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A BASIC METHOD FOR THE IMMEDIATE STUDY OF LICHEN GROWTH RATES AND SUCCESSION

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This paper describes a method for growth-rate determinations of lichens which can be carried out immediately with respect to particular species of lichens on various substrates. It provides a quantitative basis for selected studies of succession with respect to microenvironmental factors.

The determination of representative lichens was kindly done by Dr. John W. Thompson of the University of Wisconsin, who also provided a number of references. Preparation of most of the samples and development of techniques pertaining thereto, were carried out by the junior author. The other samples were prepared by Dr. Richard E. Garth. The study was supported in part by a grant-in-aid from the Research Committee of Emory University.

Very few reports have been published on growth rates of lichens. According to our search of the literature, the principal method used in the past has been basically that of noting changes which have occurred in individual lichens or in the lichen flora of a marked area over a given period or periods of time, the periods usually being measured in years. For example, the first definitive study, and the most comprehensive to date, was by Fink in 1917, in which he recounts observations on 45 individual lichens observed at one to three year intervals for a period of eight years. His concluding statement may be almost as true now as it was then, "Other similar data could be summarized. However, they would scarcely add to the conclusions regarding the rate of growth and ecesis in lichens, a subject about which so little has been known that one could scarcely form any opinion based on knowledge." Although results from his and other studies have yielded valuable data on the magnitude of growth, variation, and ecesis for individual lichens, they have not provided data on which generalizations and conclusions can be drawn on the population and species levels.

Although at least two refinements of the above method have been suggested, no studies on them, according to our knowledge, have been published. The first of these and obviously the most accurate of any yet proposed for growth under natural conditions is that of making very frequent observations on large large numbers of individual lichens over long periods of time. (Thompson, 1952). This has the added advantage of providing data on fruiting, branching, etc., which is not easily obtainable

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by the method presented here. The other, primarily for sociological studies (Hale, 1954), is to observe at frequent intervals changes in the increase or decrease in total coverage within stated periods of time. Simple applications of the method proposed here have been used to some extent. For example Sowter (1950) obtained average radial growth increments for several lichens growing on a stone bridge which had been in existence for only six years.

Basic Method

The method described in this paper is based on the premise that a lichen could not have been growing on any given substrate longer than the substrate had been either in existence or in its present location or condition. This approach differs from the classical one by providing a technique for immediately deducing what has happened in the past, rather than waiting to record events as they occur in the future. The obvious difficulty of this method—the impossibility of knowing when any given lichen began its growth—is more apparent than real. By the wise selection of sampling areas, and use of sufficiently large numbers, this difficulty may be essentially eliminated.

Three particular advantages of this approach not stressed later in the paper are: (1) The more accurate growth index of dry weight may be used, as well as that of radial increment. (2) This advantage makes the method equally applicable to foliose and fruiticose, as well as to crustose lichens to which the classical method is usually limited. (3) The method should be equally well suited to comparable studies of mosses and other selected plant groups, such as small epiphytes.

Growth Rates on Woody Twigs

Method

Application of the method for this substrate is based on the fact that a lichen growing on a live twig cannot be older than that part of the twig on which it is growing.

Dry weight was selected as the most accurate index of growth. The lichens were dampened slightly to prevent breakage, stripped from the twig with forceps and scalpel under a binocular lens, dried in an oven for one hour at 97° to 100° C to reduce the moisture content to a constant, and weighed to the nearest milligram within 30 seconds after removal from the oven. Storage for 24 hours in a dessicator over 100% glycerin also proved satisfactory. Care was taken not to remove pieces of the substrate with the lichen. Samples which showed evidence of damage from handling or were intertwined and did not provide a clear-cut sample were discarded. Otherwise all samples from a given twig were used.

