INTROGRESSIVE HYBRIDIZATION BETWEEN SHORTLEAF AND LOBLOLLY PINE IN SOUTHEAST OKLAHOMA

By

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

I	- Intermediate clones
L	- Loblolly clones
m	- Number of characters observed (see page 16)
S	- Shortleaf clones
$\delta^2{}_{ji}$	- Variance of character i in population j (see page 18)
U_{ji}	- Mean of character i in population j (see page 18)
X_{ki}	- Mean of character i of clone k (see page 18)
$\overline{X}_L$	- Loblolly mean
$\overline{X}_S$	- Shortleaf mean
Y_i	- Maximum value for character i (see page 16)

CHAPTER I

INTRODUCTION

Hybridization between closely related species of plants and animals has been the subject of much interest and study as evidenced by the writings of Anderson (1949), Mayr (1963), Stebbins (1950) and many others. The objective of many studies has been to identify the hybrid of two related species and describe it in relation to its parental types. That is, in what characters is it similar to one parent or the other and in what characters is it intermediate between the parents. A basic requirement to the identification or postulation of hybridization is a determination of what a species is and of the limits of the particular species in a particular environment. The definition of a species is the subject of various opinions and arguments (Burma, 1949; Mayr, 1949; Simpson, 1951; Mettler and Gregg, 1969). For the purpose of the research reported in this paper, a species may be defined as an intrabreeding population which rarely interbreeds with members of other populations. There are species which are so remote from each other, either physiologically or geographically, that they never cross. Of those that are more closely related, what prevents frequent crossing and what are the results of limiting the exchange of genes among species?

The ability of species to freely cross with each other is limited by what has been termed isolating mechanisms (Dobzhansky, 1941). In plants these fall into two major categories: prezygotic and postzygotic

(Stebbins, 1966). These isolating mechanisms function to prevent or reduce the chances of interspecific hybridization. In this light, Mayr (1963) views the species as an integrated gene system which has accumulated favorable genes and gene complexes that are protected against break-up by the isolating mechanisms of a particular species. If these isolating mechanisms fail and hybridization occurs, the subsequent backcrossing of the hybrid with either or both parental types may lead to introgressive hybridization (Anderson, 1949; Grant, 1971; Mayr, 1963; Stebbins, 1950). It is this process of introgressive hybridization which allows certain genes to pass from one species to another, resulting in an increase in variability in the species receiving the new genes. Hare and Switzer (1969) suggest that this introgressive process may be responsible for the resistance of western sources of loblolly pine (*Pinus taeda* L.) to fusiform rust. This is possible since both shortleaf pine (*Pinus echinata* Mill.) and shortleaf x loblolly hybrids are resistant to the rust, while loblolly is very susceptible over most of its range (Henry and Bercaw, 1956; Sluder, 1970). Hybridization is thus a method by which species are able to cope with environmental change through evolution (Anderson and Stebbins, 1954).

Purpose of Study

The objective of this study is to examine certain clones of loblolly and shortleaf seed orchards for the possibility of introgression between the two species. The study was initiated as a result of observations which indicated that one particular clone (number 73) in the loblolly orchard was not typical in appearance. The information obtained may be useful for decisions on roguing undesirable clones and for general knowledge of the species involved. A clone which is a possible hybrid may be undesirable as a seed producer due to a differential flowering period. As yet, reliable data on the flowering date of specific clones is not available.

CHAPTER II

MATERIALS

The Study Area

The data were collected from two clonal seed orchards, one of shortleaf pine and one of loblolly pine, located on the Kiamichi Research Station in Idabel, Oklahoma. The purpose of these orchards is the production of genetically improved seed. As such, they are located on favorable soil and receive intensive culture. Both orchards are laid out in complete block designs.

The loblolly orchard consists of 20 clones. The total number of ramets is 1255. A clone is a group of plants derived asexually from a single individual. Each plant of a clone is called a ramet and the individual from which they were propagated is called an ortet. For the loblolly orchard, 20 ortets were selected based on a phenotypic evaluation of desirable traits. Cuttings or scion material taken from each ortet was grafted onto rootstock of unknown pedigree to produce a clone. That part of the plant above the graft union is the same genotype as the ortet from which it came. Thus, there are approximately 60 ramets from each clone available for study. A few clones had fewer than 60 ramets as a result of incompatibility between the stock and the scion. The shortleaf orchard is composed of 30 clones and 1488 ramets, approximately 50 ramets per clone. The major portion of both orchards was established in 1967.

Source of Ortets

The ortets from which the orchards were established are from southeast Oklahoma, southwest Arkansas, and northeast Texas. Of the 20 loblolly pine ortets, 19 were chosen for study. Eleven of the loblolly ortets are located in McCurtain County, Oklahoma. The eight other ortets are from western Arkansas, within approximately 75 miles of the orchard site at Idabel, Oklahoma. Of the 12 shortleaf pine ortets chosen for study, 10 are from McCurtain County. The other two ortets are from counties in Arkansas and Texas which border McCurtain County, both within approximately 40 miles of Idabel.

The loblolly pine in McCurtain County expresses the northwestern limit of the range for that species, as shown in Figure 1. The situation is about the same for the Arkansas clones in that they too are near the edge of the species range (Sternitzke and Nelson, 1970). The shortleaf range extends somewhat further west as shown in Figure 1. The area of overlap of the loblolly pine and shortleaf pine in Figure 1 is where the majority of the loblolly pine ortets are located. As such, these ortets often occur in mixed stands.

