NATURAL VARIATION OF YELLOW POPLAR IN NORTH CAROLINA

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INTRODUCTION

The demand being made for premium-grade yellow-poplar for veneer and lumber, and to a lesser extent for pulpwood, has precipitated a need to improve the species through genetic means. To this end, a number of organizations have proceeded to establish seed orchards utilizing the principle of mass selection. If this approach is to be followed, one of the axioms is that variation within the species must be of a magnitude that will allow selection of individual trees to be made. However, this very concept is challenged by many who profess that little variation would be expected since yellow-poplar attains its best growth on moist but well-drained fertile soils, irrespective of its geographical location. In order to test the validity of this hypothesis and to obtain some of the more basic facts about the natural variability of yellow-poplar, a study was initiated in North Carolina in 1962 with the major objectives being:

1. Is there natural variability within the species?
2. If variability is present, is it of a magnitude to warrant a tree breeding program utilizing the mass selection approach, if the other axioms of mass selection are met?
3. If variability is present, is it clinal or ecotypic in character?

SAMPLING

A nested classification sampling scheme was used to obtain representative samples from the natural population. The first major subdivision was to partition the state into its three commonly recognized physiographic provinces: Coastal Plains, Piedmont, and Mountains. Within each province three areas were chosen in a manner that would best represent longitudinal and latitudinal transects. A further subdivision reduced each area to three stands, with the stands having the restrictions that they would be of the thirty- to fifty-year age group and that contiguous stands would be avoided where possible. The last major subdivision was the reduction of each stand to four sample trees. The four trees per stand were chosen at random, with the exception that they must be separated by at least 200 feet to reduce the possibility of selecting

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trees that were close relative, and they must be producing an acceptable seed crop and be sound of bole to the extent that they were considered safe to climb. Depending upon the characteristic being investigated, further subdivisions to samples within trees and determinations within samples were employed when applicable.

In summary of the sampling scheme, there were four trees per stand, tree stands per area, three areas per province, and three provinces for a total of 108 trees. Each of the 108 trees sampled was the source of information for branch angle determinations, foliage, seed, wood and soil properties, and mensurational data.

RESULTS AND DISCUSSION

Branch Angle

Results from a preliminary investigation of twenty trees within a single stand showed that the measurement of six branch angles from the upper central portion of the crown would give a good indication of the branch angle of the whole tree ($r = .80$). Consequently, this sampling scheme was used in obtaining data from the main study.

When the branch angle determinations from the main study were subjected to an analysis of variance it was found that trees within stands were significant at the .01 level while stands within areas were significant at the .05 level; no differences were found among areas within provinces or among provinces. Some surprise was expressed at the significant differences found among stands within areas, as this was not anticipated. Possibly the similarity of branch angles within stands or, conversely, the absence of similarity among stands within an area can result because the four trees which constitute a stand were closely related. Several investigators, such as Taft (1965), Boyce and Kaeiser (1961), and Carpenter and Guard (1950) have expressed the opinion that yellow-poplar is subject to a considerable amount of inbreeding from pollination occurring among a limited number of trees within a given area.

Foliage Properties

Eight leaves were collected from each of the 108 trees sampled from the periphery of the crown, two from each cardinal direction, at a height that would correspond to the zone from whence branch angles were measured. In order to describe the shape of a leaf, and not knowing the measurement that would best depict that shape, a total of eleven measurements were recorded from each leaf. Several of these measurements were later discarded as being of no significance for defining leaf shape, but two linear measurements and five ratios were retained for analysis (table 1). Almost without exception the seven leaf characteristics exhibited the same pattern of variability, i.e., significance at the .01 level among cardinal directions within a crown, among trees within stands, and among areas within provinces, but with no significance being shown among stands within areas and among provinces.

Although all leaf characteristics analyzed exhibited similar differences the length-width ratio of the leaf is recommended as the most suitable characteristic for study because of its uniformity, because of the probability that it best exhibits genetic differences, and because it best describes leaf shape. If other characteristics of the leaf are desired for study, the next two most suitable measurements appear to be depth of top sinus and depth of lateral sinus.