The age of the twig at the point from which the lichen was removed was determined by direct ring count. Because of the extremely slow growth of the twigs used, special techniques had to be employed. For lichens of more than one centimeter in diameter, ring counts were made at both the upper and lower limits of its growth, and the two counts (which varied by as much as four or five years) were then averaged. The samples were first obtained by cutting above and below the lichen with pruning snips. Ring counts were then obtained from temporary cross-sections of the branch which had been cut freehand with a razor blade and stained with 1% Fast Green in 95% alcohol. The count was made immediately after application of the stain with a 30X dissecting microscope using reflected light. When complete cross-sections could not be obtained due to the size of the limb, pie-shaped sections from at least three different points were used to calculate the age. Distance from stem apex was also recorded.

A total of 277 specimens representing 11 species and varieties were prepared and are in the Emory University Herbarium. Special data cards were devised and one completed for each specimen. The twigs were collected in the fall of 1950 from *Juniperus virginiana* L. and *Ulmus alata* Michx. growing in crevices in exposed granite outcrops near Atlanta. The twigs, thickly branched, were about two feet in length and varied in having from one to several lichens per linear inch. Lichens varied from a fraction of a millimeter to about three centimeters in diameter.

Evaluation

When time is plotted against the logarithm of growth, the slopes of the resulting exponential curves represent relative rates of growth. In this case, then, age in years is plotted against dry weight in milligrams as shown in Figure 1. For such curves these observations may be made: (1) The uppermost dot for any given age class represents the maximum growth observed for that age class; therefore, these are the only dots useful in growth rate determinations, and the curve must be fitted to them. Statistical procedures may be applied. (2) The lowermost dots for any given age class approximate the time of establishment of particular lichens. (3) All data intermediate between these extremes cannot be evaluated with respect to the determination of growth-rates or of establishment, but are of direct value in studies of succession, as indicated below. However, an investigator working with growth-rates alone need only consider the largest lichens per age class, and by discarding the obviously intermediate and smaller samples could greatly expedite his study. (4) Comparisons may be made between different species on the same substrate, the same species on different substrates, and the effects of environmental conditions on the same species on the same substrate.

