The only appreciable correlations between characters were between height and d.b.h. (0.75 genetic, 0.56 phenotypic) and between limb frequency and branch angle (0.25 genetic, 0.19 phenotypic). SCHMITT and WILCOX (1969), studying phenotypic correlations in natural stands, obtained a similar correlation between height and d.b.h. (0.58) and a slightly higher correlation between limb frequency and branch angle (0.31).

The two crown characters showed low heritabilities and should therefore be considered lecs important in a selection index for sycamore tree improvement than should height and diameter growth. It might be advisable to ignore limb characteristics during the first cycles of improvement and to concentrate on selection for diameter and height growth. However, if the breeder is concerned with improving branch angle and limb frequency, he will need to develop more precise measurement techniques than were used in this study. The low correlation between growth and crown characters would allow selection for growth without sacrificing variability in crown characters, which might then be improved in later generations.

Abstract

At age five, genetic variation was detected both among and within seed sources for d.b.h., height and limb frequency, and within seed sources for branch angle. Pooled narrow-sense heritabilities were 0.26 for d.b.h., 0.26 for height, 0.15 for limb frequency and 0.16 for branch angle. The only appreciable genetic correlation was one of 0.75 between d.b.h. and height.

Key words: Platanus occidentalis L., branch characters, genetic gains, phenotypic and genetic correlation.

Zusammenfassung

Sämlingsnachkommenschaften von je 25 ausgewählten Einzelbäumen von Platanus occidentalis L. in 5 Beständen wurden im Wachstum und in ihren Formeigenschaften mit den Elternbäurnen verglichen. Im Alter 5 der Sämlinge waren in mehreren Eigenschaften, insbesondere im Höhenwachstum und im erreichten Durchmesser Beziehungen zu den Elternbäumen zu erkennen.

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Comparison of Shortleaf, Loblolly, and Putative Hybrid Pines in the Piedmont of South Carolina

By R. E. SCHOENIKE, D. H. VAN LEAR, and J. D. BENSON[1])

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Introduction

Shortleaf pine (Pinus echinata MILL.) is the most common pine native to the Piedmont of South Carolina. However, since the 1930's, loblolly pine (P. taeda L.) has been the preferred pine for planting in that area. Growth rates of loblolly pine are generally greater than those of shortleaf pine on eroded Piedmont sites, especially on rotations of short or intermediate lengths. Shortleaf pine is also more susceptible to littleleaf diseace caused by *Phytophthora* cinnamomi RANDS. The fungus can cause severe epidemics on eroded Piedmont sites where it attacks pine root systems.

Shortleaf pine, however, does have some advantages over loblolly pine. The former species, typically, has better stem form and is more resistant to ice damage. In addition, it is less susceptible to fusiform rust (Cronartium fusiforme HEDGC. and HUNT ex CUMM.), the most serious disease of the southern pines.

For years, forest research and management personnel have observed trees on the Clemson Experimental Forest which exhibited characteristics intermediate between shortleaf and another pine. These trees nearly always occurred in natural stands of shortleaf pine. Loblolly pine, whose natural range barley extends into the upper Piedmont of South Carolina (SCHOENIKE, et al., 1975), but which certainly was planted at scattered locations in the region during the early 1900's and which is known to interbreed with the other southern pines species, appeared in most cases to be the other parent.

These putative hybrid pines often occurred on typical littleleaf sites, i.e., on eroded, compacted, and heavy-textured soils. In fact, the more vigorous appearance of these trees in relation to neighboring shortleaf pines exhibiting typical littleleaf symptoms was the primary reason for categorizing them as putative hybrids. In this study, a com-

[1]) Professors and Research Forester, respectively, Department of Forestry, Clemson University, Clemson, South Carolina.

parison was made of the naturally occurring putative hybrids and associated shortleaf pines, and of the performance of the progeny of the hybrids as compared with shortleaf and loblolly pines.

Methods

The putative hybrids are located on the 17,000-acre Clemson Experimental Forest in northwestern South Carolina. A search concluded in May 1976 resulted in the discovery of 68 putative hybrids. The frequency of these hybrids in shortleaf pine stands was about 1 in 10,000 trees. A number of the trees have been lost to windthrow, littleleaf disease, bark beetle attacks, and timber cutting. The present inventory of putative hybrids stands at 54.

An early attempt was made to identify the parentage of 21 putative hybrids, and an analysis of all putative hybrids is currently under study. Traits measured were needle length, needle sheath length and width, cone length and width, bud length and diameter, and twig diameter. Number of needles per fascicle was recorded. These features were determined not only on the putative hybrids but also on 20 native shortleaf and 20 plantation-grown loblolly pines. From these measurements and counts, a formula approach similar to that of Smouse and Saylor (1973) was employed to indicate if shortleaf and loblolly pine were parents of the putative hybrids. In this technique, character indices are computed that reflect the degree to which putative hybrid trees resembled loblolly or shortleaf pine.