Table 1.--Levels of statistical significance for foliage properties by source

Characteristic	Provinces	Areas	Stands	Trees	Samples
Top sinus (depth)	NS	**	NS	**	**
Lateral sinus (depth)	*	**	*	**	NS
Petiole length to midrib length	NS	**	NS	**	**
Petiole length to top sinus (depth)	NS	**	NS	**	**
Midrib length to top sinus (depth)	NS	**	NS	**	**
Leaf width to length	NS	**	NS	**	**
Lateral sinus extension to lateral sinus	NS	**	NS	**	**

NS = Nonsignificant
* = Significant at the 5% level
** = Significant at the 1% level

There was a general trend for values to increase from the coast to the mountains for top sinus depth and lateral sinus depth, but none of the leaf ratios showed a similar trend. Though lacking logical explanation, a relatively high negative correlation (r = -0.764) was found between length of frost-free season and top sinus depth. Thus, peculiar as it seems, leaves with greater top sinus depths appear to occur in areas with shorter growing seasons. There is also a strong indication that leaves of the mountain areas are larger than those on the coast. Perhaps the shape of the leaf of the coastal province, with the more shallow sinuses, has undergone selective processes as the tree has adapted to new environments. Of particular significance is the fact that leaves of the southern coastal area exhibited extreme values for every characteristic analyzed. Their shape is of such a peculiar nature that they are easily distinguished among leaves of all other sources (fig. 1).

Fruit and Seed Characteristics

Seed was collected from each of the sample trees in the fall of 1962, and data were collected and analyzed for cone length, number of samaras per cone, samara length and samara width (table 2).

Table 2.--Levels of statistical significance for cone and seed characteristics by sourc

Characteristic	Provinces	Areas	Stands	Trees	Samples
Cone length	NS	NS	NS	**	--
Number of samaras per cone	*	*	NS	**	--
Samara length	NS	*	*	**	**
Samara width	*	NS	NS	**	**

NS = Nonsignificant
* = Significant at 5% level
** = Significant at 1% level

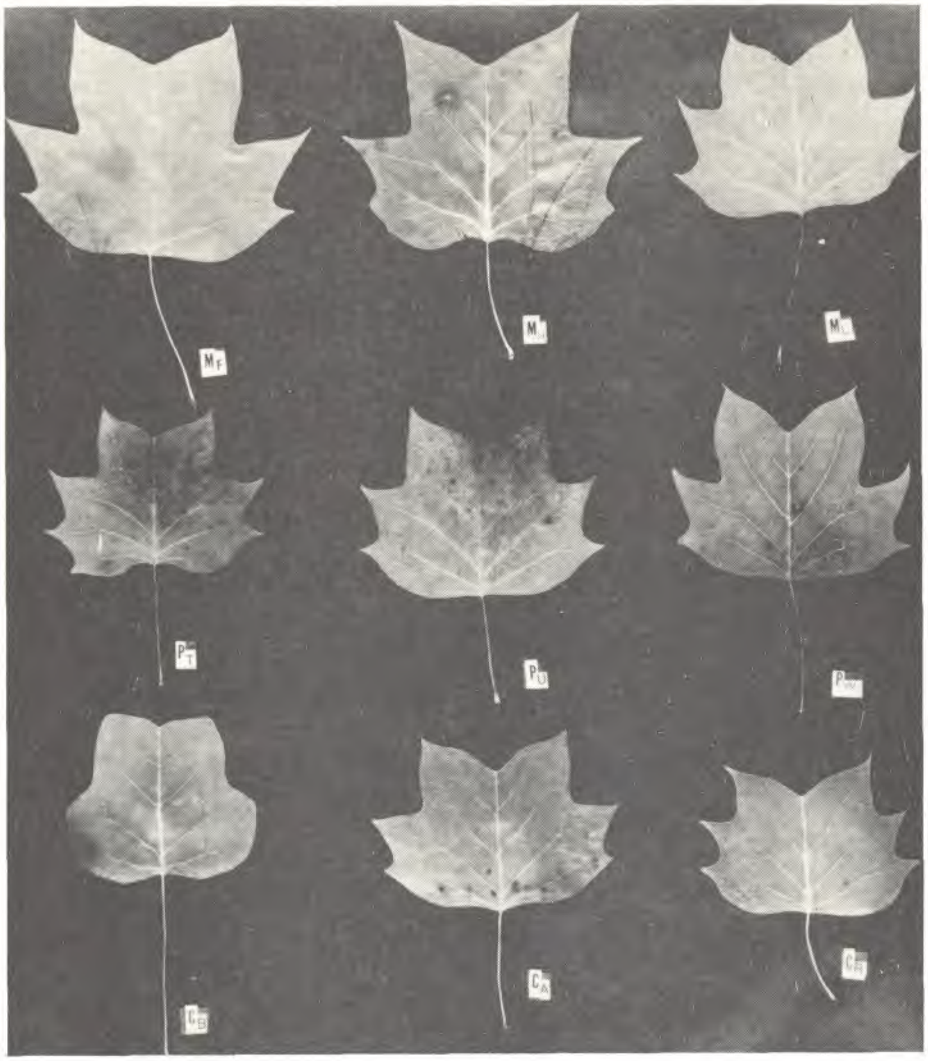

Figure 1.--A comparison of leaf morphology by areas is illustrated by a typical leaf from each of the nine areas studied. Note especially the striking appearance of the leaf from the C_B (southern coastal) area, the "deep-peat" ecotype.