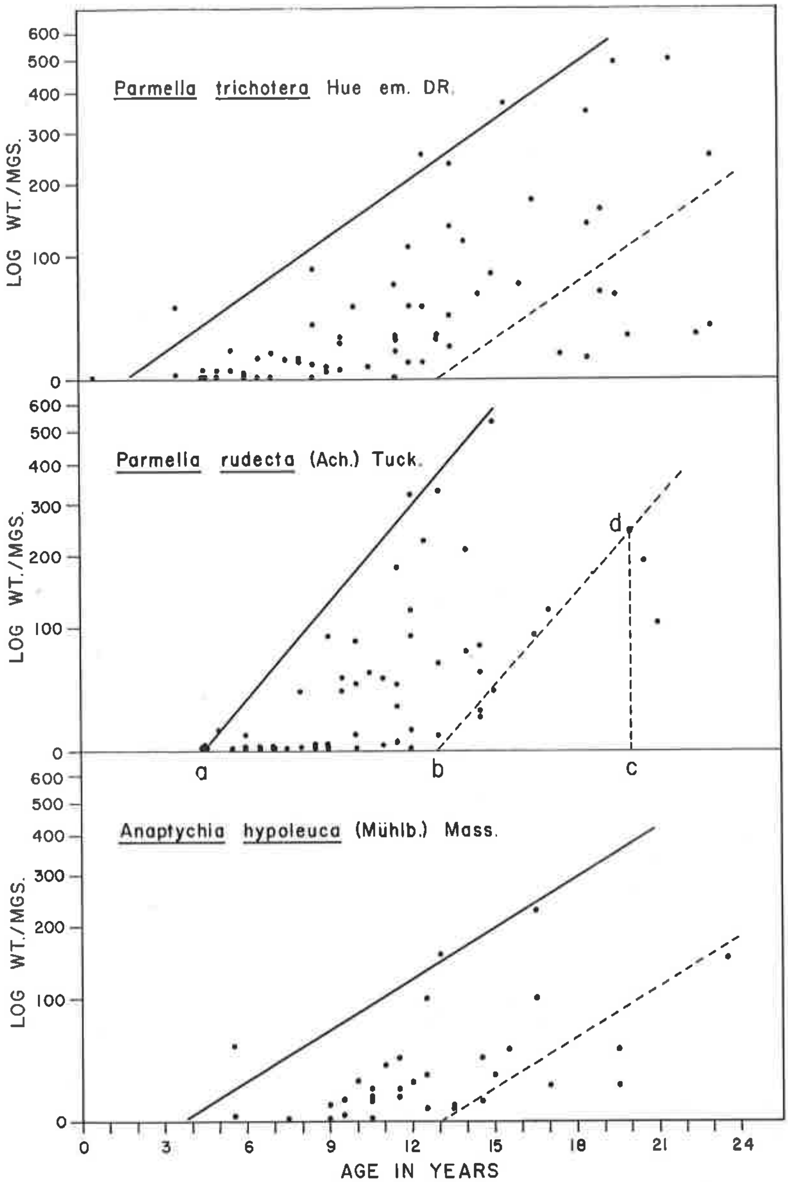

Fig. 1. Growth rate approximations for three species of lichens, all growing on *Juniperus virginiana*. Age in years is that of the substrate. See text for explanation.

GROWTH RATES ON ROCK, SOIL, AND BARK SUBSTRATES

The same problem exists here as above—that of accurately dating the position, location, or age of the substrate.

The condition or location of rock and soil may be accurately dated by collecting samples from areas disturbed by man. For example, highway and railroad cuts may be found which range from a few months to a few years in age. Stone quarries and native stone structures provide additional examples.

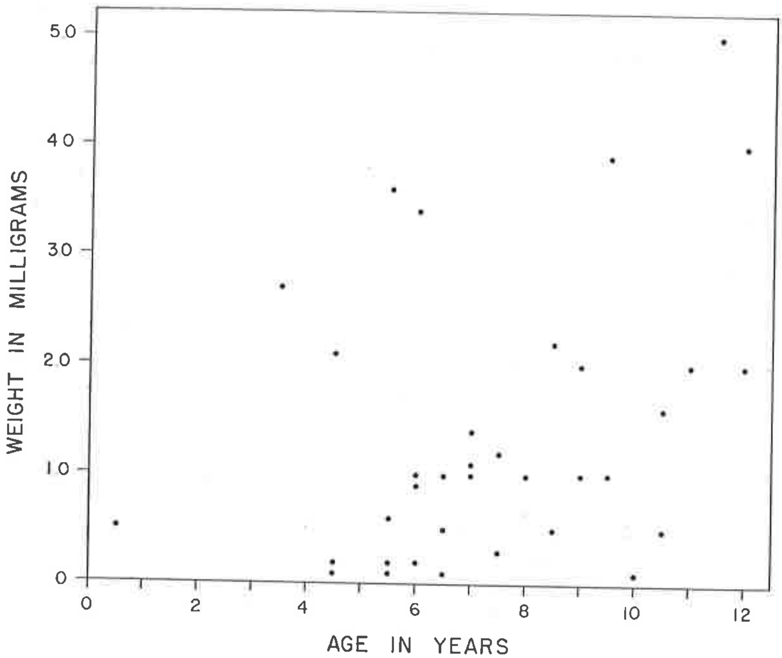

Fig. 2 Correlation between age of substrate and weight of very small lichens. Several species of lichens are represented from two species of trees. See text for explanation.

For soil substrates one has, in addition to the above, abandoned fields where accurately dated series ranging from one year up may be available.

For bark substrates, the age of the outer surface may be approximated at times by examination of growth rings in the bark itself. With regard to all of these substrates, exploitation of these and other sources are limited figuratively only by one's imagination and ingenuity.

SUCCESSIONAL STUDIES

In successional studies all satisfactory specimens from the sampling area should be used. Within a single species the maximum growth rate will be determined by the largest specimens per age class of twig. A probable time of establishment of intermediate sized specimens may be predicted by superimposing parallely the maximum growth rate curve on the coordinates of an individual (or groups of individuals) to be determined, and locating the new abscissal intersection, as is shown in the middle diagram of Figure 1. In the example given, the predicted probable time of establishment for specimen *d*, indicated by point *b*, is a twig age of 13 years. The predicted age of the specimen would be 7 years, obtained by subtracting *b* from *c*. The point *c*, of course, represents the age of the twig at the time the specimen was harvested.

