PLANT ECOLOGY AND ITS RELATION TO AGRICULTURE

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I. CONTENT OF ECOLOGY

A. *Nature and Scope.* In beginning this discussion, a brief statement as to the nature and scope of ecology seems to be desirable on account of the hazy popular notions on the subject. Outside of a rather narrow circle one usually finds a total ignorance of the meaning of the word itself, and even among biologists, some are familiar only with the observational side, due probably to the early prominence of the "car window" school of ecologists, while others consider that the subject matter of ecology might better be divided between morphology and physiology, and frankly state their opinion that there is no such subject as ecology.

However, there seems to be a mass of subject matter belonging to neither department exclusively, but partly to each, which would fairly warrant the formation of another department. This has been named ecology, and may be defined as the science of the forms of organisms as affected by the factors of their environment. The connection with physiology is the closer of the two, and in fact, the two subjects overlap to a certain extent, but whether we call this overlapping segment ecological physiology or physiological ecology, the character of this subject matter is sufficiently different to warrant a separate category and different treatment.

The methods of ecology have been, of course, largely descriptive, but they are also becoming increasingly quantitative, employing in many cases elaborate and delicate instruments. The work is pursued both in the field and in the laboratory, and under experimentally controlled conditions, as well as under natural. The great task of ecology and the purpose of its observation and experimentation lies in the interpretation of the phenomena and the deduction from these data of the general principles underlying the reaction of plants to their environmental factors.

B. *Content of General Ecology.*

1. Autecology. This branch of ecology studies the plant as an individual, and is largely physiological in nature. It considers (a) the general results of the relation of the plant to its environmental factors, as shown in the division of plants into great classes according to their reaction to each of the leading factors. Chief among these is the moisture relation, expressed in the more or less familiar division into hydrophytes or water lovers, xerophytes or dry-climate plants, and mesophytes inhabiting an intermediate habitat. A similar relation to light and temperature divides plants into sun tolerant and shade-tolerant; heat-tolerant and cold-tolerant groups. The relation to the chemical elements in the soil is not so marked as was once thought to be the case, yet we still hear such words as "calciphiles" and calciphobes," and the terms probably represent to a certain extent a real situation. (b) Special relation to environment is shown by the structure and function of the organs. Whatever may be our belief as to the method by which variations are produced and fixed in plants, it is evident that structures correspond more or less to function and are conditioned directly or indirectly by the environment. A comparative study of plants in different habitats leads us to identify or construct from the imagination certain "normal" or original types of organs. We find also modifications of these types, which are either temporary, where the plant tissues are plastic; or permanent, constituting variations. In tracing the correspondence of these changes to environmental differences, we look for and frequently think we find what may be called ecological causes. The best illustration of this is shown in a comparison of organs, especially leaves, of hydrophytic as compared with xerophytic and mesophytic plants. Here there seems to be a very distinct correspondence between structure and the markedly different environments of these different habitats.

2. Synecology, which studies plants in the mass is largely concerned with distribution of plants, and may be regarded as an application of autecology in the grouping of plants within greater or smaller areas of the earth's surface. It may be divided into (a) "Phytogeography" in which the groupings are regional and the result of climatic factors, and (b) "Physiographic Ecology," in which the groupings are local, as the result of physiography with attendant climatic modifications.

These groupings are called Plant Associations and the fact that different associations follow each other successively is expressed in the term "Plant Succession."

C. *Special Ecology of Structural Groups.*

While all ecological groups have more or less specific reactions which are considered under their appropriate heads, there is one grouping which demands separate treatment because it is based on the most striking structural feature—the presence or absence of woody tissue, and also because of its practical relation to man's activities. Although verging more closely on agriculture, it may still be classed as ecology because the point of approach is from the side of the environmental relations. On the basis of woody structure we classify plants as trees and herbaceous plants with shrubs and lianas occupying an intermediate position, and it is at once evident that these two groups have decidedly different ecological reactions.