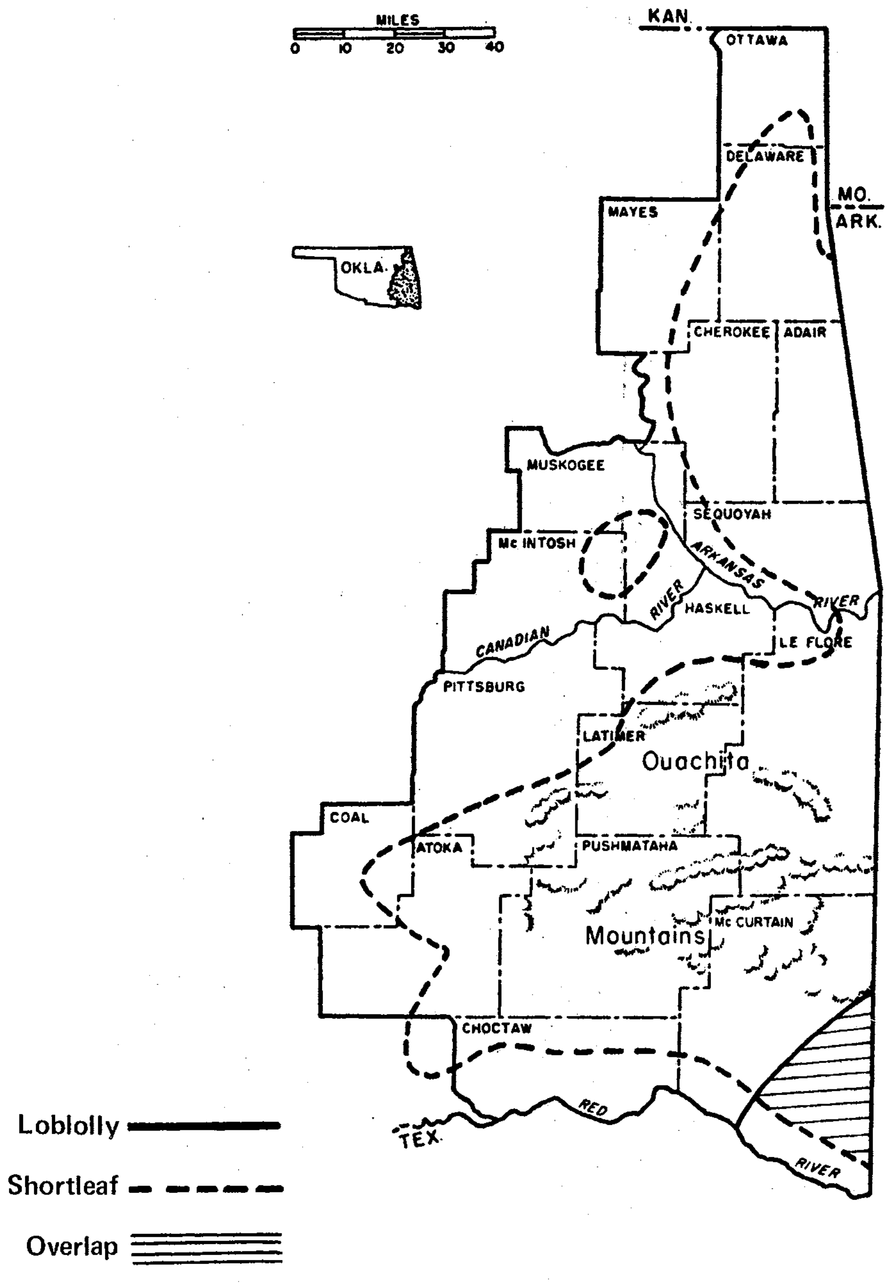


Figure 1. Species Ranges for Loblolly and Shortleaf Pine. Reference (Sternitzke and Nelson, 1970)

CHAPTER III

METHODS

Choice of Characters

The choice of which characters to measure was subject to several considerations. The characters chosen must differ significantly between the two species so that an intermediate type will be discernible. Hicks (1973) suggests that for effective use in the classification of hybrids, the morphological characters chosen should be easily and accurately measureable and should reflect genetic differences between the taxa involved. In a personal communication, Hicks suggested five characters for use in classifying loblolly, shortleaf, and possible hybrids between the two species. These characters were: needle length, number of needles per fascicle, fascicle sheath length, terminal bud width, and cone length. Terminal bud width was not used because the buds were actively elongating during the period of data collection. Consequently, it was felt that bud data taken during this period would not be reliable. The remaining characters, along with seed weight, were measured. However, the number of needles per fascicle was not included in the analysis due to a disagreement in the literature as to the number of needles per fascicle for loblolly. Harlow and Harrar (1968) describe loblolly as having three and occasionally two needles per fascicle while Kurz and Godfrey (1962) describe it as having three needles per fascicle.

This trait will be considered, along with other general observations, later in this paper.

Table I compares shortleaf and loblolly pine with respect to the four morphological characters measured in this study and included in the analysis. These values apply to the species in a natural situation. They may not be the same in an intensively managed orchard. However, the relative differences between the species should permit a morphological separation using these traits. Since the orchard environment of this study is more uniform than a wild stand, a better estimate of the difference between clones should result.

TABLE I

COMPARISON OF MORPHOLOGICAL CHARACTERS BETWEEN SHORTLEAF AND LOBLOLLY PINE

Character	Shortleaf	Loblolly
Needle Length (cm.)	7.6 - 12.7	15.2 - 22.9
Number of Needles/Fascicle	2 and 3	3 (occasionally 2)
Cone Length (cm.)	3.8 - 6.4	7.6 - 15.2
Number of Seeds/Gram	79 - 136	35 - 55
Fascicle Sheath Length (cm.)	.3 - .5	.6 - 1.3

Sources: Harlow and Harrar (1968); Kurz and Godfrey (1962)

Data Collection

The objective of the sample was to obtain reasonably accurate estimates of the mean and variance of the loblolly and shortleaf populations for those morphological characters of interest. In this way clone 73 could be compared with both populations.