Because of variations between individuals, the prediction above may have little reality for any given individual. However, it would have considerable validity for groups of individuals, or for populations. For example, dotted lines for each of the three species in Figure 1 have been drawn parallel to the maximum growth rate curves, from the same abscissal point of 13 years. All specimens plotted between these sets of parallel lines would probably have become established on twigs ranging in age between points indicated by *a* and *b*. Thus, for the upper species, the range is 2 to 12 years, whereas for the other two it is from about 4 to 13 years.

Note, from the example just given, that after 13 years of age conditions on the twig, for the particular sampling areas used, are apparently unfavorable for the invasion of new individuals, especially for the middle species. This conclusion assumes that a very careful search has been made for new individuals on the older twigs. Figure2 shows the results of such a search. Although specimens are plotted of several species of lichens on two different substrates, the same twigs used for Figure 1 are included. The abscissa is terminated at 12 years, because very small lichens were not found on twigs above this age. Note that the range in size of lichens in Figure 2 is to five milligrams, whereas in Figure 1 it is to 600 milligrams weight.

Statistical note:

After submitting this paper to the editors, some of the data were subjected to statistical analysis. For growth rate determinations, only those specimens were used which represented maximum growth per age class, excluding any which were less than the highest preceeding weight. Using these points, regressions of log Y (Y=wt. in mgs.) on X (X=time in years) were calculated for each species, using the method of least squares and the formula log Y=a+bX, where a=O and b=the regression coefficient. In the case of *P. rudecta* X = the actual time in years minus 4.5 so that a=O. The regression lines for each species are thus:

*P. trichotera*_____log Y = 0.156X
A. hypoleuca ____log Y = 0.162X
P. rudecta _______log Y = 0.31 (X—4.5)

These lines are in close accord with those drawn by inspection, which are shown in Fig. 1. They result in plants of significantly different sizes when their distance apart exceeds three times the standard error of difference between them. Thus between *P. trichotera* and *P. rudecta* (3 sigma d= 0.837) a significant difference exists beyond the 14 year age class, and between *A. hypoleuca* and *P. rudecta* (3 sigma d=0.954), beyond the 15.5 year age class. A very high degree of correlation exists between age and weight of those specimens used for growth rate determinations, the coefficients of correlation being for *P. trichotera* 0.94, for *A. hypoleuca* 0.92, and for *P. rudecta* 0.93.

Summary

A basic method for the immediate study of lichen growth rates and succession is described. The method is based on the premise that a lichen could not have been growing on any given sustrate longer than the substrate had been either in existence or in its present location or condition. This approach differs from the classical one by providing a technique for immediately deducing what has happened in the past, rather than waiting to record events as they occur in the future. The obvious difficulty of this method—the impossibility of knowing when any given lichen began its growth—is more apparent than real. By wise selection of sampling areas and use of sufficiently large numbers, this difficulty may be essentially eliminated.

Detailed methods are presented for growth-rate determinations on woody twigs. Application of the method to other substrates, and to the study of establishment and succession are outlined.

The method has these advantages: (1) Studies may be initiated and carried through in a short period of time. (2) Observations may be made to extend over long periods of past time (24 years in the example given). (3) A quantitative basis for study is provided. (4) The more accurate growth index of dry weight may be used, as well as that of radial increment. (5) The preceding advantage makes the method equally applicable to foliose and fruticose, as well as to crustose lichens to which the classical method is usually limited. (6) Traumatic effects of plants and animals are eliminated by using only maximum-size lichens per age class. (7) Comparisons may be made between the same species on different substrates, two or more species on the same substrate, and the effects of environmental conditions on the same species on the same substrate. (8) Ecological studies, including those on succession, may be made using the same procedures. (9) The method should be equally well suited to comparable studies of mosses and other selected plant groups, such as small epiphytes.

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