Crooked Stem Form in Loblolly Pine[1]

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Bole sweep, crook, and twist are serious defects of trees which can cause substantial losses of volume and value. Although the effect of sweep can be minimized in sawlogs by careful log bucking, sweep remaining in a log may cause reduction in grade (4). Short crooks or abrupt bends result in loss of log scale. Any of these deviations beyond specified maximum acceptable limits leads to disqualification of poles (1). Because of the association between compression wood and bole defects of this type, the defects cause a reduction in pulp yield and fiber quality in proportion to their severity (17). Crooked trees are less valuable and produce lower quality in nearly all products made from wood.

Because of the economic importance of bole straightness, this characteristic has been incorporated into many tree improvement programs (2, 5, 14, 16). In individual tree selection, straightness is often weighted as much as or more than any other tree feature even though there is only scanty information available concerning its degree of inheritance.

There are frequent inferences that deviations from straight bole form in various tree species may be caused by environmental agencies such as wind, snow, mechanical damage to leaders, response to light, or even nutrition. Scientists and naturalists have long been intrigued by spiraling in tree boles and have attributed this to various causal agencies (6, 9, 15). However, most agree with Knorr (8) that this is largely a genetic trait although the intensity of inheritance is not known. While sweep and crook may be more subject to external influence, reports such as those of Hopp (7) with a locust, Mergen (12) and McWilliam and Florence (11) with slash pine, and others indicate at least partial genetic control.

Materials and Methods

Definitive information concerning inheritance patterns is best obtained from progeny tests. To obtain data on stem form inheritance several crosses between crooked and straight loblolly pines were made at the University of Florida. Perry (13) has reported on measurements of trees resulting from these pollinations two years after out-planting. To study the development of bole form defects and to check the reliability of their very early assessment, measurements of crook in these trees were again made in the fall of 1963. At the time of this measurement the trees had been established seven years, and many were over 30 feet in height.

As reported by Perry (13) crosses were made between two very crooked and two essentially straight loblolly pines. All possible crosses among the four trees were attempted, but because of losses between pollination and cone collection, only five specific crosses (full-sibs) were available in sufficient numbers for study. These included reciprocal crosses between the two crooked parents. In addition to the controlled pollinated lots, wind pollinated progeny (half-sibs) from five trees (3 of them also parents of the controlled lots) and a bulk lot from the state nursery were also included.

There is no "standard" quantitative measure of crook. Barber (3) made an ocular estimate of crook in evaluating young slash pine progenies. Mergen (12) classified trees as having or lacking sweep but made no quantitative measure of sweep severity. Littlefield and Eliason (10) set up three crook categories – none, one well defined crook, and two or more crooks – without specifying severity. Anticipating future measurements of crook in progenies of parents with less extremely crooked phenotypes, we felt that more refined distinctions were needed. Thus, an adaptation of Perry's method was used (13). Perry's students determined the number of crooks per meter of bole plus the magnitude of the crook nearest breast height for the two-year-old trees. In the measurements reported here, the number of crooks in the first log (17.3 feet) and the deviation of the most severe crook in the same portion were determined. The most severe crook was measured by stretching a plastic line from top to bottom of the crook and measuring the greatest distance from the inside of the crook to the line (*Figure 1*). A "Crook Index" was computed – the product of the number of crooks times the deviation of the most severe crook.

The original planting design for this study was five replications of five-tree row plots in randomized blocks. However, due to shortages in some lots at time of planting and because of subsequent mortality, some lots were not represented in all blocks. Because of variable numbers of the several progenies, and, as there is no reason to assume that tree crookedness would be influenced by the minor variations in site on a small, uniform area (.55 acre), original blocks were ignored and the data were analyzed as a completely randomized design. In Perry's earlier analysis of crookedness in this material the mean square for blocks was inconsequential.

Results and Discussion

The mean "crook index" for each of the lots is presented in *Table 1*. Analysis of variance indicated very highly significant differences among lot means in crookedness (*Table* 2). Comparisons among the means were tested by the Duncan method (*Table 1*).