Seed Weight

The sources of variation obtainable from this trait were those due to the variation among clones and within clones. The ability to separate variation due to ramets within clones and samples within ramets was lost because of the collection procedure. This procedure was to composite all the seed obtained from a particular clone. Since a single seed could not be weighed accurately, each sample consisted of 100 randomly drawn seeds. Each sample of 100 seeds was weighed to the nearest thousandth of a gram. Six 100 seed samples were weighed from each of the 17 loblolly clones which produced seed in the fall of 1973. The shortleaf sample consisted of three 100 seed samples from each of the 12 clones measured in the shortleaf orchard.

Cone Length

Cones were measured on the tree after they were fully elongated. In both orchards, a number of cones were measured and tagged after growth had apparently stopped. The tagged cones were remeasured after a period of 10 days to 2 weeks and it was found that growth had ceased. The shortleaf orchard was measured about three weeks after the loblolly orchard. This was because shortleaf in southeast Oklahoma is normally two or three weeks behind loblolly both in flowering and in cone maturation.

Cone measurement in the loblolly orchard was hampered as a result of a poor cone crop. This was apparently due to wet weather which prevented the pollen from becoming windborne. Since shortleaf anthesis is later than loblolly, pollination occured during dry weather and was therefore more effective. As a result, cones were not as difficult to find in the shortleaf orchard. In the loblolly orchard, 17 clones were included in the sample of cone length. The number of cones per clone ranged from 6 to 13, with two ramets per clone included in the sample. More ramets were not used as a result of the difficulty in finding cones on many of the clones. The 12 shortleaf clones were measured using six cones from each of three ramets for each clone. In both orchards, cones were measured with a caliper to the nearest millimeter.

One characteristic which was noticed as a result of measuring the cones on the tree, was the presence or absence of a peduncle (cone stalk). Harlow and Harrar (1968) list loblolly cones as being sessile, or without a peduncle, while stating that shortleaf cones are nearly sessile. It was observed during measurement that loblolly cones were indeed sessile, making measurement more difficult. However, clone 73 differed from the other clones in the loblolly orchard in that the cones had enough of a peduncle to make measurement easier. In this trait clone 73 resembled the shortleaf clones, for they too had enough of a peduncle to facilitate measurement.

Needle Length

Needle length was determined by measuring the longest needle per fascicle to the nearest millimeter. The sample consisted of nine randomly selected fascicles from each of 10 randomly selected ramets from each of 19 clones for the loblolly orchard. In all 1710 fascicles were measured for needle length in the loblolly orchard. The shortleaf sample size was five needle fascicles from each of three ramets from each of the 12 clones included in the study. In each orchard, needles were collected in plastic bags and stored in a refrigerator. This was done to prevent water loss and shrinkage before measurements were taken. Measurement with a metric ruler was accomplished the same day the needles were collected.

Fascicle Sheath Length

The fascicle sheath is the structure at the base of the needles which holds the group of needles together. The sample size for this trait is exactly the same as for needle length, since this structure was measured on the same fascicles used for needle length. Measurements were taken with a small vernier caliper to the nearest tenth of a millimeter.

CHAPTER IV

RESULTS AND DISCUSSION

Table II gives the mean and standard error for each morphological character for the loblolly and shortleaf orchards, and for clone 73. Means for individual clones for these traits are shown in the Appendix, Table III.

TABLE II

MEAN AND STANDARD ERROR FOR EACH MORPHOLOGICAL CHARACTER

	Loblolly	Shortleaf	Clone 73
Cone Length (cm.)	8.5 ±1.6*	4.5 ±.6	6.2 ±.4
Number Seeds/Gram	39 ±5.9	82 ±15	57 ±6.9
Needle Length (cm.)	22.5 ±1.8	12.4 ±.7	20.6 ±.6
Fascicle Length (cm.)	1.18 ±.16	0.88 ±.08	1.09 ±.04

* standard error approximated

It is of interest to note that the mean values for both loblolly and shortleaf, with the exception of fascicle length in shortleaf, fell within the range of values for the species (Table I). Clone 73 was intermediate in all characteristics measured. For cone length and seed weight, both populations were near the lower limit for their species. This would indicate that the favorable environment of the orchard may have had little effect on these maternal characters. The number of seeds per gram for clone 73 fell between the upper limit for loblolly and the lower limit for shortleaf, while cone length for that clone fell within the limits for the shortleaf species. Needle lengths for both species were near the upper limit described in Table I, as was fascicle sheath length for loblolly. Fascicle sheath length for shortleaf exceeded the value described by Kurz and Godfrey (1962). They were dealing with the species in Florida however, and their values may not be appropriate for southeast Oklahoma. The important thing is that there is no overlap between the two species for this trait. Possibly the environment had a greater effect on needle length and fascicle sheath length, since both characters were high for both populations. Again, clone 73 was intermediate, but in these traits resembled loblolly more than shortleaf.

Analysis

Scatter Diagram

The scatter diagram is a technique which shows the relationship between individuals for two traits (Anderson, 1949). However, all four of the study characters can be incorporated into a two dimensional graph if cone length and seed weight are grouped into cone characters, and needle length and fascicle length are grouped into needle characters. This was done using the hybrid index formula by summing the scores for the cone and needle characters separately. An explanation of how the hybrid index was calculated will be given in the following section.

