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TYPE AND VARIABILITY IN THE ANNUAL WOOD-INCREMENT OF ACER RUBRUM L.

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In all temperate zones, at least, trees form annually one layer of wood, which appears on a cross-section of a tree as a ring, more or less clearly defined. The rate at which the diameter and the area of any cross-section of the tree increases, can therefore be easily ascertained by measuring the width of the rings. To obtain direct evidence as to the relation of the rate of wood formation to the nature of the habitat, and to obtain information on the value of a biometric study in differentiating such habitats, statistical work has been carried out during the past winter of 1907-8. The work was done in connection with an inquiry on the toxic properties of bogwater and bogsoils, the data of which, correlated with this and other studies, will be brought out elsewhere in another paper.

The purpose of the article here briefed is to call attention to the fact that statistical methods first used by Galton and now applied by Pearson (7), Davenport (4), Shull (8), and others to the more complicated questions in variation and heredity, may be of service also in Forestry problems as well as in questions of Ecology.

About 25 miles east of Columbus occurs an extensive lake, approximately ten miles long and one mile wide, known as Buckeye Lake. Near the northern bank, and midway between the small towns of Lakeside and Avondale is a bog-island very nearly one-tenth the dimensions of the lake. Soundings made to determine the character of the peat gave 30 to 40 feet as the depth of the island. Its vegetation presents two well-marked zones,—a central one consisting of Sphagnum, Carex, Eriophorum, Oxycoccus, Drosera, Rhus vernix, Aronia nigra, and others, and a marginal zone which includes besides several species of Salix, Alnus incana, A. rugosa, Ilex verticillata, Cornus canadensis, etc., a few small oaks, and Acer rubrum as the dominant form. An interesting comparison is afforded when we note that the country surrounding the lake and especially the northern shore near the bog-island supports at various places a forest vegetation in the form of woodlots. The most common trees are the beech, elm, maple, oak, chestnut and walnut,—examples of a temporary mesophytic climate society.

In determining the influence on annual accretion of wood the stumps of red maple were selected. A number of these trees had been just recently felled both in the bog and on the shores near by. It seemed desirable therefore to procure and record data on measurements from such trees of the two conditions of habitat, as were nearly the same in size, age, uniformly concentric growth of wood, and general environment. The general climate is assumed to be almost identical for both places, and being thus eliminated, it became more easy to determine the effect of edaphic conditions upon the rate of diameter growth of the species.

From the number of trees at disposal five were selected from the marginal bog-zone, and three were chosen from the woodlots near the shore. It may be objected that not enough trees were analyzed to permit the conclusion drawn. In order to eliminate sources of error, measurements were made, indeed, on a larger number of sample trees. To the writer, however, it seemed that the degree of confidence and the accuracy of the statistical result depended not so much upon numbers, as upon the functional criteria of the environment. It was not so much the object of this study to establish variability, as to find a suitable method of determining the influence of various factors in the environment. A method was sought by which temperature, light, humidity and soil data could be combined in a single number. The fact that so large a part of plant activities and adaptation is directly or indirectly connected with climatic and edaphic factors, suggested that if a comparative and statistical study of secondary growth on similar trees of various pronounced habitats were made, a new basis for determining climatic and edaphic regions of optimum development would be at hand.

Put in tabular form the results of the measurements are as follows:

Width of Rings in mm.	1.	1.5	2.	2.5	3.	3.5	4.	4.5	5.	5.5	6.	6.5	7.	7.5	8.	8.5	9.	9.5	10.	Tot.
Frequencies in Bog habitat	16.	10.	23.	20.	27.	12.	20.	5.	7.	5.	5.	5.	6.	1.	2.	0.	1.	0.	2.	167
Frequencies in Woodlots	26.	30.	31.	9.	6.															102

These frequency distributions are shown graphically in Fig. 1. The abscissæ give width in millimeters, the ordinates frequencies of rings. The variation constants deduced from them are indicated on page 347.

For the benefit of those unfamiliar with the biometric method of study employed here, a brief discussion of the more salient points is appended. For a more complete statement the reader is referred to Davenport's "Statistical Methods" (4) or the more popular work of Pearson (6).