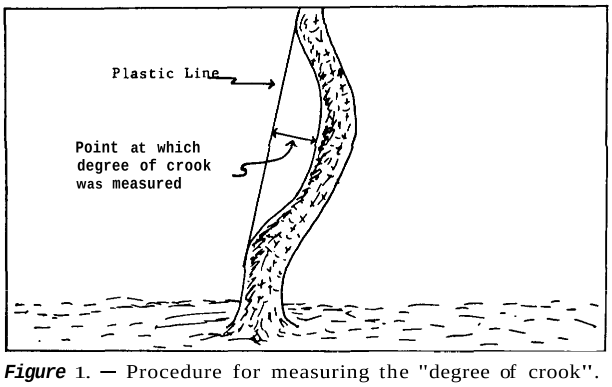

Figure 1. — Procedure for measuring the "degree of crook".

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[1] The authors wish to acknowledge the work of graduate students James Arnold, Donovan Forbes, Richard King and James McMinn. They helped in the development of the rating system and in making measurements upon which this report is based.

Table 1. — "Crook Index" for loblolly pine progenies.

Lot[1]	Trees	Percent of straight trees 1958[3]	Percent of straight trees 1963	Mean Crook Score 1958[3]	Mean "Crook Index" 1963[2]
C 2 × C 1	24	11.5	1.4	30.59	17.89
C 1 × C 2	44				16.53
C 2 × S 2	13	26.7	7.6	28.33	15.06
C 155 × 0	15	—	6.7	—	12.47
C 2 × 0	33	33.3	24.0	18.59	10.96
C 1 × S1	12	21.5	41.6	19.14	7.64
S 1 × S 2	25	48.2	32.0	16.42	7.39
SN	70	34.8	45.7	22.54	6.77
S 2 × 0	9	33.4	22.2	16.52	5.51
S 1 × 0	18	42.9	50.0	21.59	5.30
S 150 × 0	27	—	66.7	—	3.75

[1] Explanation of symbols:
C1, C2, C155 = crooked parents; S1, S2, S150 = straight parents; 0 = open pollinated; SN = state nursery stock.

[2] Lines indicate groups of means that are not significantly different at the 1% confidence level.

[3] From PERRY, 1960.

These analyses revealed no significant difference between the reciprocal crosses C1 × C2 and C2 × C1. In all subsequent calculations these progenies were combined. The combined C1 × C2 and C2 × S2 progeny were significantly more crooked at the .01 level of probability than all other lots except the open pollinated lot 155, progeny of another very crooked tree. Most straight tree progenies were relatively straight. The relatively low crookedness index of most straight tree progenies is evident.

For further comparison, the percentage of trees with "acceptably" straight boles was calculated. For this purpose a straight tree was defined as: (a) having no more than five minor crooks within the lower 17.3 feet; (b) having no single crook more severe than 2.5 inches deviation, and (c) having a total crook index no larger than 7. The ranking of lots by percentage of straight trees is in general agreement with ranking by mean crook index. Lot S2 ×0 is an exception with fewer trees in the "acceptable" class than its low mean score would suggest because of a high proportion of stems with numerous small crooks.

In the analysis of variance the mean square for lots may be separated into two parts, one reflecting natural variation and the other peculiar to the individual lots. The ratio of these two variances, intraclass correlation, indicates the degree of genetic similarity within the various lots and the genetic differences between the lots. Intraclass correlation based on the analysis of variance of all lots was 0.48, suggesting a high genetic component of variance for crookedness (*Table 2*). Separate analyses were made including only full-sib lots and half-sib lots. Rather unexpectedly, the genetic component of variance was the same in both groups (0.47). This may be largely due to the close similarity of individuals in the open-pollinated lot S150 which had many very straight trees. Although intraclass correlations are frequently used to estimate the heritability of a trait in a population, they cannot be used in this case due to the non-random selection of parents. There is, however, a strong implication that crooked parents beget crooked offspring.

Table 2. — Analysis of variance for crook index.

