UNIFORM SEEDLING DENSITY IS IMPORTANT IN HARDWOOD PROGENY TEST NURSERIES

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Efficient progeny testing is an important component of pine tree improvement programs. But, it may be even more important in hardwood improvement programs because the variability of natural stands of hardwoods complicates the process of phenotypic selection. In order for a progeny test to be efficient, either the environment must be held constant from one family to the next, or uncontrollable environmental variation must be accounted for by sound experimental design in the nursery and in field plantings. Usually, efforts are made to do both. Emphasis is placed on selecting uniform nursery beds for growing seedlings and on careful blocking in field plantings.

Additional environmental variation, often not accounted for in the experimental design, can be caused by normal differences in percentage of germination among seedlots. Unless care is taken to plant only sound seed at a constant spacing, or unless seedlings are thinned to a constant density, unequal germination results in variable numbers of seedlings per square foot of nursery bed. And, variable seedling density can affect growth in the field for several years. Although these environmental effects may eventually disappear and true genetic differences in growth rate assert themselves, valuable time is lost. Or, if the test is thinned to form a seedling seed orchard, erroneous selections may result. Hence,. I believe that considerable effort is justified in maintaining constant seedling densities among hardwood progenies in the nursery. This belief is based on the following data from a sweetgum seedling grade study and progeny tests in sweetgum and sycamore.

SEEDLING DENSITY AND SEEDLING GRADE

In April 1963, wind-pollinated seed from 15 sweetgum parent trees were sown at Morgan Memorial Nursery 2/ at Byron, Georgia. Soon after germination, the beds were thinned to approximate densities of 10, 20, 30, and 40 seedlings per square foot within each family. The densities could not be held exactly as intended., but a variety of seedling sizes were produced within each family. Seedlings were lifted from 238 plots distributed over all seedling densities and all families; height and root-collar diameter were measured on each seedling.

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Maintained by the Georgia Forestry Commission.

There was a strong, negative relationship between seedling density and root-collar diameter (figure 1). The logarithmic equation fitted to the data (log Y = 0.9726 - 0.300466 log X) accounted for 73 percent of the variation. Seedling height, however, was not related to seedling density.

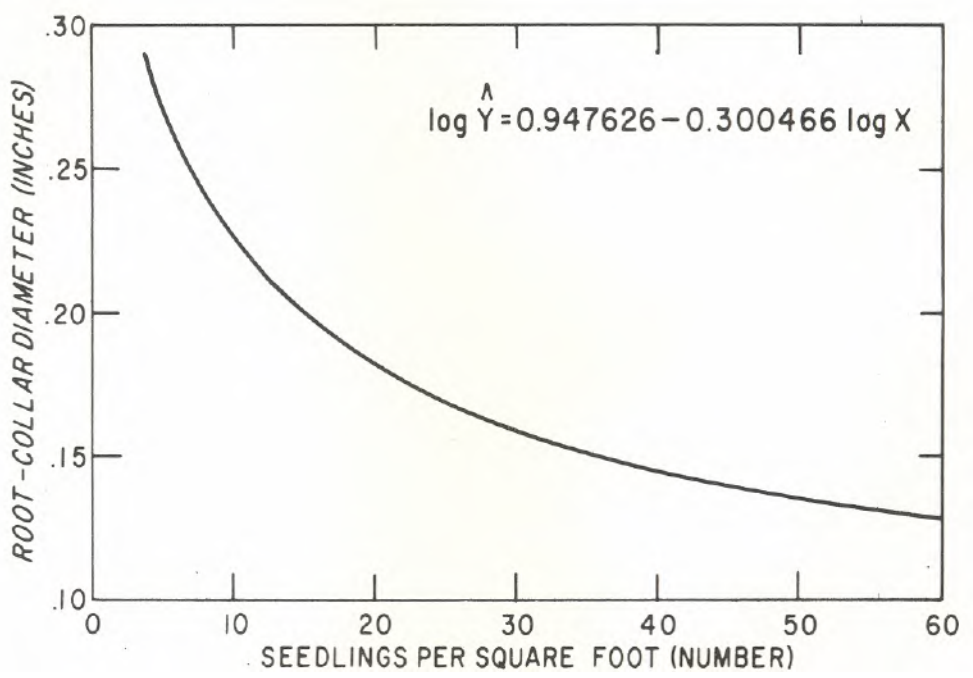

Figure 1.--A strong, negative relationship existed between root-collar diameter and number of seedlings per square foot ($r^2 = 0.73$; d.f. = 236).

