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CROP ECOLOGY AND THE PRIMARY VEGETATIONAL SURVEY.*

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At a meeting of Agricultural Experiment Station workers, it seems fitting to quote a statement made at the British Association meeting recently by the Director of Rothamstead, (8). In discussing the organization of the experiment stations to meet the problems of crop production and the complexity of the results furnished by various members of the staffs, he asks, "What is the purpose of it all? Team-work, co-operation, the great expenditure of time and money now being incurred in agricultural science and experiment, these are justified only if the end is worthy of the effort. The nineteenth century took the view that agricultural science was justified only in so far as it was useful. That view we now believe to be too narrow. The practical purpose is of course essential; the station must help the farmer in his daily difficulties—which again necessitates co-operation, this time between the practical grower and the scientific worker. But history has shown that institutions and investigations that tie themselves down to purely practical problems do not get very far."

A bird's eye perspective of the work at experiment stations all over the country seems to indicate that a number of them are offering the daily bread of empiricism without much scientific jam on it to meet the daily difficulty. A number of them and fortunately an increasing number each year devote their best talent to the investigation of fundamental problems. It is my purpose to try to sketch some of the fundamental problems of crop ecology, not so much pointing out specific problems, but instead attempting to outline them.

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Remembering the great scope and tremendous complexity of the problems which the agriculturalists must face, we can put up a defence without shame for the use of some empirical methods of attacking these problems. If by empiricism be meant a trial and error method we cannot reject it altogether in spite of its cumbersomeness and expense, for a strictly logical method of attack. The reason is plain enough. There are so many unknown quantities in all biological phenomena. The mathematician has the advantage of assuming certain conditions and handling his unknown quantities piece-meal. The agriculturalist must face his unknowns all massed within the living plant. He is forced to make deductions from experiments which he may find impossible to duplicate exactly. He must therefore expect to get his best results from a combination of empirical and scientific methods.

How, you may ask, does this relate to any of the problems of crop ecology? In its broadest sense this would include all of the problems of agriculture as we are now facing them, both to meet the present difficulties of a practical grower and the broad general needs of the people of our State of Ohio. If all the problems which we face could be massed into one, we would instantly perceive that crop ecology is the central scientific basis upon which to build and that the keystone problem is *adaptation*.

Now by adaption in our crop plants we do not necessarily have in mind the same kinds of adjustments merely that we have in the native and naturalized plants of a region. It is sufficient for the native plants that they are not killed in the winter or burned by the summer's drouth, that the soil supplies the water and minerals needed, that their enemies are not so numerous or so persistent that they cannot outgrow them, that they ripen seeds or store food in vegetative organs. In perennials it is not even necessary to ripen seeds each year. In our crop plants on the other hand, not only must the plant produce some desired product, but this yield must be produced in a given season and must be of a marketable quality if the plants are to return a profit to the grower. The highest yielding wheats are not always the most desirable. Milling and baking tests must be made to show whether the plant is suited to consumers demands as well as the growers' interests. A dwarfed timothy plant would be a menace if it also happened to produce seeds very abundantly. A common barberry bush of any color is accursed. Flax and hemp, formerly acceptable and suited to both the soils and climate of the state have practically disappeared. Clover failure presents an acute farm problem in our older agricultural sections. All of these instances indicate that we must look to the kind of product and to its quality before determining whether or not our crop plants are adapted. The work of the plant breeder and of the ecologist must be co-ordinated. We can expect permanent advances in our agricultural position only in proportion to the amount of linked effort that is made.

Briefly, we have variables in the plant and in its surroundings. In both the interior of the plant and in its environment we are, within limits, able to exercise some control. We call the facts relating to the interior of cells of plants its heredity and we hide our ignorance of the way these inherited characteristics may descend from one generation to another in the terminology of genetics. We classify the groups of factors that surround the plant and modify the expression of its heredity as climatic, edaphic and biotic, and we are led away by some words into thinking that our case can rest. But we often fail to synthesize observations and experiments made in these groups of facts and apply them. Here is where our true problem of adaptation comes in and where the ecology of our crops will find its real phase of usefulness—interpreting the results, because of the methods of analysis.

