STEM-CROWN RELATIONSHIPS IN SCOTCH PINE

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The history of this Conference and the history of forest genetics appear to be quite similar. From the question, "Is there genetic variability in the trees with which we are working?", the tenor of the questions has shifted to ones containing such phrases as, "how much," "what influences," "how to measure", and so on. There is no need to document here this history in detail.

Rather, let us take a more pragmatic approach. There is genetic variability in trees, in the present case Scotch pine. With this knowledge, what can we find out that will be of significance to the growers of trees? This paper will attempt to show that from a consideration of some of the basic relationships in plant form a rational model of tree form can be built, that the model will fit empirical observation and that the fitted model can be used as a discriminatory tool in some phases of forest productivity.

Greenhill (1881) in the last century showed that for plants with homogeneous stems the diameter must increase as the power of 3/2 of the height. This exponential relationship suggests the reason for the "whippy" appearance of young trees and the somewhat "squat" appearance of older trees.

In the 1930's Schumacher and his students showed that a second degree equation could be fitted to the relationship between diameter breast high (DBH) and the cross-sectional area of the crown at the maximum limits of the crown (Lexen, 1939; Chisman and Schumacher, 1940). Shortly thereafter Rashevsky (1943) showed that for a tree there is this relationship:

$$L = f\ (R_B, S) \qquad (1)$$

where L = branch length; R_B = Radius of branch; and S = Average density of plant and, it is submitted, branching angle.

From this relationship and others in the papers cited, several considerations are apparent (Rashevsky, 1943, 1944; Opatowski, 1944, 1944, 1945; and Esser, 1946). For our purposes the following will suffice: the branch can be no longer than the limits imposed by the strength of the wood of the branch, by the branch angle, and by the branch radius. Species have characteristic wood properties. The radius of the branch cannot exceed in the horizontal plane the radius of the trunk to which it is attached. There should, therefore, be a relationship between the length of a limb and the radius of the trunk.

Since Rashevsky's paper others have reported relationships similar to those of Chisman and Schumacher. In some cases the relationship has been presented as curvilinear and in others linear (Ferree, 1953; Krajicek et al., 1961; Arnold, 1948; and others).

It has been shown that a dimensionally balanced stem-crown equation is linear. That is, if the stem is measured in diameter and the crown in diameter, or if both are measured in area, the equation expressing the relationship will be a straight line (Stout, 1963).

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The stem-crown equation should allow for tests of differences between genotypes. The parameter that should reflect the difference, if any, is the slope of the regression line. Standard statistical procedures have been developed to make the tests of the slopes (e.g. Bennett and Franklin, 1954).

In the Cranbury plantation of the Regional Project NE-27 Scotch pine provenance plantations four sources were chosen to determing two things:

1. Is there a linear relationship between the diameter of the stem and the length of the largest limb in the third whorl of branches from the top?

2 Is there a significant difference between the slopes of the regression lines representing each source?

The third whorl and longest limb in the whorl were chosen arbitrarily. The five percent level was chosen as the appropriate level of significance.

METHODS

The sources chosen were numbers 3, 13, 23, 30. The plantation originall y had 30 plants for each source; in the spring of 1963 sources 3 and 23 still had 30 plants each and sources 13 and 30 had 29 plants each. The plantations were established in 1959 using 2-0 stock.

The trees were calipered to the nearest 0.1 inch, six inches above the ground level (the independent variable). The longest limb in the 3rd whorl was measured to the nearest 01 inch in a straight line from the angle formed by the top of the limb and the stem to the tip of the bud (the dependent variable).

These data were plotted and first and second degree equations were fitted using least squares procedures.