Seedlings from 10 of the 15 families were sorted into four groups based on root-collar diameter: less than 3/16 inch, 3/16 to 3/8 inch, 3/8 to 1/2 inch, and greater than 1/2 inch. These seedlings were planted near Athens, Georgia, on a riverbottom site in two replications of a split-plot experiment. The four grades within each family were planted together so that seedlings from the same family were the main plots, and grades within families were the subplots.

From the start, seedlings with larger diameters have grown faster and survived better than those with smaller diameters. After five growing seasons, seedlings from the smallest grade averaged 7.92 feet in height, and those from the largest grade averaged 12.33 feet, a difference of 4.41 feet (figure 2).

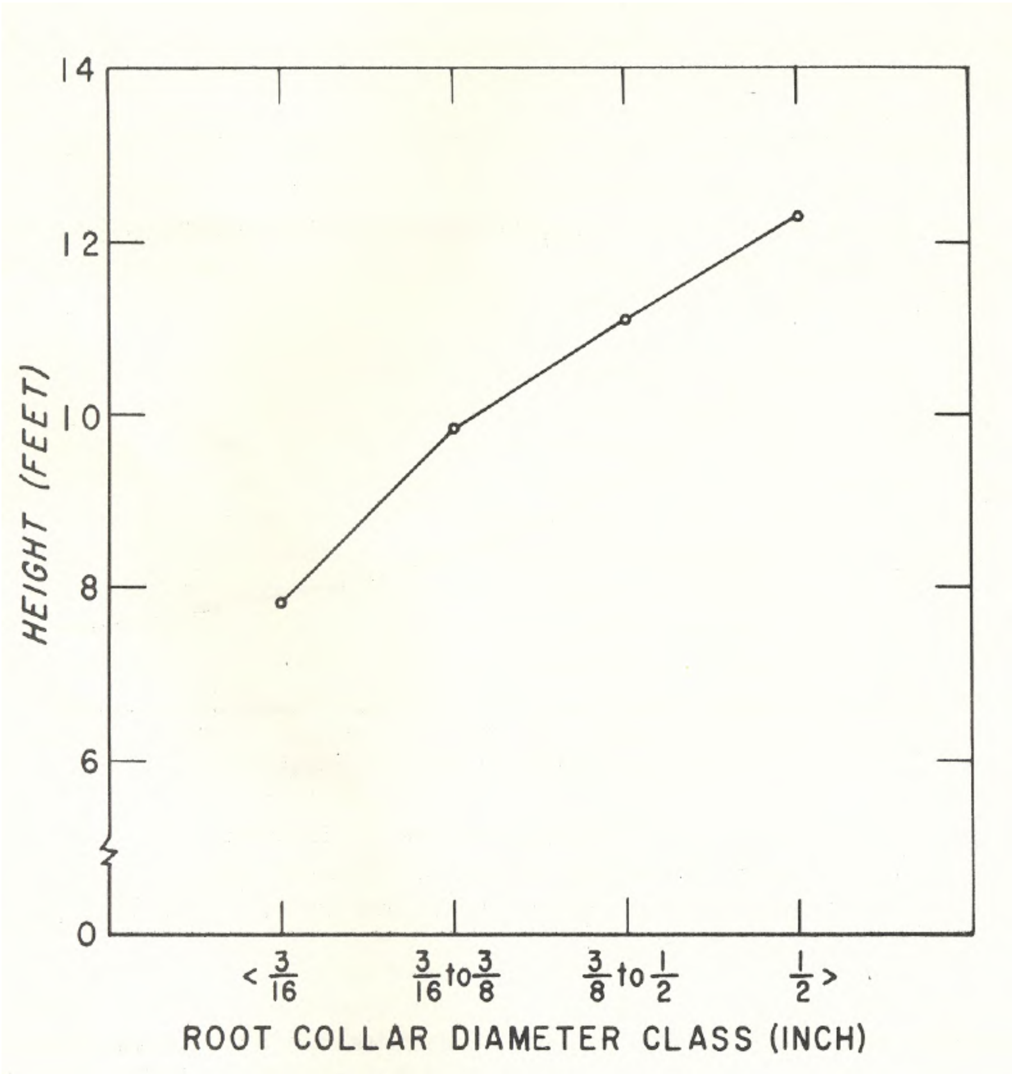

Figure 2.--After five growing seasons in the field, total height was strongly related to initial root-collar diameter of seedlings.