Let me take an example, from our agricultural history, of an empirical method of meeting a pressing need. Cotton was reported in 1789 to be growing successfully at Marietta. Moreover, the colony had some surplus product which was advertised for sale in Paris. Cotton was grown until 1840 as one of the crops of Lawrence County. While no one could now think of growing cotton in Ohio, starting with the seeds of the plants at the present time grown in Southern States, who knows but that we lost a most valuable agricultural plant by failing to maintain an interest in what is a most unique phase of a great industry. The empirical method led to a valuable result, but after commercial contact between the states was on a firmer footing the pioneer industry died away for lack of interest.

Rice also was grown by the Marietta pioneers, but it seemed less promising and certainly was less needed than cotton.

It might be mentioned in passing that a native industry in growing our wild rice grass may yet offer possibilities, since it has already been introduced into some markets as a variant in our diets. Mention is made of this to show that while the pioneers practiced their own empiricisms, they were not willing to learn from the experience of the Indians the use of native plants.

In contrast to this type of empirical method let us consider another. This has to do with a distributional problem in which but one factor in the environment of the plants was employed as a means of showing graphically plant distribution. This factor is one that is directly related to growth, but is not so directly related to geographic distribution. The scheme proposed by the directors of the biological survey is the one which employed only the single factor, temperature, to indicate plant and animal distribution. Within a short while after it was proposed, a number of ecologists, Adams, Shelford, Cowles and Transeau among them, pointed out its fallacy. However, it has not stopped the Survey from using its own method, nor a great many people from employing terminology used at that time. The principal paper on the subject was by Dr. C. Hart Merriam (7) and called "Life Zones and Crop Zones." In one section called "Laws of temperature control of geographic distribution of animals and plants," it is stated that temperature is the most important single factor, apart from mechanical barriers, in fixing the limits beyond which certain species cannot go. The United States is divided into a series of zones with bands running east and west and named, Boreal, Transition, Upper Austral, Lower Austral, Gulf strip of the Lower Austral, and Tropical. These zones are obtained along the isotherms made by connecting, on a large map of the U. S., the stations where the sums of the positive temperatures are the same during the season when the mean daily temperature is about 60 c. No accounting for moisture is allowed, though the plan divides the Eastern half of the United States into a region called humid, and the Western half, while not designated, is presumably arid, with no account taken of the region of highest rainfall in the United States, on the Northwestern Coast. It is most remarkable that this should have obtained much credence with biologists in North America. Not only is it still reported in all the biological survey publications, but even some of our

Canadian Naturalists have made use of the terminology as late as the current year. Lloyd in a paper on the vegegation of Canada has continued to use the terminology with the plea that it is well known. Unfortunately its fault of being based on a single factor of the environment is not well enough known. What does it lead us to? To take the zone designated as Upper Austral as an example, it embraces the Atlantic Coast from Connecticut to the Potomac River; the Western, but not the Eastern half of Long Island, the Hudson River Valley; it extends Southwest from Maryland to Alabama and West to Northeastern Montana, nearly to the Canadian border and south through the Mexican State of Durango. It would lump together such distinctive types of vegetation as our Eastern deciduous forests, the prairies, the plains, and some of the semiarid regions in New Mexico and Mexico. The Lower Austral includes the coast of Virginia, the Mississippi Valley on the Western boundary of Kentucky and Lower California. The species or the groups of species in these regions are certainly not closely related to each other. With the crop plants such an unfortunate attempt to bolster up misapprehension of the fact appears as in the statement, "that while corn is no exception to the fact that cereals thrive best in cool climates, most of the varieties are found in the lower Austral zone."

Is it any wonder then that with the impetus that has been given to the promulgation of this particular misconception that the Experiment Stations have not taken into serious account of the work of those of the ecologists whose ideas of the distribution of plants and animals have been more conservatively formed and offered with some reserve and many exceptions pointed out as to geographic detail?

In order to study distribution it is necessary to take some measure to account of all of the factors of the environment. There is no empiricism about this. It is simply a record of observation. And as the record is a long one many conservative ecologists—notably Tansley, Cowles and others still emphasize the need of more descriptive ecology. This does not mean a mere listing of the plants in a given area, but a definite attempt to show the relations existing between environmental factors and the development of a particular association of plants. There is no definite border line between the best type of descriptive ecology and the beginning of experimental ecology.