The purpose of using this technique was to show the relationship between: 1) individual clones within a species, and 2) clones classified as being of different species. The results of this procedure are presented in Figure 2. Each clone is identified by number as they are in the orchards. Of special interest is clone number 73, which was the suspected hybrid when the study began. The values for cone characters and needle characters used to construct the scatter diagram are found in the Appendix, Table IV. The clones in the shortleaf orchard are numbered 30 or less, those in the loblolly orchard are numbered from 71 through 89.

Hybrid Index

The purpose of the hybrid index is a graphical presentation of the relationship of intermediate plants, or in this case clones, to other plants of the two species from which they may have originated. This technique was originated by Anderson (1936) and is discussed in his paper on introgressive hybridization (Anderson, 1949). An excellent example of the use of the hybrid index is also found in Dansereau and Desmaris (1947), in a paper dealing with introgression in sugar maples. Further discussion of the hybrid index can be found in Hatheway (1962), Goodman (1966), and Hicks (1974).

The hybrid index for this study was calculated for each clone from the mean values for the morphological characters: cone length, seed weight, needle length, and fascicle sheath length (Appendix, Table IV). The score for each clone was calculated using the formula:

$$\sum_{i=1}^{m} \frac{X_{ki}}{Y_i} \qquad (1)$$

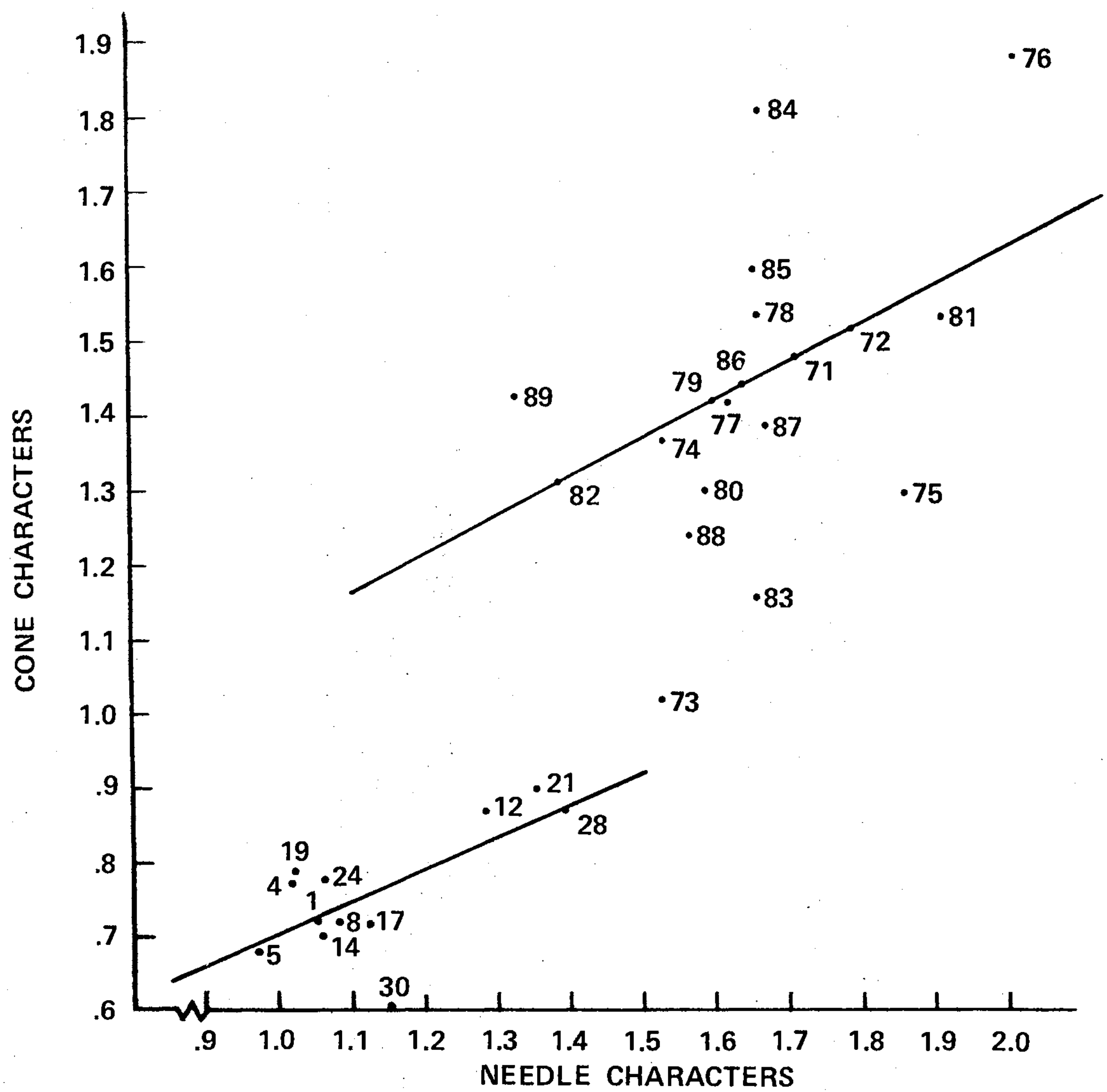


Figure 2. Scatter Diagram for Loblolly and Shortleaf Pine, Including the Regression for Each Population

where: m = the number of characters observed

X_{ki} = the mean value for character i of clone k

Y_i = the maximum value for character i

For each morphological character, the maximum value (Y_i) becomes a constant with the only variable being the mean value for clones (X_{ki}). Since the value of character i of clone k is divided by the maximum value for that character, the index value for each character for each clone must be between zero and one. Therefore, the index value of any clone for all four characters must be between zero and four. The index values for all clones studied are presented in Figure 3 as a bar graph indicating the number of clones for each particular index value class. The calculated index values for each clone, from which the hybrid index was constructed, are presented in the Appendix, Table IV. The intermediate clones in Figure 3 are numbers 12, 21, and 28 from the shortleaf orchard and number 73 from the loblolly orchard. Their exact location can be determined from the Appendix, Table IV.