RESULTS

The fitted equations for the four sources are:

$$Y_3 = 2.99 + 9.89X_3 \quad (r = .86) \quad (2)$$

$$Y_{13} = 6.02 + 7.38X_{13} \quad (r = .68) \quad (3)$$

$$Y_{23} = 6.85 + 6.40X_{23} \quad (r = .77) \quad (4)$$

$$Y_{30} = 1.19 + 11.86X_{30} \quad (r = .92) \quad (5)$$

where Y_i = the length of the longest branch in inches in the third whorl from the top of the particular tree and source in the Cranbury, N. J., Scotch pine plantation.

X_i = stem diameter in inches, six inches above ground level.

The scatter diagrams with the fitted line drawn are shown in figures 1-4. All of the correlation coefficients are significant. None of the second degree equations provided a significant reduction in the variance of the dependent variable.

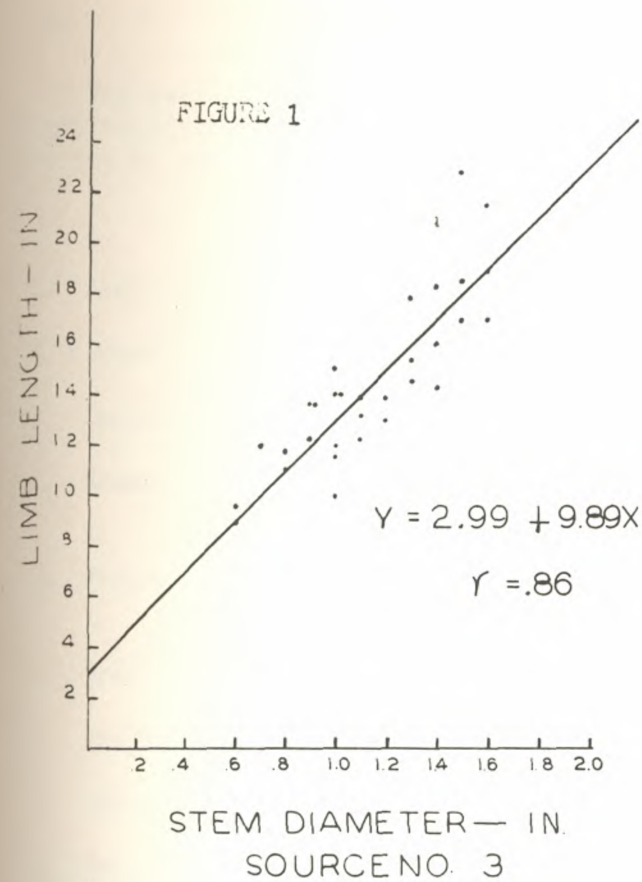


FIGURE 1
LIMB LENGTH — IN.
STEM DIAMETER — IN.
SOURCE NO. 3
Y = 2.99 + 9.89X
r = .86

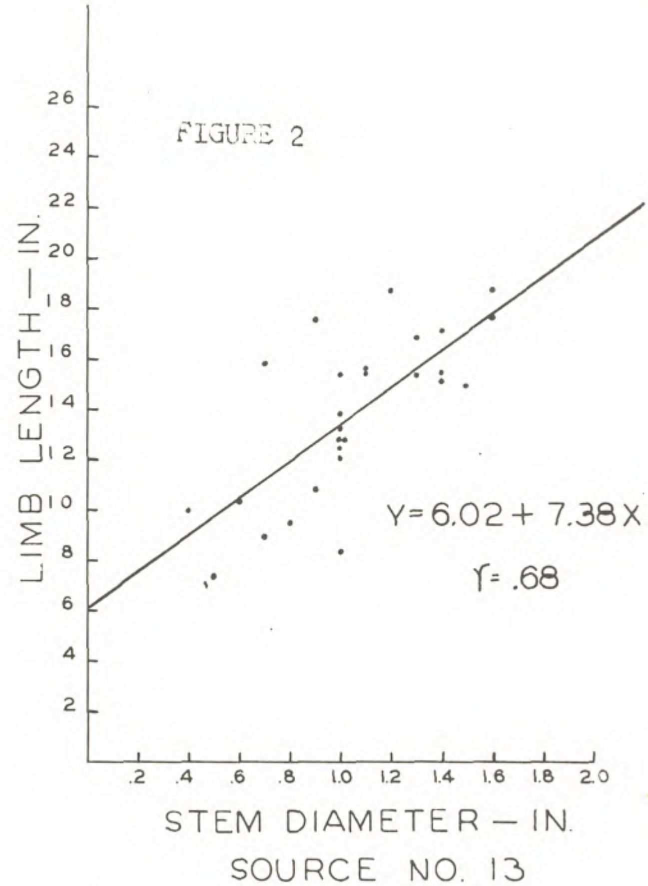


FIGURE 2
LIMB LENGTH — IN.
STEM DIAMETER — IN.