A general trend of increasing value from the coast to the mountains was evident in cone length, number of samaras per cone, and samara width. However, a notable exception to this trend was the southern coastal source, where cone length and number of samaras per cone were comparable in value to the mountain sources. Thus, as with the peculiar shape of the leaves, the samaras and cones of the southern coastal areas were conspicuous by their long, narrow shape.

<u>Wood Specific</u>

Two 11-mm. increment cores, extending from the bark to the pith, were extracted from each tree sampled. Specific gravity as determined by the standard method of oven-dry weight to green volume was obtained from the first thirty-year age segment. No separation was made between juvenile and mature wood, and the values obtained represent unextracted specific gravity.

Differences in specific gravity were found to be significant at the .01 level among trees within stands and among stands within areas; areas within provinces differed significantly at the .05 level. Results from this study supplement the investigations of Taylor (1965), Taft (1965), and Thorbjornsen (1961), each of whom concluded that the among-tree component of specific gravity in yellow-poplar is large. Because of the large among-tree differences and because specific gravity appears to be strongly genetically controlled (Stonecypher and Zobel, 1965), it is concluded that meaningful gains can be achieved in yellow-poplar through breeding programs that utilize mass selection.

The highly significant among-stand differences in wood specific gravity came as somewhat of a surprise since the majority of wood property studies of both conifers and hardwoods have not revealed such differences. A comparison of specific gravity means among the 27 stands in this study (table 3) reveals that the differences resulted from the extreme values between stands in the southern coastal area. For example, stands 1, 2 and 3 exhibited values of 0.45, 0.36 and 0.40, respectively, representing one of the highest and the two lowest means among all stands. Although

Table 3.--Soil textural class, pH, organic matter percentage, and site index by stands

Stand designation	Area	Wood specific gravity	pH Horizon A	pH Horizon B	Organic matter Horizon A	Organic matter Horizon B	Site index[1/]
					pct.		feet
M_F - 1	Southern	.41	4.8	5.0	4.0	3.6	95
M_F - 2	Mountain	.40	5.1	5.0	9.0	2.9	85
M_F - 3		.40	4.8	5.2	2.4	1.5	95
M_H - 1	Central	.41	4.7	4.8	9.6	2.5	90
M_H - 2	Mountain	.42	5.1	4.8	4.3	1.7	90
M_H - 3		.43	5.0	4.8	3.0	1.0	90
M_L - 1	Northern	.40	5.0	4.8	4.5	1.8	90
M_L - 2	Mountain	.40	4.6	4.7	3.6	1.6	75
M_L - 3		.43	4.5	4.7	3.3	1.5	75
P_T - 1	Southern	.40	5.3	4.8	3.6	1.1	85
P_T - 2	Piedmont	.44	5.5	5.2	4.2	1.7	75
P_T - 3		.45	4.6	4.7	3.3	1.2	60
P_U - 1	Central	.44	5.6	5.0	2.9	1.4	75
P_U - 2	Piedmont	.41	5.4	5.3	1.1	1.1	85
P_U - 3		.46	5.3	5.4	2.3	1.2	75
P_W - 1	Northern	.45	4.6	5.0	1.2	1.2	85
P_W - 2	Piedmont	.40	5.3	4.9	3.9	2.1	80
P_W - 3		.45	5.0	4.8	1.9	1.9	70
C_B - 1	Southern	.45	3.7	3.9	16.6	2.9	75
C_B - 2	Coastal	.36	3.6	4.0	37.1	3.8	90
C_B - 3		.40	4.2	4.3	3.7	1.9	70
C_A - 1	Central	.40	4.3	4.5	3.7	1.0	80
C_A - 2	Coastal	.40	4.5	4.8	2.6	0.8	85
C_A - 3		.41	4.4	4.6	2.8	0.8	70
C_R - 1	Northern	.46	4.7	4.7	3.0	0.8	85
C_R - 2	Coastal	.46	5.3	5.2	2.4	0.8	85
C_R - 3		.45	4.7	4.7	2.4	0.8	80