In comparing the putative hybrids with associated shortleaf pines, a grading system similar to that used in superior tree evaluation was employed. Traits evaluated included height, volume, form class, crown size, straightness, branch angle, and evidence of disease. Hybrid trees were compared with the three nearest shortleaf pines that were either dominant or codominant.

To evaluate the performance of the progeny of the hybrids, cone collections, were made beginning in 1967. Seedlings raised from these seed, along with loblolly and/or shortleaf pine seedlings, have been established in six test plantations. These plantings are located on eroded sites formerly occupied by littleleaf-diseased shortleaf pines in Pickens and Spartanburg Counties, South Carolina. They were evaluated for survival, height, and incidence of fusiform rust in 1975. In five of the six plantations, a randomized complete block design was used. The sixth planting utilized a Latin square design. Analyses were performed on survival and height using the computerized Statistical Analysis System (SAS).

Results

Identification of the putative hybrids:

Computed character indices indicated that the morphological characteristics of most of the putative hybrids were intermediate between loblolly and shortleaf pine. Most of the putative hybrids were clustered more toward loblolly pine than shortleaf pine. For example, when needle length was plotted over the character index scale, the putative hybrid pines were skewed mainly toward loblolly pine *(Figure 1)*. Other hybrid traits, including number of needles per fascicle, needle width, and cone width, also had values intermediate between the two species.

Growth and form characteristics of the putative hybrids:

In six measured traits, the putative hybrids proved equal or superior to associated shortleaf pine of the same age. The hybrids were 27 percent greater than shortleaf in height, 31 percent greater in diameter, and nearly 100 percent better in volume. They were not significantly different from shortleaf in straightness, form class, or pruning ability. Average age of the putative hybrids was 53 years, while associated shortleaf pine averaged 54 years.

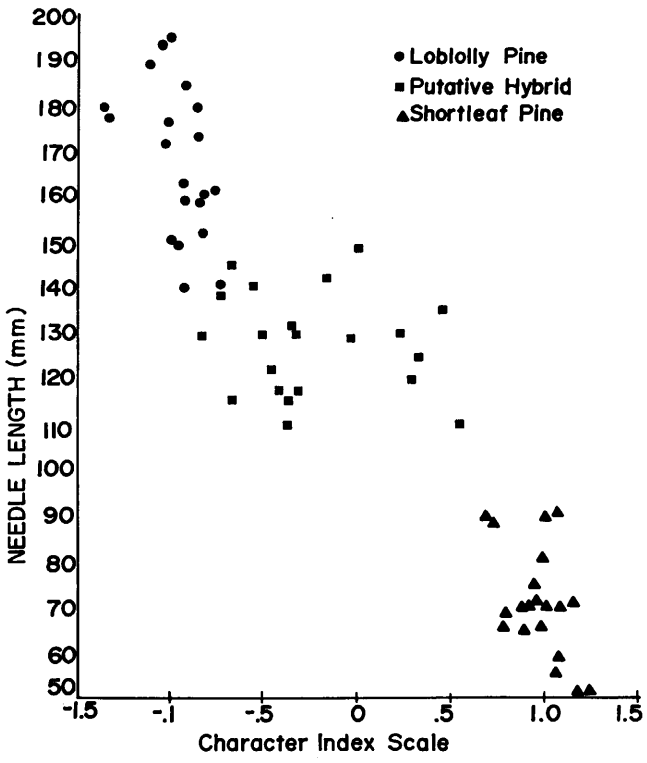

Fig. 1. — Needle length versus character index values for loblolly, shortleaf, and putative hybrid pines in the Piedmont of South Carolina.

Progeny evaluation:

Growth and survival of open-pollinated progeny of putative hybrid, loblolly, and shortleaf pines were compared in six plantations established in the South Carolina Piedmont during the years 1969—1973 *(Table 1)*. Growth rates of the putative hybrid pine progeny were clearly intermediate between loblolly and shortleaf pines in all plantations where comparisons could be made. Hybrid progeny were 13 to 27 percent taller than shortleaf pine and 3 to 26 percent shorter than loblolly pine. With respect to survival rates, the hybrid progeny were similar to shortleaf pine, except in the earliest planting. Loblolly pine had the best survival rates in all plantings.

Table 1. — Height of Open-Pollinated Progeny of Putative Hybrid, Shortleaf, and Loblolly Pines in Six Plantations Located in the South Carolina Piedmont.