SOURCE NO. 13
Y = 6.02 + 7.38X
r = .68

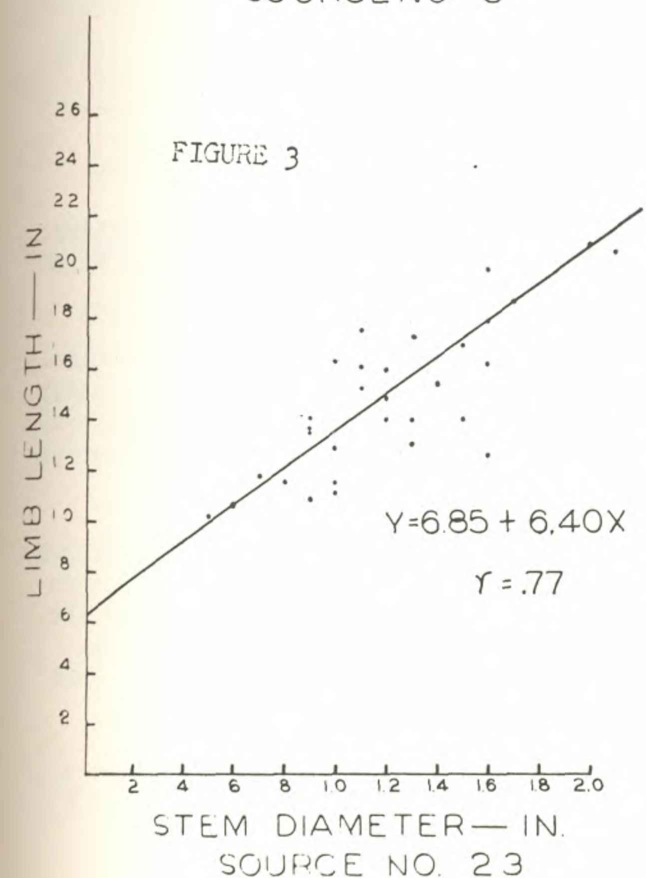


FIGURE 3
LIMB LENGTH — IN.
STEM DIAMETER — IN.
SOURCE NO. 23
Y = 6.85 + 6.40X
r = .77

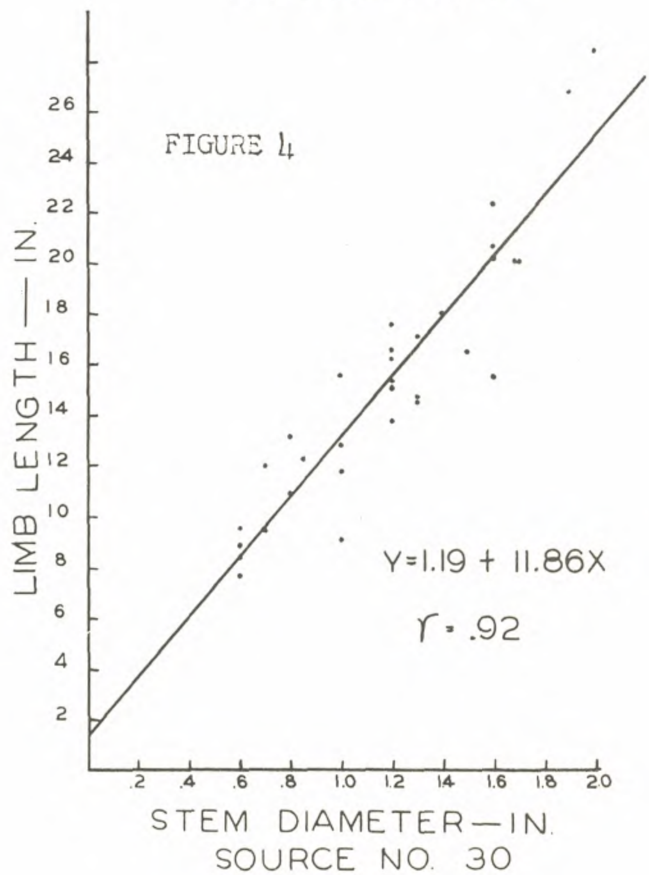
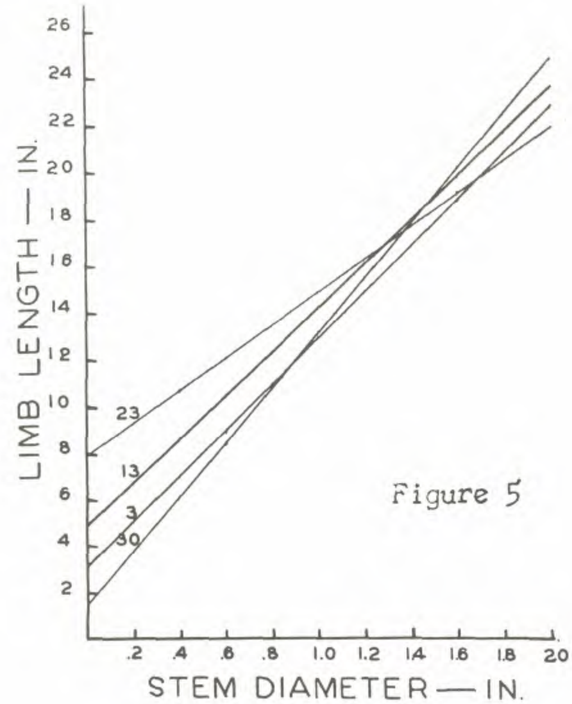


FIGURE 4
LIMB LENGTH — IN.
STEM DIAMETER — IN.
SOURCE NO. 30
Y = 1.19 + 11.86X
r = .92



The tests of the slopes of the regression lines gave the following results (figure 5): There is no significant difference between 3 and 13, 3 and 30, 13 and 23. There is a significant difference between 3 and 23, 13 and 30, and 23 and 30.

DISCUSSION

Subject to the restriction of a small sample it seems that the theoretical model of stem-crown relationship can be extended to some Scotch pine less than 10 years of age.

For the geneticist this means that he may be able to make at least preliminary selection of his stock for his particular purpose quite early. How early is a matter for speculation; it may be that similar relationships are manifested shortly after seed germination. It is also subject to the restriction that the relationships may change with age.

The geneticist concerned with Christmas tree production may use the slopes of the regression lines in this way: if a wide spreading tree is desired then source number 30 would be chosen; if a tall slender tree were desired then the lesser b value such as source 23 would be chosen. This assumes, of course, equal height growth. This assumption will be tested in the course of project NE-27.

If one were selecting for forest productivity--again speculating--then the lesser the slope of the regression line the more trees it would be possible to have per unit area, and presumably, more productivity at optimum stocking.

ACKNOWLEDGEMENTS

The well designed experiment of Professors Gerhold, Hamilton and West greatly facilitated the work reported here. I extend to them sincere appreciation for the use of one of the NE-27 plantations.