1/ Tables from Beck (1962) were used to determine site index for the Mountain and Piedmont regions, whereas those from McCarthy (1933) were used for the Coastal Plain region.

no single biological factor would seem to account for the fluctuation of the southern coastal area, it may be significant that all three of these stands are growing on very acid, deep-peat soils, the pH of the "A" horizon being 3.7, 3.6, and 4.0 for sands 1, 2 and 3, respectively. Nevertheless, an attempt to correlate soil acidity of the "A" horizon and wood specific gravity between stands resulted only in a non-significant, negative relationship (r = -0.24); likewise, in the "B" horizon no correlation between specific gravity and soil acidity was evident.

Progeny Testing

A comparison of area means (table 4) would indicate that a clinal pattern of variation from the coast to the mountains exists for number of samaras per cone, samara width, leaf top-sinus depth, leaf lateral-sinus depth, and bark thickness. Of even greater significance, however, are the extreme values common to the southern coastal source. Of the twelve foliage, seed and wood characteristics studied, nine from the southern coastal area attained either a maximum or minimum value. It is evident that this population is so strikingly different from all other areas in this study that it is probably a distinct ecotype. However, this preliminary evidence needs to be confirmed through growth and physiological studies before a distinct ecotype can be declared.

Seed from each of the 108 trees sampled was collected in the fall of 1962 and sown in the nursery in the spring of 1963, using a complete randomized design with four replications.

Table 4.--Area means of nine characteristics which showed maximum or minimum values for the southern coastal population

Characteristic	Southern Mountain	Central Mountain	Northern Mountain	Southern Piedmont	Central Piedmont	Northern Piedmont	Northern Coastal	Central Coastal	Southern Coastal
Leaf top-lobe depth	19.6	15.4	15.8	14.4	14.6	14.4	17.1	11.7	8.6
Leaf lateral-lobe depth	20.2	20.3	17.2	16.4	14.4	15.8	13.9	12.1	5.8
Leaf width to length	1.31	1.38	1.32	1.35	1.29	1.28	1.20	1.29	1.17
Leaf petiole to midrib	.92	.88	.95	.84	.83	.89	.90	.88	1.09
Leaf petiole to top-lobe depth	3.62	4.59	4.25	3.36	3.75	4.11	3.29	5.56	7.76
Leaf midrib to top-lobe depth	3.98	5.23	4.58	4.07	4.67	4.72	3.67	6.22	7.05
Leaf lateral-lobe depth to lateral-lobe extension	2.25	2.24	2.39	2.14	2.82	2.36	2.91	3.36	7.28
Samara width	7.44	7.89	7.89	6.79	7.55	7.22	6.86	6.97	6.40
Wood specific gravity	.404	.420	.412	.431	.436	.432	.457	.402	.402

Striking differences became apparent in leaf morphology soon after the secondary leaves were formed on the seedlings in the nursery bed, allowing progenies from the twelve trees of the southern coastal area to be unmistakably recognized. The leaves were conspicuous by their rounded lobes, shallow sinuses, reddish petioles and a lighter green color than any of the progenies from companion areas. Even today, after four growing seasons in the field, the characteristic leaves have persisted to the extent that they serve to identify the progenies of the southern coastal sources.

After one growing season in the nursery, six seedlings from which total height was obtained were randomly selected from each seed lot in each of the four replications. Statistically significant differences in height growth were found at the .01 level among families within stands, among areas within pro-vinces and among provenances. A comparison of heights by area means indicates that the progenies from southern and central coastal sources are considerably faster growing than those from any other source, whereas the northern Piedmont progenies have a noticeably slower growth rate. However, the apparent superiority of the central coastal source is probably an anomaly because total seed germination from all twelve parent trees of that area was poor, resulting in a more open stocking density than for other seed lots. The remaining 96 families were comparable in seed bed density since the six-inch wide drills were overstocked and seed bed density was controlled by thinning to the desired level.

The seedling's were outplanted in the spring of 1964 as 1-0 stock, using a com pletely randomized design with four replications and three locations. A location representing an area of six acres was established in each of the provinces -- Coastal Plains, Piedmont and Mountains.

