growth rate with other traits.

4. There seems to be little or nc correlation between gum-yielding ability and stem straightness or branch thickness. This statement is made on the basis of two studies recently conducted at our Station.

In Gansel's report mentioned earlier, no correlation was found between stem straightness or branch size of 7-year-old clones and the gum-yielding ability of their 19-year-old ortets (Gansel, 1965). Likewise, data from the 20-year-old plantation discussed earlier showed very little correlation between gum yield and either stem straightness or branch size (Table 1). Thus, there seem to be no adverse relationships in respect to stem straightness or branch size to impede development of strains with good gum yield, growth, and form.

5. The frequency of trees that have combinations of all desired traits being considered is apparently relatively high. For example, in the 20-year-old plantation studied, two superior trees were found. One had 2-1/2 times "normal" yield, with a stem volume of 2-1/2 times "normal." The other had a yield superiority of 1-1/2 and a volume superiority of 2. Both were classified as "straight" and "finely-branched." Since only about 4,050 trees were evaluated in the plantation, the frequency of superior trees is very high and lends encouragement to our program.

SEED-PRODUCTION AREA

As an interim measure to obtain seed having modest superiority in gum yield, growth rate, and timber quality, we recently established a 10-acre seed-production area. It was installed on the Osceola National Forest, in the 20-year-old plantation mentioned earlier.

This seed-production area is unique in several respects. First, it was established in a plantation rather than in a natural stand, because selection is more efficient in a plantation than in a natural stand. Secondly, a young stand, 20 years old, was selected. A stand of this age permits evaluation of a greater number of trees than does an old stand, and yet is old enough to begin cone production upon release.

Table 2. Evaluation data for the original stand and selected seed trees in slash pine seed-production area.

Item		Original stand	Seed trees
Trees per acre	Number	404	22
Avg. microchip yield per tree	Grams	222	393
Avg. estimated standard-face, full-season, yield per tree	Grams	1360	2810
Avg. yield ratio[1/]	Ratio	1.01	1.41
Avg. d.b.h.	Inches	5.82	7.11
Avg. total height	Feet	45.3	50.4
Avg. stem volume per tree	Cu. ft.	3.8	6.4
Avg. stem volume per tree, excluding suppressed trees	Cu. ft.	4.4	6.4
Bole straightness:			
Straight	Percent	4	26
Slightly crooked	Percent	84	74
Very crooked	Percent	12	0
Branch thickness:			
Fine	Percent	13	18
Medium	Percent	68	80
Heavy	Percent	19	2
Trees with fusiform rust	Percent	3	0

1/ Yield of tree/average yield of trees of same d.b.h., using estimated standard face yields.

The plantation is on a flatwoods site of about average site quality. The seed source was north Florida. Spacing was 8 by 8 feet, but subsequent mortality reduced the number of trees per acre to about 400. Systematically spaced sample plots were installed to obtain original stand data for comparison against selections.

We first made a preliminary screening, selecting trees for good growth, stem form, and branching habit, and for freedom from fusiform rust. Then these preliminary selections (about 200 per acre) were microchipped --four bi weekly, one-inch square chips were applied during June and July. A final marking was made, on the basis of gum yield in combination with the other desired traits, leaving about 22 seed trees per acre.

A comparison of data for the original stand and the final selections, or seed trees, is shown in Table 2. Significant features are the high increases in average gum yield, tree size, and proportions of good trees in respect to bole straightness and branch thickness.

It is of interest to estimate the genetic gains expected by using seed from the seed-production area. For gum yield, the gain should be considered as coming from two sources: (1) the superiority of seed trees over average trees of the same d.b.h. and (2) the gain in gum yield resulting from the expected increase in diameter growth.

Assuming a heritability of .50 for gum yield, and using relative yield data of Table 2, we estimated gain from the first source to be

$$\frac{.50\ (1.41-1.01)}{1.01} \times 100 = 20 \text{ percent.}$$

To estimate gain in gum yield from the second source, we first need to determine expected gain in d.b.h. growth. Assuming a heritability of .25 for d.b.h., the expected gain in d.b.h. is .25 (7.11 - 5.82) = 0.32 inch. Now, the estimated standard-face yield of the average tree, 5.8 inches d.b.h., is 1360 grams of gum, while a tree 0.32 inch larger in d.b.h. would yield 1510 grams. Thus, gain from this source is

$$\frac{1510 - 1360}{1360} \times 100 = 11 \text{ percent.}$$

Total expected gain in gum yield, then, is 20 + 11 = 31 percent.

The expected gain in growth rate is probably best estimated using volume increase data. If heritability of this trait is assumed to be 25 percent, expected gain is

$$\frac{.25\ (6.4 - 4.4)}{4.4} \times 100 = 11 \text{ percent.}$$

Genetic gains in stem straightness, branch size, and rust resistance are difficult to estimate because of the nature of these data. However, from our knowledge of the inheritance of stem straightness and branch size, appreciable gains can be expected for these traits. Little can be said of possible gain in rust resistance because of the low incidence of rust in the stand.

CLONAL SEED ORCHARDS

As mentioned earlier our long-term, concerted effort to develop a strain of slash pine having a combination of superior traits will be through the clonal seed orchard approach. Briefly, we are working within a framework of trees already selected for superiority in growth and timber quality, seeking out among them those individuals which are the highest gum yielders. The job entails cooperation with a number of organizations which in the past have made slash pine selections for growth and timber quality characteristics. Steps in the procedure are outlined briefly below.

1. Cooperators' superior trees will be evaluated for gum yielding ability by one of the following procedures, depending upon particular circumstances: (1) microchipping of clonal orchards (as done by Goddard and Peters, 1965); (2) microchipping of selections in the field; or (3) use of wind-pollinated seed in a nursery progeny test. The latter is a recently developed technique for evaluating gum-yielding ability of progenies grown at a very wide spacing, at 2 years in the nurserybed. It is expected that approximately 800 to 1,000 selections will be screened.

2. Selections showing promise under the, preliminary screening will then be bred with three proven high-yielding clones at Olustee, using the selections as pollen parents.

3. Seed from the controlled pollinations will then be subjected to the same type of nursery progeny test for gum yield mentioned in step 1 above.

4. Selections whose control-pollinated progenies pass the short-term nursery test for gum yield will then be recommended for use in the establishment of clonal orchards. At the same time progenies of these selections will be outplanted for long-term testing of all traits.

5. At the end of the long-term tests (possibly about 10 years), recommendations for roguing of clonal orchards will be given.

Our goal in this clonal orchard program is a genetic gain of at least 50 percent in gum yield and this is reasonable according to data on variation discussed earlier. Just how much to expect in the way of gains in growth rate and timber quality is not possible to estimate until we get data on selection differentials. However, because of the intensity with which the original selections were made and the progeny testing, gains should be appreciable.

The feasibility of developing a special strain with an appreciable degree of resistance to fusiform rust, for use in high infection areas, will be considered. Screening for this purpose could be done in step 3 above, using artificial inoculation techniques. Although other desirable traits, such as improved gum composition and wood quality, are not strongly considered at present, we hope to keep the genetic base wide enough to permit screening for such traits in subsequent generations.

SUMMARY

Available data on the variation and inheritance of gum yield, growth rate, and timber quality traits and on the nature of correlations among them show that incorporation of high yield with superior growth and timber quality is feasible. A seed-production area and several clonal orchards are being established with this objective, in cooperation with several organizations. The seed-production area is an interim measure designed to provide modestly superior but immediately available seed. The clonal seed orchards will provide greater gains but will require more time.

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