1. Ecology of Trees and Shrubs. This study would involve (a) a description of leading species with their habits of growth, characteristic structures, and ecological interpretation of the same. This would be the autecology of the group. (b) The synecology would involve the distribution and range of the leading species and their relation of ecological causes. (c) We might notice also the influence of the species on their environment, as illustrated in the influence of forests on soil moisture content through their control of run-off; and the influence of individual trees, as for example, the eucalyptus in the reduction of soil water; also the influence of forests on soil in the formation of humus and the effect of trees on wind, as in protection by wind breaks. (d) It could include also a classification of trees according to the character of their wood, including distribution of the different woods and methods of utilizing. Also a similar classification according to the character of their fruits, their chemical products, and their value for ornament.

2. Ecology of Herbs. Here should be studied (a) the general characteristics of herbs as distinguishing them from trees, with the ecological differences involved under the heads of shoot, root, flower, and fruit, with the characteristic differ-

ences between perennials and annuals; (b) a study of herbs as classified according to their value to man, as: valueless or "wild," those of economic value or "cultivated," and those undesirable or injurious, which we call "weeds." Uncultivated herbs are of interest chiefly synecologically as the associates of trees in their different groupings and as indicators of the characteristics of the environment, as hydrophytic, xerophytic, etc. As the subject of taxonomy has to do chiefly with the wild herbs, it is frequently included under ecology today.

Cultivated herbs and their attendant, though undesirable forms, are considered more from the autecological side. Their reactions to and tolerance of extremes of temperature and moisture and chemical conditions, are of course of chief importance. Original habitat and distribution and to some extent taxonomic relations, are also important as indicating suitability for certain environments. This value is testified to by the systematic search for new varieties carried on by the United States Department of Agriculture. Herbs vary greatly in their reactions to environmental factors, and should be grouped as far as possible along the lines of similar behavior. Knowledge of these groups should be as complete as possible, but a thorough study of the ecological reactions of a few type genera and species should be included in any comprehensive course in ecology.

3. The ecology of lower types of plants is not treated separately, but on account of economic importance under the special subject of bacteriology, mycology, etc.

II. RELATION OF ECOLOGY TO AGRICULTURE.

A. *Purpose and Scope of Agriculture.* The subject of agriculture is extremely complex and even the terminology is not uniform in usage. Even the word agriculture itself is employed in a general and a special manner. It is used here in the general sense of the cultivation of plant products from the soil. Its complexity is made evident by consideration of the varied ends sought, which include size, strength, water content, and chemical contents of stem, leaves, roots, flowers, fruit, and special parts such as fibers, cork, etc.

The resulting subdivisions of the subject following largely the usage of Bailey's Cyclopedia of Horticulture, are: Agri-

culture (in its special sense), which includes the culture of grain, forage crops, bread stuffs, textiles, etc.; Horticulture, which includes fruits, vegetables, flowers, and ornamental plants; and Forestry which is the complete treatment of other trees, and includes the subjects of sylviculture, mensuration, and harvesting. Through all this complexity runs a general unity of purpose, namely, the preparing and maintaining of optimum conditions for the production of maximum returns. Therefore the processes and principles are in the main the same, being varied in practice for the different ends.

B. *Agricultural processes* with their ecological significance.

1. The preparation of optimum conditions. The preparation of the soil is the first condition, but as the principles are the same as those in the preservation of optimum conditions, it will be considered under that heading. The second important factor is the securing of suitable stock, either seed or vegetative, for which the criteria are the taxonomic relations and the reactions to the environment. The choosing of this stock is a question of balancing specific reactions of the desired plant with the factors of the necessary location, or vice versa. The securing of this stock is brought about either through breeding by pollination, or by grafting; and by choice, through the testing of known varieties, the selecting of the results of breeding, or the discovery of new varieties. Of course through all these methods runs the question of reaction to the desired environment. A third ecological factor in preparation of conditions consists in the choice of a suitable time and location for the culture.