Although part of the differences among grades was due to genetic variation within families, most of the variation was created by thinning the nursery bed to different seedling densities. Therefore, by varying seedling density in the nursery, height growth was affected for five growing seasons, and significant differences will persist for a few more years.

In this plantation, height differences among the 10 families were not statistically significant. This possibly may be related to several factors: either there were no genetic differences among these families, or grading all families to the same seedling sizes removed much of the genetic variation, or the statistical design did not account for the large amount of site variation within the area.

These results on sweetgum agree with numerous reports on a variety of pine and hardwood species (Ike 1962; Johnson and McElwee 1967; Taft 1966; Limstrom et al. 1955; Baron and Schubert 1963; Clark and Phares 1961). The consensus of these authors is that as seedling density in the nursery increases, root-collar diameter decreases. Also, root-collar diameter is a good indicator of seedling growth potential: seedlings with large root collars grow faster after planting than seedlings with small root collars. In shortleaf pine, differences in growth rate related to root-collar diameter have persisted up to 20 years of age (Clark and Phares 1961).

It appears, therefore, that relative growth rate of two families in a progeny test may be altered by the densities at which seedlings were grown in the nursery. That is, if two families of equal genetic potential were grown at widely different nursery bed densities, the seedlings of the family grown at a lower density would have larger root collars and grow faster after transplanting. Conversely, seedlings of the family grown at a higher density would grow more slowly. Therefore, if we permit excessive variation in seedling density in the nursery, we may alter the relative ranking of family averages, confound genetic selection, and cast serious doubts on the reliability of components of genetic variance estimated from the plantation. My experience with sweetgum and sycamore suggests this has, in fact, happened.

A SWEETGUM PROGENY TEST

Seedlings left over from the seedling grade study were planted on a low-lying site in the Upper Coastal Plain in Bleckley County, Georgia. All 15 families were planted in a randomized block design with 12 replications of five-tree row plots. Height was measured annually for the first five growing seasons. Survival has been good, but growth disappointing.

Analyses of variance and F-tests of family effects showed highly significant differences in height in each of the 5 years. On the surface, this appears to be a sensitive F-test with 14 degrees of freedom for families and 154 degrees of freedom for the error term. But a closer look is necessary before any conclusions can be drawn from the data.

When the seedlings were lifted from the nursery, most of them came from plots thinned to 20 seedlings per square foot. In several families, however, it was obvious that actual density was below the intended 20; in these families, seedlings were lifted from plots supposedly thinned to 30 or 40 seedlings per square foot. Later, it was found that there was an alarming variation in actual seedling density among families. On the plots where the seedlings were lifted, density ranged from 8 to 26 seedlings per square foot.

Planting height of the 15 families was not related to the density of the plots from which the seedlings came. However, by the end of the third growing season, a negative trend appeared between family height and seedling density in the nursery. Although the correlation at 3 years of age (r = -0.507) was not statistically significant, it was only slightly smaller than the coefficient required for statistical significance ($r_{.05}$ = -0.514, df = 13). At the end of the fourth growing season the correlation had dropped to -0.409, and by the end of the fifth growing season it dropped further to -0.364.

In spite of the weakness of this relationship, the <u>direction</u> of the trend is consistent with the hypothesis based upon the seedling grade study. Of the three tallest families (families 2, 14, and 15), two came from plots with low seedling densities. The three shortest families (families 11, 13, and 17) came from plots with high seedling densities (figure 3).