Weighted Hybrid Index

The weighted hybrid index differs from the hybrid index in that the variance of a character is included in the calculation of an index value. The deviation of a particular clone from the popular mean for a given character is weighted by the variance of that character over all the clones sampled in that population. The formula for the weighted hybrid index from Goodman (1966) is:

$$\sum_{i=1}^{m} \frac{(X_{ki}-U_{2i})^2}{\delta^2_{ji}} - \frac{(X_{ki}-U_{1i})^2}{\delta^2_{ji}} \qquad (2)$$

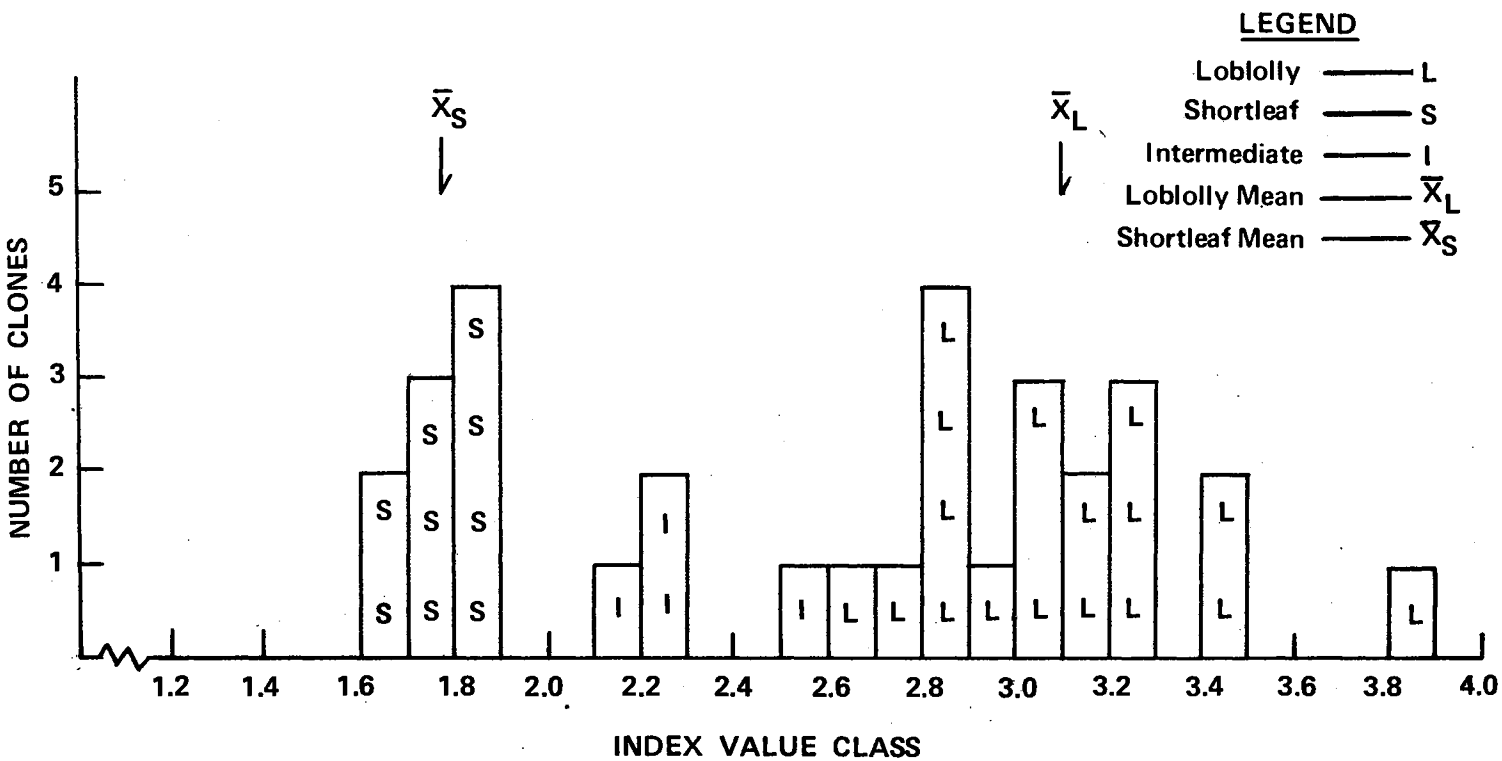


Figure 3. Hybrid Index Bar Graph

where: m = the number of characters observed

X_{ki} = the mean value of character i of clone k

U_{ji} = the mean of character i in population j

U_{2i} = the mean of character i for shortleaf

U_{1i} = the mean of character i for loblolly

$\delta^2{}_{ji}$ = the variance of character i in population j

The weighted hybrid index is given in Figure 4 as a bar graph and the calculated values for each clone are in the Appendix, Table V. The scale for figure 4 was obtained by adding 60 to every index value, making all index values positive. A comparison of the hybrid index versus the weighted hybrid index is given in Figures 5 and 6. The scale for Figure 6 was obtained by dividing all the index values by 100, resulting in the same scale for Figures 5 and 6. Again, the same clones are intermediate as in Figures 2 and 3. Clones 12, 21, and 28 are located between index values 40 and 60; clone 73 between 80 and 100.