2. The preservation of optimum conditions. (a) The condition of first importance is the soil. In its moisture content the maintenance of optimum moisture conditions is of course extremely important. The maintenance of its physical condition is popularly called tillage. The chemical composition is shown by analysis and experiments with plants, and is modified by the use of fertilizers and of other chemicals. The temperature of the soil is less considered, but may be determined by the use of soil thermometers. (b) Optimum conditions of light, wind, and temperature depend upon exposure and may be controlled by modifications of this exposure. Light is studied by light intensity experiments and controlled by screening or by thinning. The effect of wind is shown largely

by transpiration, measured by the atmometer, controlled by thinning or by windbreaks. Temperature is observed by the thermometer controlled by shelters and by protective covering. (c) The importance of disease as a factor has been recognized by the great development of the subject of plant pathology.

3. The third agricultural process is the harvesting of crops, in which ecology does not function very largely, except in so far as it may assist in the determining of the time of maximum returns.

C. *Nature of Contributions of Ecology.* Agriculture, as its name implies, is a practical process and its methods heretofore have been largely empirical. This may be observed by reference to any agricultural textbook or farmer's bulletin, where frequently processes are referred to as having been tested in certain localities and are recommended as having succeeded, or are condemned as failing. Even in our more recent Experiment Station work, the same tendency is shown in the accumulation of masses of data with too little correlation and generalization. The purpose of experimentation is to determine causes and draw general principles whose application will avoid the necessity of further experiments. Failure to generalize nullifies this purpose; in fact, unlimited experimentation is empiricism.

On the other hand, the ecological method is scientific, involving interpreting as well as observation. Its materials are largely the same as those of agriculture, and when its methods are applied to these materials, we have the only result that can truly be called "the science of agriculture." In so far as agriculture uses scientific methods, it is ecology.

D. *Illustrations from Definite Contributions of Ecology.*

Atmospheric moisture is observed quantitatively by means of the atmometer, which may be used as a measure of plant transpiration. Recent results show a most remarkable detailed correspondence between the curve of an open pan atmometer and that of a controlled plant of alfalfa. In soil moisture content the mechanical determining of the wilting coefficient by the centrifugal method is a valuable achievement, and is having an increasing application in the determining of the quantity of water to be applied in irrigation. The study of

the extension of root systems is having an increasing influence in determining the relation of plants to the soil moisture content.

In light we have both the measure of the intensity of light by Wiesner and Clements, and recently the measurement of photolytic ability of light by a delicate apparatus devised by MacDougal. Under chemical content the recent work of Coville with blueberries is widely known on account of its publication in the National Geographic Magazine. One of the difficulties of this quantitative work lies in the fact that the factors all work together on the plant, and measurement taken of individual factors may not indicate the true effect of the same factor working with others. Livingston's suggestion of using the living plant as an index is aimed at overcoming this difficulty.

Along physiographic lines, Cowles' recent work on so-called lakes of the Mississippi Valley, has applied the principles of plant succession in a very practical way. The control of moving sand is best accomplished by application of ecological principles in the choice of plants for that extremely xerophytic habitat.

E. *Place of Ecology in an Agricultural Course of Study.*

Up to the present the method has been to use a little morphology, a chapter on plant activities, and then nine-tenths of the work on agricultural practice. In addition to that we would recommend the insertion of a section on ecological principles, covering the content of ecology as outlined above, which should be general and theoretical, yet so related to agricultural practice as to form a suitable foundation for an agricultural course. A knowledge of these principles is fundamental to any real grasp of the subject.

In conclusion, emphasis should be laid on the fact that this discussion does not aim to criticise agricultural activities at present, but to emphasize what is now being done along scientific lines for the development of general principles underlying the practice of agriculture, and the importance of its extension as far as possible. Secondly, to point out the opportunity in this growing branch of botany and to urge the teaching of some brief but comprehensive study of the principles of ecology in all agricultural courses.