Sources	Degrees of Freedom	Sums of Squares	Mean Squares	F	rI
		All Lots			
Between lots	10	6,422.90	642.29	24.31	0.48
Within lots	279	7,371.22	26.42		
Total	289	13,794.12			
		Full-sib Lots			
Between lots	3	2,201.65	733.88	21.91	0.47
Within lots	114	3,817.46	33.49		
Total	117	6,019.11			
		Half-sib Lots			
Between lots	4	1,258.74	314.68	14.67	0.47
Within lots	97	2,080.55	21.45		
Total	101	3,339.29			

In addition, implications regarding combining ability were present in the data although the unfortunate loss of key combinations from the original plan reduced the reliability of the conclusions that may be drawn. High specific and general combining ability for crookedness was evident in all progenies of C2, regardless of the other parent involved. The average crook index for C2 progenies was 14.41. In contrast the average crook index of all S1 progenies was 6.78 with a fairly high proportion of relatively straight trees even in combination with a crooked mate. On the basis of crook index, progeny of the specific cross S1 × S2 were not as straight as the open-pollinated progenies of these two trees. This suggests that these two trees had rather high general combining ability for straightness but lower specific combining ability, although the lack of significant differences among these crook index means does not lend weight to this comparison.

The reliability of assessment of crookedness two years after test establishment was indicated by comparison of crookedness ratings in 1958 and 1963 and by comparing the percentages of trees considered straight at those times. In general there was a high degree of agreement in so far as the very crooked progenies were concerned. There was also fair agreement concerning the more straight lots but rather general shifting of place in the middle rankings. Individual tree ratings from the 1958 measurements were not available to the present authors, but the correlation of plot means from the two measurements was computed. The highly significant correlation coefficient (r = 0.83) indicates that the earlier assessment of this characteristic was fairly reliable in this case. Had the differences among the progenies been less extreme the agreement would undoubtedly have been poorer. However, the extent of agreement between second and seventh year evaluations of crookedness indicates that the tendency for bole form is apparent at a fairly early age and that sufficiently reliable estimates of mature form need not be delayed for an extended period.

Summary

Controlled and open-pollinated progenies of crooked and straight loblolly pines were evaluated for crookedness seven years after out-planting. A "crook-index" for each individual was determined as the product of the number of crooks in the first log and the deviation in inches of the most severe crook in that bole portion. Analysis of variance indicated highly significant differences among progeny means, and intraclass correlations suggested high genetic components of variance. There was some suggestion of parental differences in general and specific combining ability for crookedness and straightness. Rather good agreement between crookness evaluations two and seven years after test establishment was indicated by a high correlation between progeny means from the two measurements.

Résumé

Titre de l'article: *Flexuosité du fût chez Pinus taeda.*

Des descendances issues de croisements contrôlés et de pollinisation libre de *Pinus taeda* à fût rectiligne ou flexueux ont été étudiées pour ce caractère sept ans après la plantation. On a déterminé pour chaque individu un «index de flexuosité»: produit du nombre de courbures dans la première bille par la déviation en centimètres de la courbure la plus forte dans cette portion du tronc. L'analyse de variance montre des différences hautement significatives entre les descendances et les corrélations intraclasses suggèrent des composants de la variance fortement contrôlés par l'hérédité. Il existe certaines indications de différences entre parents pour l'aptitude générale et spécifique à la combinaison en ce qui concerne la flexuosité et la rectitude. Les mesures de flexuosité à 2 ans et à 7 ans sont liées par une forte corrélation.

Zusammenfassung

Titel der Arbeit: *Über Stamm-Krümmung bei der Loblolly-Kiefer.*

An Nachkommenschaften von kontrolliert bestäubten und frei abgeblühten krummen und geraden Loblolly-Kiefern wurden 7 Jahre nach ihrem Auspflanzen Vermessungen hinsichtlich vorhandener Krümmungen vorgenommen. Für jedes Individuum wurde ein „Krümmungs-Index" festgestellt, und zwar als Produkt aus der Anzahl der Krümmungen im untersten Stammabschnitt von etwa 5½ m und der Abweichung der stärksten dortigen Krümmung von der Geraden. Die Varianzanalyse ergab hochsignifikante Unterschiede zwischen den Mitteln; ferner wiesen die Intraklassen-Korrelationen auf eine starke genetische Varianz-Komponente hin. Es fanden sich Anhaltspunkte für die Eltern-Unterschiede im allgemeinen und für die spezifischen Kombinationsfähigkeiten von Krümmung und Geradheit. Die recht gute Übereinstimmung zwischen den Krümmungsermittlungen nach 2 und 7 Jahren zeigte die starke Korrelation zwischen den Nachkommenschaftsmitteln von 2 Messungen an.