One problem encountered in deriving the weighted hybrid index was whether to include the mean values from every clone in calculating the population mean U_{ji} for the loblolly population. To resolve this problem, several indices were constructed omitting certain clones in order to ascertain what effect this would have on the calculated index values. It was observed that the changes were so small as to have a negligible effect on the overall relationship. Therefore, only clone number 73 was omitted in calculating the loblolly population mean ($\overline{X}_L$). The population mean for shortleaf ($\overline{X}_S$) was calculated omitting clones 12, 21, and 28.

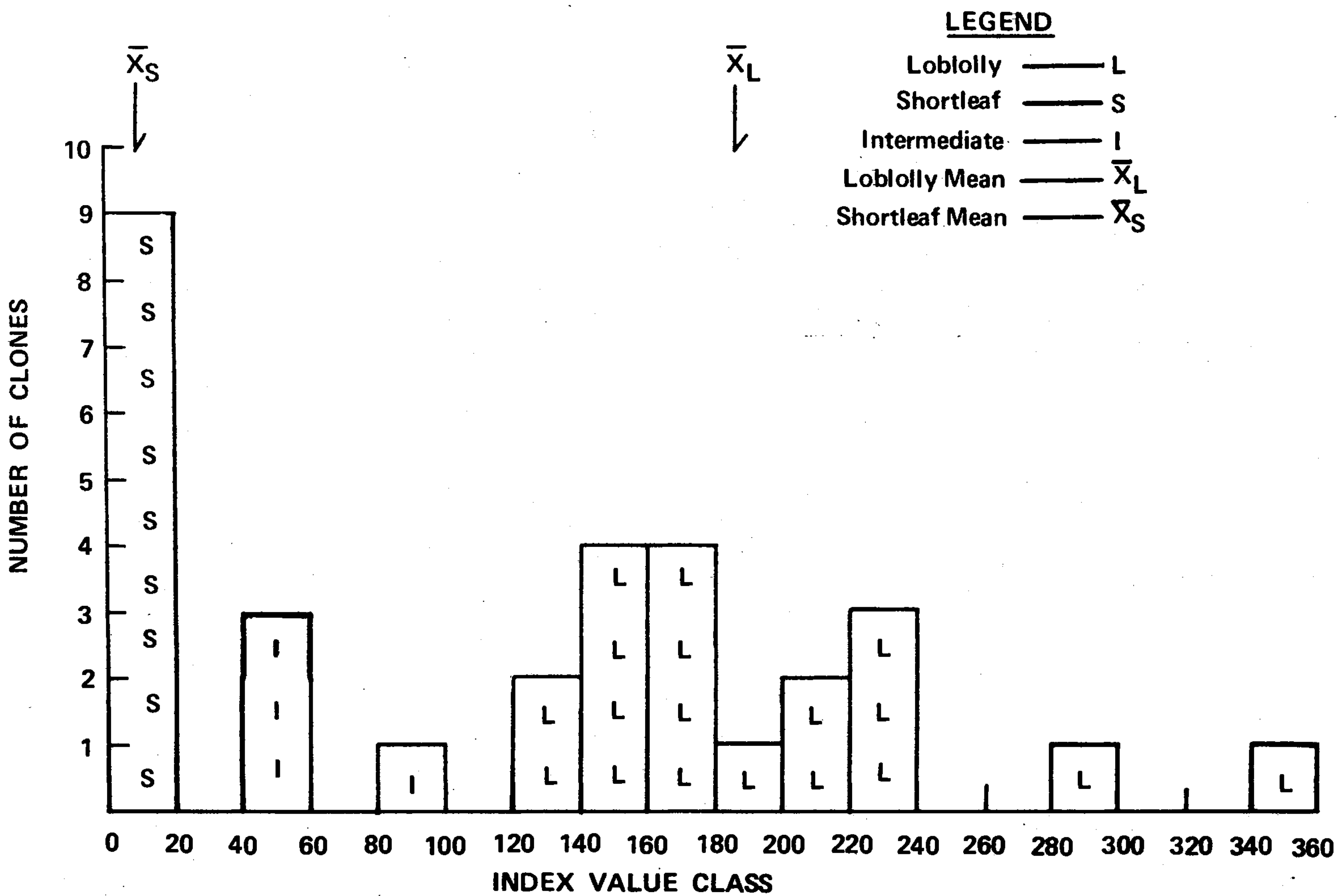


Figure 4. Weighted Hybrid Index Bar Graph

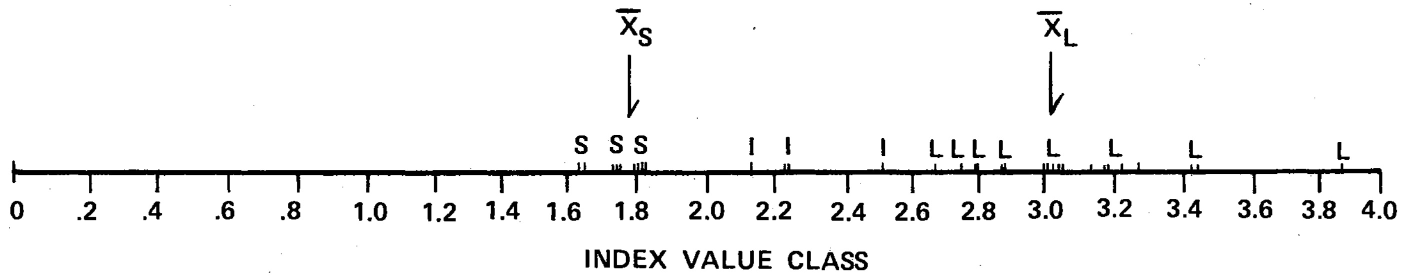
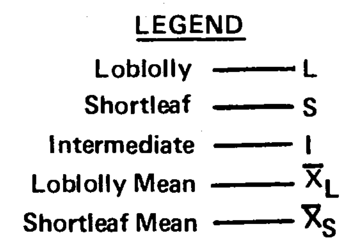