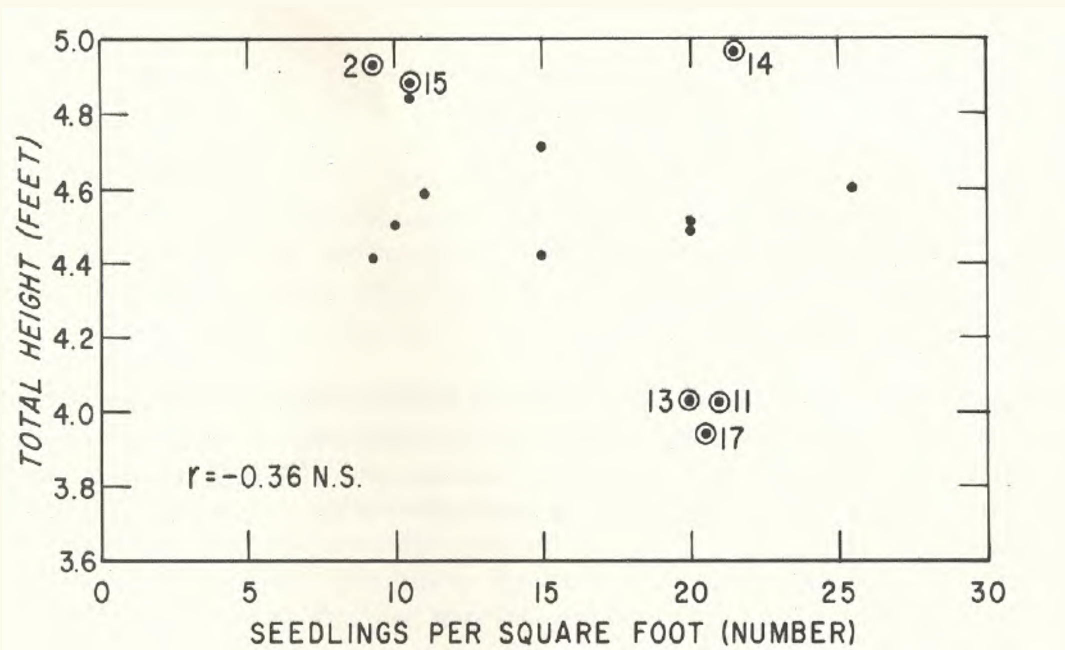

Figure 3.--After five growing seasons in the field, the total height of 15 wind-pollinated progenies was still confounded by variable seedling density in the nursery bed. The numbers beside encircled points identify different families.

Because families 2 and 15 came from low-density plots, 1 am reluctant to accept them as being genetically superior. However, family 14 came from a high-density plot and has moved from a rank of twelfth in nursery height to first in field height. In time, family 14 may prove to be truly superior. Also, I am reluctant to place any confidence on estimates of genetic variance based on this study. Variance components are sensitive enough as it is without the complications of variable seedling density in the nursery. By the time this plantation reaches 10 years of age, these complications may disappear. Yet, the results of the first 5 years are useless because of the excessive variation in nursery bed density.

A SYCAMORE PROGENY TEST

A similar complication appeared in a sycamore progeny test, but the effects seem to be disappearing quickly. Fifty wind-pollinated families were sown in a nursery at the Harrison Experimental Forest near Gulfport, Mississippi, in May 1966. The parent trees came from five locations along the Chattahoochee River from the mountains of Georgia to west Florida. The seed were sown in the nursery in rows 3 inches apart across beds 48 inches wide; about 1,000 seed were sown in each row. Soon after germination it was obvious that there were large differences among families in number of seedlings per row, a result of variable germination. Laboratory tests on 25 of the families showed germination ranged from 4 to 67 percent.

When the tallest seedlings were about 3 inches tall, all families were thinned to 16 seedlings per square foot. By that time the effects of competition were already apparent. The taller seedlings were concentrated in families with poor germination; and in families having good germination and severe competition, the seedlings were noticeably shorter. Even after being thinned to a uniform density, this difference persisted until the end of the growing season. There was a significant, negative relationship between total nursery height and germination percentage in the laboratory test (figure 4).