Survival after two growing seasons differed markedly among locations. A high of 95% was obtained in the Piedmont planting, 83% in the mountains, and a low of 69% was obtained in the Coastal Plains planting. Sources from all provinces survived equally well when planted in the Piedmont and mountains, whereas the survival of the mountain (59%) and Piedmont (67%) sources when planted in the Coastal Plain was con siderably poorer than for local Coastal Plain (82%) progenies. The most logical explanation for these differences in survival was that the Coastal Plain planting location was pocked by potholes as a result of site preparation where water was prone to accumulate. When seedlings from a mountain or Piedmont source were planted in one of these low-lying areas, survival was always poorer than for a similar lot from the Coastal Plain. These results substantiate the conclusion obtained from the study of the parent trees that the Coastal Plain sources have adapted to acid, deep-peat soils which are inundated by water for lengthy periods.

Total height measurements were also obtained at the end of the second growing season. Although calculations have not been finalized it appears that growth differences among planting locations and among all major subdivisions are minimal at this early age. This paradox has resulted because of top dieback of the seed lings following field planting and because the faster-growing families fail to set dormant buds in time to escape early fall frosts. For example, the Coastal Plain sources, when grown in the Piedmont, invariably attain greater height growth than local sources, but just as invariably the top portion of the stem suffers from cold damage. Thus, even though the Coastal Plain sources exhibited a height superiority in the nursery and also grow more rapidly in field plantings, their overall height is no greater than the average of all other families.

Failure to obtain significant differences in height growth among sources may have been caused by the young age at which they were measured. Measurements are scheduled to be made following the current growing season, at which time it is expected that growth trends will become apparent.

SUMMARY

A study to determine the natural variation of yellow-poplar in North Carolina was initiated in 1962. A nested classification scheme was used to sample 108 mature trees from the coast to the mountains. Each tree was the source of branch angle determinations, foliage, seed, wood and soil properties, and mensurational data.

Every characteristic studied exhibited highly significant differences among trees. This would indicate that a tree breeding program using a mass selection approach would be applicable if the additive genetic variance within the species is of a reasonable magnitude. In addition, there was a moderate pattern of clinal variation for number of samaras per cone, cone length, samara width, leaf top-sinus depth, leaf lateral-sinus depth, and bark thickness, increasing in magnitude from the coast to the mountains. Of more significance, however, are the extreme values obtained from the southern coastal source where nine of the twelve characteristics studied exhibited a maximum or minimum value. It was concluded from these results that the southern coastal population probably represents a deep-peat, acid soil ecotype.

Open-pollinated seed, kept separate by family lots, was planted in the nursery in 1963 and the seedlings were outplanted in 1964 at three widely separate locations. After two growing seasons, there were great differences in percent survival, 95% being obtained in the Piedmont planting, 83% in the mountains, and a law of 69% obtained at the Coastal Plain location. Insignificant differences were obtained in height growth after two growing seasons, probably as a result of top dieback and freeze damage.

LITERATURE CITED

Beck, D. E. 1962. Yellow-poplar site index curves. U. S. Forest Service, Southeast. For. Expt. Sta., Res. Note No. 180.

Boyce, S. G. and M. Kaeiser. 1961. Why yellow-poplar seeds have low viability. U. S. Forest Service, Central States For. Expt. Sta. Tech. Paper 186.

Carpenter, I. W. and A T. Guard. 1950. Some effects of cross-pollination on seed production and hybrid vigor of tulip tree. Jour. Forestry 48: 852-855.

McCarthy, E. F. 1933. Yellow-poplar characteristics, growth and management. U. S. Dept. Agr. Tech. Bull. 356.

Stonecypher, R. W. and B. J. Zobel. 1965. Inheritance of specific gravity in five-year-old seedlings of loblolly pine. Proc. Third Forest Biology Conference, Tech. Assn. Pulp and Paper Industry. U. S. Dept. Agr., Forest Service, Forest Products Lab., Madison, Wisconsin.

Taft, K. A., Jr. 1965. An investigation of the genetics of seedling characteristics of yellow-poplar (Liriodendron tulipifera L.) by means of a diallel crossing scheme. Unpublished Ph.D. Thesis, School of Forestry, N. C. State Univ., Raleigh.

Taylor, F. W. 1965. A study of the natural variation of certain properties of the wood of yellow-poplar (Liriodendron tulipifera L.) within trees, between trees, and between geographic areas. Unpublished Ph.D. Thesis, N. C. State Univ., School of Forestry, Raleigh.

Thorbjornsen, E. 1961. Variation in density and fiber length in wood of yellow-poplar. Tappi 44 (3): 192-195.