Figure 5. Hybrid Index Point Graph



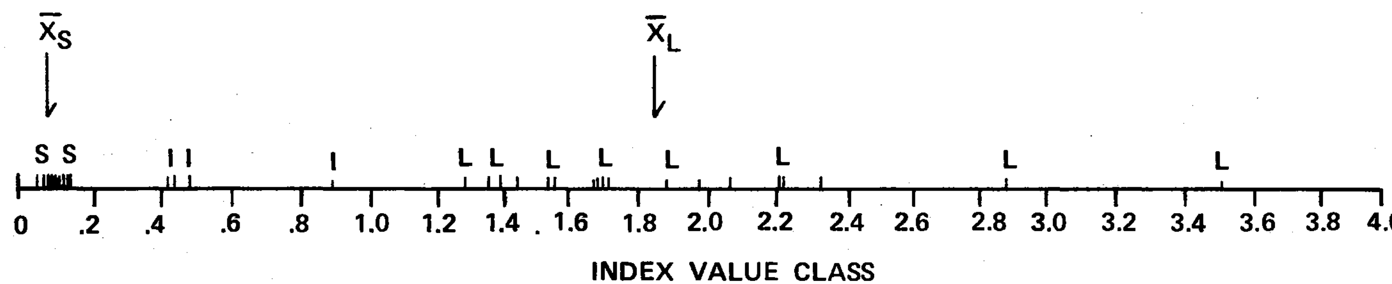


Figure 6. Weighted Hybrid Index Point Graph

CHAPTER V

SUMMARY AND CONCLUSIONS

The significant features of these data are the consistently intermediate position of clones 12, 21, 28, and 73 over the three methods of analysis, and the fact that the loblolly population is much more variable than the shortleaf population for those characters evaluated in this study.

That the four clones are intermediate does not necessarily mean they are hybrids. However, in a study of natural and controlled loblolly x shortleaf hybrids in Mississippi; Mergen, Stairs, and Snyder (1965) found that means for 20 vegetative characters of young F_1 hybrids were generally intermediate to those of interplanted paternal checks. In this study, Figures 5 and 6 show best the exact position of the intermediate clones in relation to both species and the index values derived from the mean values ($\overline{X}_S$ and $\overline{X}_L$) for each population. Although stating that the hybrid was intermediate for vegetative characters; Mergen, Stairs, and Snyder (1965) also said that the F_1 hybrid tended to resemble loblolly more than shortleaf. Hicks, in a personal communication, stated that he believes that if hybrids exist, they resemble shortleaf more than loblolly for those morphological characters he evaluated (see Chapter III). These differences may involve the different source of material as well as the difference in environment between Mississippi and Texas.

The fact that the loblolly population is so variable is another characteristic of these data which indicates that hybridization and subsequent introgression may be occurring. Grant (1972) states "the expected effects of backcrossing and introgression will be to produce a population which is variable and which approaches one parental species in its phenotypic characteristics" (p. 166). Kang (1966), in a study of the relationships between loblolly and pond pine (*Pinus serotina* Michx.) in North Carolina, found that hybridization was common between the two species. He noted that tree to tree variation was greater in loblolly than in pond pine and concluded that this was a result of introgression from pond pine to loblolly pine. Figures 2 through 6 all show that the variation in the loblolly orchard is much greater than that in the shortleaf orchard. Some of this variation may be due to the fact that the ortets are spread over some distance. However, the shortleaf from essentially the same area, do not exhibit this variation. The variation is so large in fact, that it is certainly possible that clone 73 is just a normal variant of the loblolly and not of hybrid origin. Figure 2 shows that clone 76 varies more than clone 73 from the general population, and in the opposite direction. Since the characters measured are all larger in loblolly than in shortleaf, a greater amount of variability could be expected in the loblolly orchard. It is not known what amount of the total variability in the loblolly orchard is due to the larger size of the structures measured. Were it not for the variation of clones 12, 21, and 28 from the shortleaf population, it would appear that loblolly was just a more variable species than shortleaf. However, the intermediate position of clones 12, 21, 28, and 73 plus the large amount of variability in the loblolly clones, tend to indicate that introgression is taking place from shortleaf to loblolly.

Two observations of a qualitative nature were made which supported the possibility of clone 73 being a hybrid. One was the occurrence of a peduncle, which was mentioned in Chapter III. It was noted that clone 73 was the only clone in the loblolly orchard that had a peduncle, a characteristic common to all the shortleaf clones sampled. The other observation was the occurrence of fascicles containing two needles. The shortleaf needles sampled had fascicles which contained both two and three needles per fascicle in the ratio of approximately 2:1. The loblolly needles sampled consisted almost entirely of three needle fascicles (98.5 percent). The remaining 1.5 percent of fascicles contained either four or two needles per fascicle. Of the four needle fascicles, nothing could be found in the literature. Concerning the two needle fascicles, Harlow and Harrar (1968) and Preston (1948) list loblolly as having three or occasionally two needles per fascicle, while Kurz and Godfrey (1962), Hough (1947), and Harlow (1936) show three needles per fascicle for the species. In this study, it may be significant that only three fascicles were found in the loblolly orchard which contained two needles per fascicle, and all of those came from different ramets of clone 73. It should be considered also, that only a very small percentage of the total number of needles present in the orchard were sampled.