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Buchbesprechungen

Statistical Genetics and Plant Breeding. (A Symposium and Workshop Sponsored by the Committee on Plant Breeding and Genetics of the Agricultural Board at the North Carolina State College, Raleigh, N. C., March 20–29, 1961.) Ed. by W. D. Hanson and H. F. Robinson. Nat Acad. Sci. — Nat. Res. Counc., Wash. D. C., Publ. 982, 1963, pp 624. 16.– US-Doll.

Ziel des Symposiums war es, den einleitenden Ausführungen G. F. Spragues zufolge, "to minimize any limitations arising from either lack of familiarity with statistical genetic theory and philosophy or from a lack of appreciation of the utility of statistical genetic methodology in the solution of breeding problems". Symposium und Workshop waren je in mehrere Sektionen unterteilt, wie aus der nachfolgenden Besprechung der Beiträge zu ersehen.

Biologische und Statistische Konzeptionen der genetischen Theory.

Wallace, B.: Modes of reproduction and their genetic consequences. — Die Rolle des „Geschlechts" (worunter alle Mechanismen verstanden werden, die zu Rekombination führen können), der Ploidie, Heterosis Koadaptation, Introgression, des Paarungstyps, der asexuellen Fortpflanzung und der genetischen Theorie der Evolution in der Theorie der Züchtungsforschung werden eingehend und durch viele Beispiele erläutert besprochen. —

Kempthorne, O.: The role of systems of mating in the determination of means. variances and covariances in genetic populations. — Ausgehend von einer diploiden, zufallspaarenden Population mit nur einem spaltenden Locus und einfachster Vorstellung über die Genwirkung werden die Grundprinzipien der Methoden der quantitativen Genetik und deren Anwendung auch in mehr komplexen Situationen dargestellt. —

Dempster, E. R.: Concepts and definitions in relation to selection schemes. — Im Zusammenhang hiermit werden vor allem die Bedeutung des Paarungstyps, der Populationsgröße, epistatischer Varianzen und korrelierte Reaktion auf Auslese diskutiert. —

Hayman, B. I.: Models in quantitative genetics. — Eine Zusammenfassung der Referate zu dieser Sektion mit kritischer Sichtung der gebräuchlichen Modelle, ihrer Voraussetzungen usw. sowie Hinweise auf noch ungeklärte und in Zukunft zu bearbeitende Probleme. —

Schätzung und Ausdehnung genetischer Parameter.

Cockerham, C. C.: Estimation of genetic variances. — Eine Darstellung der gebräuchlichsten Verfahren zur Schätzung der genetischen Parameter, einschl. Genotyp-Umwelt Interaktionen und anderer Komplikationen sowie der Erwartungswerte der Mittelquadrate in Termini von Varianzkomponenten und Kovarianzen zwischen Verwandten mit anschließender Besprechung der praktischen Gesichtspunkte. —

Dickerson, G. E.: Biological interpretation of the genetic parameters of populations. — Die genetischen Parameter, zu denen auch der Selektionserfolg und Interaktionen zur Umwelt gezählt werden, müssen in realistischen, d. h. der Situation, für die der Züchter arbeitet, weitmöglichst angepaßten Versuchen geschätzt und unter Berücksichtigung aller erreichbaren biologischen Informationen gedeutet werden. "Breeding is biological engineering". —

Robertson, A.: Some comments on quantitative genetic theories. — In der Zusammenfassung wird auch auf die in den einzelnen Beiträgen nicht berührten Probleme hingewiesen, so auf die notwendige Herstellung einer Verbindung von Genfrequenzen und genetischen Varianzen, "plateauing" u. a. —