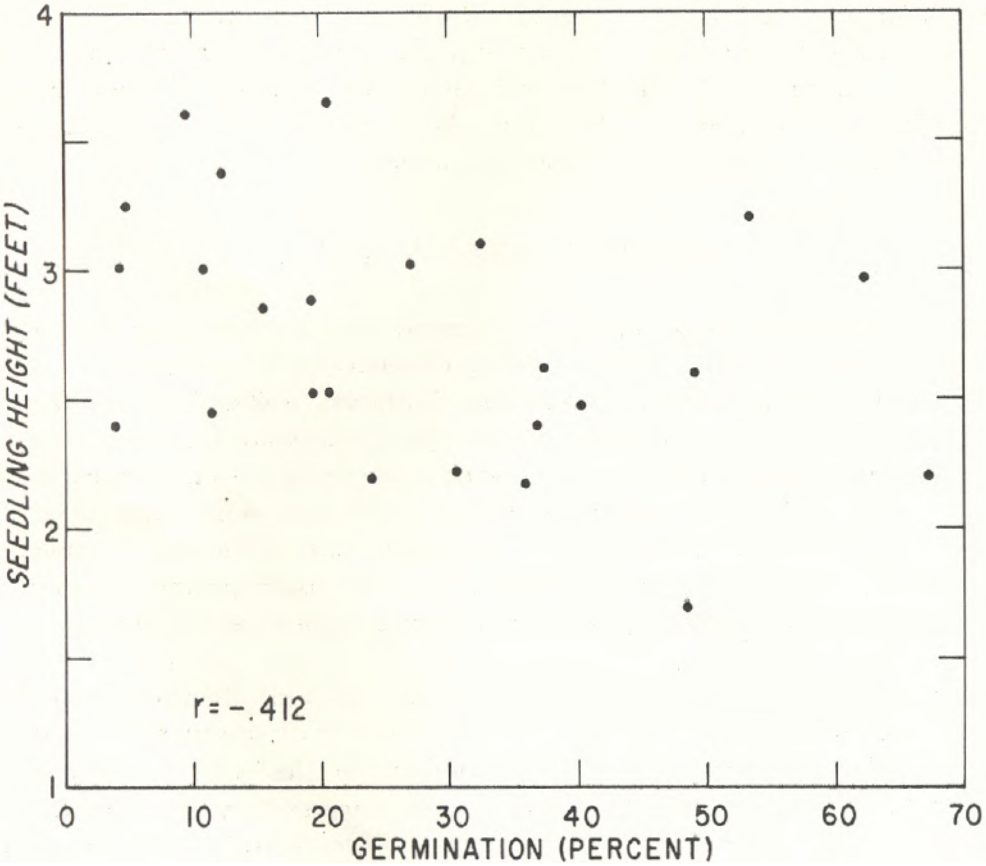

Figure 4.--In sycamore, there was a significant, negative relationship between seed germination percentage in the laboratory and seedling height of 25 wind-pollinated families.

Because the seedlings from this nursery were so large--the tallest was 7 feet tall--their tops were cut off 6 inches above the root collar and the roots, or "stumps," were planted in the field. Survival and growth has been excellent. However, growth of different families during the first season in the field was not correlated with the laboratory germination test. The topping method and planting on a good site may have helped overcome the effects of variable germination and early competition. But, variable germination and thinning too late eliminated any constructive use of the nursery measurements.

DISCUSSION

To some people working with rotation ages of 30 years or longer, these data simply confirm the unreliability of juvenile measurements of growth rate. However, variation in seedling density among progenies in the nursery bed may contribute to this unreliability. The question then becomes: Would controlling nursery bed density give meaning to juvenile measurements and therefore be worth the effort? This may remain a moot question for some time. But if meaningful juvenile-mature correlations are ever found, they will be based on seedlings grown in nurseries where a constant density has been religiously maintained from family to family.

For some hardwoods, especially sycamore, rotation ages as short as 2 to 10 years have been proposed. Tree improvement programs in this context will be vitally concerned with measurements of juvenile growth rate. Therefore, progeny tests designed to detect genetic differences in juvenile growth rate must be planted with seedlings grown at uniform nursery bed densities.

A uniform seedling density can be obtained in at least two ways. With wind-pollinated seed, which are usually cheap and abundant, the bed can be over-sown and thinned soon after germination. Thinning should be done before competition becomes severe in the seedlots having high germination.

The problem of uniform seedling density becomes complicated when control-pollinated seed are used. To use control-pollinated seed most efficiently, single seed will have to be sown in separate containers in a greenhouse or other controlled environment. After the seed have germinated and are established, the container can be transplanted in the nursery bed at the desired spacing . There is a variety of quickly decomposable containers available. Each seems to have certain limitations, but with care problems can be avoided.

The tubeling method, which has been proposed for commericial planting, is a third alternative (Jones 1967). However, tubeling techniques must be perfected before expensive control-pollinated seed are sown in tubes. In some studies, tubelings have grown poorly.

SUMMARY

Progeny testing will be an important part of hardwood tree improvement programs because the variable nature of hardwood stands complicates the process of phenotypic selection. In addition to normal statistical control of environmental variation in progeny tests, seedling density in the nursery bed is an environmental variable that must be held constant from family to family.

If seedling density is allowed to vary from family to family, genetic differences in early growth rate may be covered up, valuable time lost, and erroneous decisions made.

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