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DISCUSSION

LARSSON - I would like to ask Mr. West a question regarding lammas shoots. We pruned current season shoots and one-year-old shoots of Austrian pine at ten-day intervals during the 1960 growing season.. Many of the trees sheared up until the third week of August produced lammas shoots and yet none of the trees in the unpruned controls produced laminas nor did any of the sheared Austrian pine in another plantation one hundred miles away produce lemmas shoots. I would appreciate your comments on these observations.

WEST - I am very anxious that you folks look at some of these trees this afternoon. We haven't checked them for lammas shoots for this current season yet, but a number of the trees have produced laminas shoots which you'll be able to see. I thought your comment was very interesting. We certainly don't know all the answers as to just how and where lammas shoots occur.

STROH Mr. Stout, how about the intercepts of your regressions? It appears to me that a very high a value would indicate that the wood may be of inferior quality. I say this because the higher intercepts would apparently be associated with lower slopes, indicating that the crown would be more slender possibly due to an inability to support the limbs.

STOUT - This is a possibility; I have not tested it primarily because there are so few samples here is one reason. The other is that in the derivation of this equation it is a little difficult to decide what is involved in the a value. Strength of the wood may be; but presumably it's here and this is tied up in the b value. I've talked with Professor West before I wrote this paper and asked him if I should go through the derivation of this equation. He has sat through it a time or two, and he said, "No, please don't subject these people to it." If any of you would want to go through the derivation of it, I will be glad to do it, but I would invite those who don't want to be tortured to leave before hand. It really isn't bad, but it gets a little long and involved.

DAVIS I'd like to ask if you tried to determine the relationship using stem diameters measured at any other points than 6" above ground?

STOUT - The reason I didn't try is this, The way the equation developed there must be a relationship between the diameter of the stem and the length of the limb. Now, it doesn't matter where I measure the stem or it doesn't matter which limb I measure, this relationship will still exist. Now I might change the b value but the relationship is still there. Six inches was pulled out of the air; I could have measured twelve inches and I would have got the same linear relationship, or three inches, or two inches, whatever it happened to be.

WARD - In your phrasing., involving the function of branch radius and specific gravity or density, isn't it true that it depends upon the way in which density is distributed to different parts of a branch as to the amount of weight that the branch will sustain; just as the diameter of a pipe, for example, may have all of the density accumulated in the rim? Perhaps I should assume that growth rate here is uniform.

STOUT - I don't think so. In the b value as it develops there is tied up branching angle, characteristics of the tree, genetic characteristics of all kinds, and I don't presume to know what all these things are; strength of the wood, rate of growth; all of these finally evolve down and get tied up in the b value. Now I am sure that once we have thought about this sufficiently, we can begin to think how we can partition this b value and get some idea of what's going on there, but as yet I have not done it.

FUNK - I wonder if Professor West has correlated lammasing with growth rate. That is what we have noticed on our provenance tests. The faster growing sources have the most lammasing.

WEST - We haven't checked that. We've measured height, but haven't tried to correlate any other variables with lammas growth except the ones mentioned. There are big differences in height growth as you will see this afternoon; also large differences in form, color and branch angle and so on. There's one thing true about the Scotch pine--it certainly has all kinds of variations.

WARD - Does the occurrence of lammas shoots always result in forking?

WEST - No, as a matter of fact, I am undertaking a follow-up analysis of the number of trees that have permanent forks as a result of lammas shooting in the Scotch Pine. All the information I quoted you about forking was from previous studies. Our present study was an attempt to determine the influence of seed source on the phenomenon itself. Now we will follow that along to see what actually happens to these trees. It appears to me that a great number will be forked, but some may not even though they've been lammased three years in a row. As a preview I have marked some trees in the plantation with banded stakes. One band on the stake indicates that the tree has had laminas growth for one year, not any particular year; two white bands on the stake indicate that tree has had lammas growth for two seasons, and three indicate it has had lammased growth for three seasons. You can examine these trees this afternoon and see what effect lammas formation has had on the tree form.