For in the end experimental ecology is the interpretation of scientific observation.

Much better schemes than Merriam's for showing graphically the underlying causal factors of the geographic distribution of vegetation and of animal life have been worked out. They all employ combinations of factors instead of a single factor. Among such are Livingston's Moisture—Temperature charts and Shreve's ratio of soil moisture to evaporation and Transeau's Rainfall-Evaporation chart, (10). Livingston and Shreve (5) in discussing the Rainfall-Evaporation chart state: "The importance of the moisture ratio in controlling the leading vegetations was shown by Transeau for the Eastern United States, and our investigation has served to confirm his deductions as well as to extend their application to the entire country. The comparisons which have been made between the vegetational areas and the various other climatic conditions have served to emphasize the moisture ratio even more than was done by Transeau, since no other single datum has been found in our work to approach it as an expression of the controlling conditions for forest, grassland and desert."

Long ago Asa Gray called plants the thermometers of the ages. That is still a good statement. One of the ways in which we can apply the accumulating knowledge of the distribution of vegetation and the physical factors which underlie this distribution is in mapping out the distribution of our crop plants. The familiar work of Shantz on the indicator significance as to the capabilities of land for crop production represents an appreciation of the fact that a living plant growing in a particular habitat is often the most accurate way of measuring the environment. Clements (2) work on Plant Indicators is of much value for reference and research, especially being a record of observations in the Western sections of the United States.

A classic example of the correlation of the work of several ecologists who have studied a single region is to be found in a series of papers by Kincer (4), Marbut (6), Shantz (9) and Baker (1) on the Great Plains. These authors respectively discuss the climate, soils, vegetation and types of farming of the Great Plains region. As is to be expected, there are marked correlations to be found between the physical factors of the environment, the vegetation, and the crop plants that can be grown. It represents a wonderful Synthetic study of a region that should be duplicated for the various sections of the country as a primary survey undertaken before making permanent or radical changes in an already existing system of agriculture Shantz divides the Plains into four sections as follows:

A. Land primarily valuable for crop production. In this section needle grass and slender wheat grass are indicators of the possibilities for spring wheat and the spring cereals; Bluestem bunch-grass indicating winter wheat, corn and alfalfa and mesquite and mesquite grass indicating cotton and grain sorghums.

B. Land valuable for crop production and grazing with crop failure when the rainfall is less than normal. Grama and western needle grass indicate spring wheat and other spring grain; wire grass indicates winter wheat, corn, and in the south the grain sorghums; wheat grass indicates spring grains and corn; and grama and mountain sage indicates spring grains.

C. Land valuable for grazing and crop production; good crops only during years of more than normal rainfall. Grama and buffalo grass indicate grain sorghums corn and small grains. Mesquite grass and thorn bush indicate cotton and grain sorghums during good years only. Sand sage and sand grass indicate corn and sorghum except in the southwest and grams grass indicates spring grains during the good years.

D. Land valuable for grazing only is indicated by sagebush, western wheat grass and Blackgrama.

Baker points out that often settlers unacquainted with the nature of the region try the wrong types of farming, and that sixteen hundred acres often can produce no more than 160 acres in the Eastern States. Marbut shows the importance of an examination of a soil profile so that the underlying soil as well as the topmost layer may be used to indicate the kinds of plants that may be grown.

Putting it briefly, we seem to be justified in making a strong case for the dynamic role played by the plants. For the climatic conditions are not varying, the soil not greatly varying. The extremes in the distribution of rainfall over a period of many years, not the seasonal rainfall, determine the native vegetation and the humus has largely determined the soil conditions. Some years ago the writer (11) made use of the *E* ratio of Transeau to show graphically the general features of the distribution of our crop plants. It is very gratifying to see that the detailed studies of the Great Plains discussed above bear out in the main the location of crop centers as deduced from a study of the rainfall evaporation ratio.

In the Eastern part of the United States with a higher content of soil moisture, the evaporation rate has been shown by a number of ecologists to be correlated with distribution. Of the greatest interest is the growth of our crop plants under field conditions with a daily record of the water loss. This has not been used as yet to the extent of its possibilities in indicating the correlations between moisture and yields.