Plantation Number	Age	Mean Height Shortleaf Pine (M)	Hybrid Pine (M)	Loblolly Pine (M)
1	7	2.3	2.8	3.8
2	5	1.6	1.8	2.3
3	5	—*	2.9	3.0
4	4	1.2	1.5	1.7
5	4	1.1	1.4	1.7
6	3	—*	.5	.6

* No shortleaf pines planted.

The percentage of trees infected with fusiform rust in all plantations was not large, and results were mixed. On the average, the total incidence of rust on the hybrids was slightly higher than on shortleaf and slightly lower than

on loblolly, but the results at these young ages are inconclusive.

Discussion

Results of the search for putative hybrid pines reveal an optimistic picture of growth when these trees are compared with associated shortleaf pines. The progeny of the putative hybrids may offer a possible alternative to loblolly pine, whose long range adaptability to poor sites in the Piedmont is open to question. As shown by the results, certain lines of these putative hybrids produce progeny with growth rates and survival equivalent to those of young loblolly pines. Because the results of the progeny tests apply only to young trees, all conclusions are tentative. As the trees mature, more meaningful results should become available.

Summary

Putative hybrid pines were found on the Clemson Experimental Forest in the South Carolina Piedmont. Measured traits indicate that those trees are probably hybrids from *Pinus echinata* × *Pinus taeda* crosses. In natural stands performance of the putative hybrids, when compared with that of associated shortleaf pines, is superior in terms of volume and form. Open-pollinated progeny, three to seven years of age, of the putative hybrids were generally intermediate in height growth between loblolly and shortleaf pine when planted on eroded heavy-textured soils on which littleleaf develops. However, in a few cases, individual progenies had growth rates equivalent to those of young loblolly pines.

Key words: Putative hybrids, Rust resistance, Littleleaf sites.

Zusammenfassung

Im Versuchswald S. C. Piedmont, USA, wurden in Form und Wachstum abweichende Kiefern beobachtet. Aufgrund von Merkmalsuntersuchungen wird vermutet, daß diese höchstwahrscheinlich Hybriden aus Kreuzungen zwischen *Pinus taeda* und *P. echinata* sind. Frei abgeblühte Nachkommenschaften sind intermediär, das heißt es sind nur wenige Individuen vorhanden, die *Pinus taeda* ähnlich sind.

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Mikrospectrophotometric Determination of DNA per Cell and Polyploidy in Fraxinus americana L.

By V. G. Schaefer and J. P. Miksche[1])

Department of Biology, University of Wisconsin-Stevens Point, Stevens Point, Wisconsin and USDA Forest Serivce, North Central Forest Experiment Station, Institute of Forest Genetics, P.O. Box 898, Rhinelander Wisconsin 54501.

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Introduction

The natural range of white ash *(Fraxinus americana* L.) extends from Minnesota to Nova Scotia south to Florida and west to Texas (Fowells, 1965). A diploid (2N = 46), tetraploid (2N = 92), and hexaploid (2N = 138) euploid series has been described for the species as well as distribution and evolutionary considerations (Wright, 1944).

Various morphological criteria have been used to ascertain ploidy levels of white ash. Wright (1945) found stomata size reliable for polyploid differentiation of nursery grown trees. Stomata size of field-grown individuals, however, was only found reliable for separation of diploids and polyploids. Santamour (1962) examined nursery grown stock and reported that bud and leaf scar morphology could discriminate diploids from tetraploids. Hexaploids were similar to tetraploids in these character differing only by leaf and twig pubescence. Miller (1955), however, found the pubescent character too variable to distinguish polyploid individuals.

Several investigators have employed cytophotometry as a tool to study polyploidy in plants. Southern (1967) attempted taxonomic clarification for species of *Tulipa*. Grant (1969) determined that species of *Betula* with lower ploidy levels (2N = 28, 42, 56, 70) did have corresponding DNA values; whereas, the highest ploidy level (2N = 84) had a DNA value corresponding to approximately 63 somatic chromosomes.

Determination of chromosome numbers for polyploid species which possess large numbers of very small chromosomes is a difficult and time consuming task. The problem becomes compounded when a large number of individuals need to be determined; therefore, Feulgen cytophotometry was used in this study to correlate nuclear DNA content with chromosome number to explore the pattern of ploidy levels of white ash throughout its natural range and thereby aid in further understanding the genetic variation in the species.

Material and Methods

White ash seed provenances from three open-pollinated families (single tree collections) were used *(Table 1).*

DNA Feulgen measurements were made from radicle apex cells of three embryos per slide and contiguous with

[1]) Present Address: Department of Botany, North Carolina State University, Raleigh, North Carolina 27607.