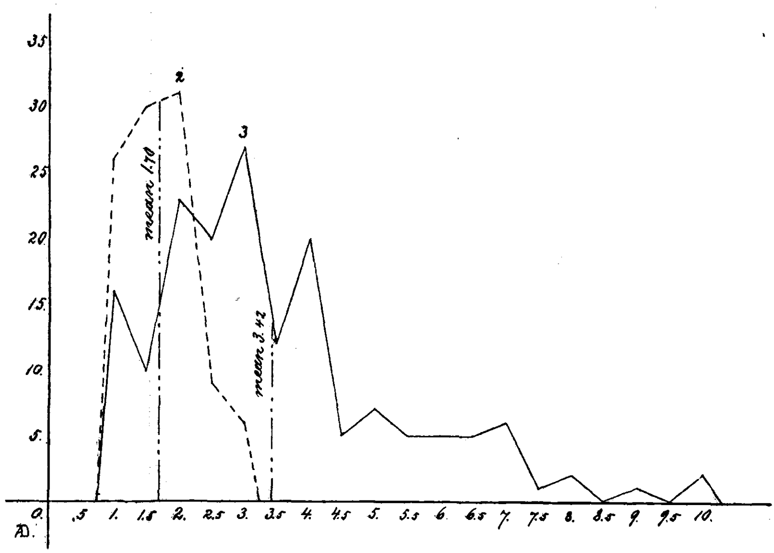

FIG. 1—Frequency curves showing variation in width of the annual wood-increment in Acer rubrum. Continuous lines—bog habitat; Dotted lines—woodlot habitat.

It will be noted that in the trees of the bog habitat, there are more rings three mm. long than of any other length, while in the second type of habitat the greater number of rings has shown two mm. This highest frequency or most common length is known as the mode. It shows clearly the prevailing *type* of wood-accretion. The distribution decreases in both directions from the mode, but least so in the woodlot habitat. The practical importance of the information afforded by this value is apparent. We have here the average prevailing state or place-habit of a similar lot of individuals from two distinct places. It is a characteristic which has been determined by influences covering a period of time (the age of the trees) long enough to eliminate the effect of incidental fluctuations in the habitat. In selecting one character for measurement it must not be forgotten, of course, that the organism is a correlated unit or whole. Change of environment may alter therefore a great variety of characters. Whatever the species, its differences constitute a distribution of deviations extending sometimes through a considerable range. Points such as these the systematist above all, must necessarily consider.

Another conception of the character and the amount of wood-accretion and its distribution is possible through the arithmetical average or mean. Multiplying the value of each variate by its frequency, adding the results and dividing the sum by the total number of rings, we thus get a determination of the mean or average length. In this case the mean length is 3.42 mm. and 1.70 mm. respectively for each of the habitats under consideration. These values differ very sensibly from the most common length or mode. It will be seen at once, that the deviations in excess of the mode are in the case of the bog habitat larger and in the woodlots smaller. The mean is in the latter case less and in the former greater than the respective mode. Such distributions are termed skew,—the mode and the mean are separated from each other by a certain measurable distance. The relative breadth of the curves exhibits to the eye the great variability and the prominent skewness.

There have been various interpretations of skewness, but it is evident that we are dealing here with the results of direct physiological reactions to the changes in the environment. On an average the annual accretion in woodlot conditions is by far less than in the bog habitat. Not all individual trees are alike sensitive to changed conditions, but the greater value of the positive skewness in the bog habitat indicates that only a small proportion of the variates is conservative. It is plain, therefore, that the position of the mode and the negative skewness in the woodlot forms has resulted from physiological variation, i. e. from the prevailing edaphic conditions of that place, and that the differences in the environment have changed the type, the variability and even the sign of the skewness.