Following the work of Garner (3) and Allard, light, too, must come into an added place of importance from the standpoint of photoperiodism. The older work has long recognized light intensity in relation to photosynthesis, and light intensities in relation to transpiration, by which it is tied up in a complicated way with both moisture and temperature factors. The new point calls attention to the direct effect of the length of the day. The significance has already been pointed out with a number of crop plants. Thatcher at the Ohio Station found that the planting dates of wheat vary somewhat with the latitude. Wanser has stated that photoperiodism is the key to the distinction between spring and winter wheats. Adams has shown that in both wheat and rye light, is, with heat in the greenhouse, important in controlling the date of heading out of the different varieties. For the explanation of spring and winter cereals we must look to an inherent rhythm in the plants adjusted to the peculiar Mediterraeann climate where these plants have long been grown. In the Mediterranean type of climate we may observe two cool moist growing seasons, the spring and autumn. There are also two dormant periods, the hot summer, too dry for plant growth, and the moist winter, too cool for plant growth. Winter wheat and rye have swung into this rhythm by growing in the fall and spring—the short day periods, and blooming in long day periods of early summer. Spring wheat lacking the autumn vegetative period has its vegetative activity telescoped and has consequently stored a less quantity of carbohydrates before blooming. Corn, on the other hand, represents a short day reproductive type. It has been modified by years of selection by the American Indian in carrying it northward from central America until there are some varieties which begin blooming a few weeks after the summer solstice. In winter time in the greenhouse we can have corn blooming in from five to seven weeks after it has been planted. Some selections of early blooming varieties of corn have been made at the Ohio Experiment Station. Potatoes show the same response to light periodicity in different latitudes. Halves of the same tubers which bloomed and set seed at Presque Isle, Maine, did not open any flowers at all in the New York Botanical Gardens.

Turning now to some of the biotic factors, the foresters know that certain groups of plants often do well when the same plants separated and grown in the open would not thrive. There is undoubtedly something gained by combining certain plants in attempting to obtain growth returns. Passing over the many varied explanations, let us look at certain suggestive experiments. At the Minnesota Station, Arny has recommended under certain conditions the combination of wheat and flax when the latter is grown for its seeds. At the Ohio Station there seem to be benefits under certain conditions resulting from combining corn and soy beans. Just as with the other factors studied there are a great many problems that need to be solved in the biotic groups as well as in the climatic and edaphic problems, all relating to adaptation. Other examples of biotic factors that have been studied in a very intensive way may be drawn from the many plant pests that produce crop yields. So definitely localized are many of the resistant varieties that in two parts of the country where the same crop may be grown, a variety found to be successful at one place is found to be perfectly worthless at the other. It seems in the interests of adaptation, therefore, that the wise plan for experiment stations over the country would be to carry on some interchange of their discards, (as in the game of rum), just as well as to exchange their more valuable selections.

One advance step that can be carried on by the co-operated activities of the Ohio Experiment Station and the University would be to undertake a complete primary survey of the vegetation of Ohio. In the State Herbarium are deposited many plants which are not any longer found in the counties in which they once were native. There are also records of the original surveys of the State in the State House and there is the group of field workers who have opportunity to make contributions to the ecology of Ohio by their observations in Forestry and Crops at the Station and at the University. It would mean much, not in any immediate practical way, but in a fundamental way, to the future development of the Agriculture of the State if all of this information could be compiled and edited and serve as the basis for recommendations as to future experimental work and also a good basis for practice. Local botanists with training in field work could co-operate with the staffs of the Experiment Station and the University to their mutual advantage. Thus with the formation of a central committee, a plan for mapping the vegetation of the entire State should be proposed. The types of vegetation already studied and the mapped areas should be examined and so furnish suggestions for proceeding with the art of the work. For we will only be able to formulate problems in general ecology and in our crop ecology after we have mapped definitely the vegetation of our area, as the first requisite is a certain number of accurately observed and recorded facts. The floristis studies made a quarter of a century and more ago will not suffice. The problems there were of discovering species, but now they consist of evaluating the physical factors that control the grouping of plants into associations.

If the work of such a committee as outlined were carried out, Ohio would be taking a step forward that would not only contribute to a knowledge of the vegetation of the world. This survey, when combined with our knowledge of physiology, pathology and genetics would offer the key to many of our most important problems of adaptation.

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