The sample size for this study, in terms of the two species, consisted of 31 clones, 12 of shortleaf pine and 19 of loblolly pine. Each clone originated from a single ortet. As such, this sample represents a very small portion of the total size of each population in southeast

Oklahoma. It seems logical that if hybridization were rare, a sample of this size would probably fail to detect any intermediate types. Since four clones appear to be possible hybrids in a sample of this size, it appears that hybridization in this area is not uncommon and may occur rather frequently. The fact that loblolly pine is at the extreme edge of the species range where environmental stress may affect hybridization, plus the fact that the two species occur in mixed stands, may tend to influence the frequency at which the two species hybridize. Moss (1949) found that jack pine (Pinus banksiana) and lodgepole pine (Pinus contorta variety latifolia) hybridize frequently where they overlap near the limits of their ranges. Dansereau and Desmarais (1947), in a study of introgression in maples, noted that: "Whenever two species likely to hybridize grow together, and conditions are more favorable to one than to the other, introgressive hybridization may occur" (p. 146).

In summation, the best hypothesis for these data is that hybridization has occurred frequently between the two species and that the hybrids backcross with loblolly more frequently than with shortleaf. Since the primary barrier to the crossing of these two species in southeast Oklahoma is the time of pollination, it is not surprising that hybridization could frequently occur. Also, in this area of southeast Oklahoma, it appears that these two species are not well separated in regard to those characters evaluated in this study. Rather, there seems to be a continuous range in morphology between the two species.

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APPENDIX

TABLES III-V

TABLE III

INDIVIDUAL CLONE MEANS FOR EACH CLONE SAMPLED WITH SPECIES MEAN AND STANDARD ERROR

Clone Number	Cone Length (cm.)	Number Seeds Per Gram	Needle Length (cm.)	Fascicle Length (cm.)
1	4.2	76.9	11.4	.92
4	5.1	82.4	13.3	.77
5	5.5	127.6	12.2	.76
8	4.7	86.3	12.5	.90
12	5.4	67.9	15.9	1.00
14	4.4	86.6	12.6	.86
17	3.8	71.4	12.4	.97
19	4.0	63.3	11.9	.85
21	5.7	68.0	16.1	1.10
24	4.8	75.1	11.6	.93
28	5.1	64.9	15.2	1.22
30	3.8	99.4	13.4	.96
$\bar{X}_S$	4.5 ±.6	82.4 ±15	12.4 ±.7	.88 ±.08
71	7.8*	34.8	22.9	1.23
72	9.0*	37.5	25.5	1.19
73	6.2	57.5	20.6	1.09
74	8.0	40.8	21.7	1.03
75	8.2	46.5	23.6	1.42
76	12.3	32.9	25.7	1.52
77	9.1	43.4	21.7	1.17
78	8.3	34.0	22.5	1.18
79	8.3	39.6	22.0	1.12
80	8.8	49.9	22.6	1.06
81	7.5	31.6	24.1	1.46
82	6.4	37.2*	19.1	.97
83	6.7	48.0	24.5	1.06
84	10.0	29.4	23.0	1.15
85	10.5	39.2	22.0	1.19
86	7.0	33.7*	22.6	1.14
87	7.9	39.2	22.0	1.23
88	6.7	42.4	21.4	1.11
89	9.1	42.3	18.4	.92
$\bar{X}_L$	8.5 ±1.6	38.6 ±5.9	22.5 ±1.8	1.18 ±.16

* Missing data; approximated from regression in Figure 2.

TABLE IV

HYBRID INDEX VALUES FOR EACH CLONE

Clone Number	Cone Characters	Needle Characters	Index Values
1	.72	1.05	1.77
4	.77	1.02	1.66
5	.68	.97	1.65
8	.72	1.08	1.80
12	.87	1.28	2.15
14	.70	1.06	1.76
17	.72	1.12	1.84
19	.79	1.02	1.81
21	.90	1.35	2.25
24	.78	1.06	1.84
28	.87	1.39	2.26
30	.60	1.15	1.75
71	1.48	1.70	3.18
72	1.52	1.78	3.29
73	1.02	1.52	2.53
74	1.37	1.52	2.89
75	1.30	1.85	3.15
76	1.89	2.00	3.89
77	1.42	1.61	3.03
78	1.54	1.65	3.19
79	1.42	1.59	3.01
80	1.30	1.58	2.88
81	1.54	1.90	3.44
82	1.37	1.38	2.69
83	1.16	1.65	2.81
84	1.81	1.65	3.46
85	1.60	1.64	3.24
86	1.44	1.63	3.06
87	1.39	1.66	3.06
88	1.24	1.56	2.80
89	1.43	1.32	2.76

TABLE V

WEIGHTED HYBRID INDEX VALUES FOR EACH CLONE

Clone Number	Index Value	Transformed Index Value
1	-53	.06
4	-45	.15
5	-52	.08
8	-48	.11
12	-15	.44
14	-50	.10
17	-45	.15
19	-46	.13
21	- 9	.51
24	-50	.10
28	-13	.46
30	-45	.15
$\overline{X}_S$	-50	.10
71	140	2.00
72	165	2.26
73	33	.94
74	98	1.58
75	110	1.70
76	293	3.53
77	113	1.74
78	149	2.09
79	112	1.73
80	96	1.56
81	176	2.36
82	72	1.33
83	82	1.42
84	230	2.90
85	164	2.25
86	131	1.92
87	111	1.71
88	74	1.35
89	86	1.47
$\overline{X}_L$	126	1.86

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