The frequency curves enable us to perceive still another relation. It will be observed that some of the rings deviate but little from the mode or the mean, while others deviate more and some even very much. For instance, the deviations from the mean in the frequencies of the woodlot samples are $-.70$, $-.20$, $+.30$, $+.80$, and $+1.30$. The average deviation is omitted here as having no particular significance. Usually a standard deviation is derived in the following manner. The deviation of each frequency from the mean is squared and then multiplied by its corresponding frequency; the products are added and then divided by the total number of variates, and the square root extracted. The result as corrected by a number representing the probable error is the standard deviation. We thus arrive at a value 1.87 mm. for the bog habitat, and 0.56 mm. for the woodlot habitat, which stands as a definite measure of variability. It enables comparisons from year to year and between different localities, advantages which are too obvious to require elaboration.

To compare variability on an abstract basis an expression combining the idea both of standard deviation and type is added here. It is found by dividing the standard deviation by the mean as a base. The result is an excellent index of variability in the form of a rate percent usually known as the coefficient of variability. The value of the coefficient of variation will change directly with changes of the standard deviation, and inversely with changes of the mean. For the case at hand the coefficient of variability is 54.60 and 33.28 for the bog conditions and the woodlots respectively.

The mode and the three important variations constants, together with the probable errors of the determination, which were deduced from the frequency curves in the manner described above, are as follows:

Habitat.	Bog	Woodlots	Difference
Mode	3 mm.	2 mm.	1 mm.
Mean	3.425 ± 0.098	1.701 ± 0.038	1.72 mm
Standard Deviation	1.870 ± 0.069	0.566 ± 0.027	1.31 mm.
Coefficient of Variability	54.60 ± 2.55	33.28 ± 2.46	21.32

The amount of variation is, as we should expect it to be, sensibly different in each of the localities selected. The extreme values for the coefficients are 54.60 and 33.28 giving a difference of 21:32. We may accept these differences in the coefficients of variability as additional proof that when organisms are introduced in changed or unusual conditions they become more or less variable. It can safely be granted that the conditions of variability which are here a function of place, are masked but little by others. In the case at hand, variability is not due to chance but is an inevitable accompaniment of the differences in the habitat. The evidence for this statement is found especially in a forthcoming paper on the response of plants to toxic bodies, and in the methods and results of experimental physiology (2). Here, however, the results appear to be of considerable interest as showing that by the use of the quantitative method we are passing to an equally definite and exact determination of the importance of environmental conditions.

The points brought out in this communication may be summarized thus:

(1) The data above presented show clearly that a biometric record of secondary growth in trees furnishes a very valuable criterion for the comparison of the conditions of different plant habitats. They are data involving climatic and edaphic factors which are of the greatest importance to plant life, and hence may be best correlated with functional and structural changes.

(2) The response to environment in the case of Acer rubrum is rapid and pronounced. The annual growth of wood automatically records in duration, intensity and quality the effect of the "various ecological factors working in concert" (3). The differences in amount and size of wood cells, in thickness of walls, extent of infiltration, etc., clearly indicates differences in type.

(3) In a study such as this the biometric data seem more valuable than long records of temperature, light, humidity, wind velocity, and others. The effect of these is included as far as they influence the plant. Greatly varying as meteorological and soil data are, it is indeed almost impossible to combine them so as to exhibit their united action to climatic and edaphic centers of development. Hence the biometric point of view is an additional criterion to furnish a suitable basis for comparing ecological data, and for determining the relation of a locality to the whole range of the species, and to the direction of its migration (1). It seems certain, therefore, that if such statistical data were exhibited for various regions, climatic and edaphic centers of distribution could be clearly indicated (9). It is hoped that investigators in other places will make studies similar to the one here presented for the purpose of testing the value of this criterion.

(4) It is well known that the ability of plants to transmit acquired characteristics is readily demonstrated in forest trees, where climatic influences continue to show themselves with plants grown from seed derived from different localities. It becomes a problem of practical as well as theoretical importance to determine to what extent such distributions in functional variations persist. The advantage of the biometric method to know definitely the behavior of plants and the effect of environment is apparent. Whether or not individuals which have proven to be more variable would be favorable to any selection process remains to be seen from experimental determinations.

Botanical Laboratory, O. S. U. March, 1908.

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