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SOME THOUGHTS ON THE AGRICULTURAL EXPERIMENT STATION[1]

By Professor C. G. WILLIAMS

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IN so far as the United States is concerned, the first agricultural experiment station dates back only 57 years, Connecticut having the honor of establishing the first station in 1875.

It is of interest to note what called the experiment station into existence. In his first annual report, Director Atwater said: "There was bitter need of a better control of the trade in commercial fertilizers in the State. One of the chief arguments used in favor of the station has been that by its means a fertilizer control system could be introduced. The demand that its first efforts should be turned in this direction was imperative."

This report gives further proof of the reason for the existence of the station, in that 103 of its 108 pages are devoted to information regarding analyses, etc., of the commercial fertilizers on the market. Strange as it may now seem, there was a time when fertilizer manufacturers had a great deal of human nature about them of the unconverted sort. Some 200 samples were received and analyzed by the Connecticut station during this first year.

The questions put up by the Connecticut farmer of the seventies sound very much like those of the Mid-West farmer of 1932, as, for instance, "Are such and such brands of fertilizers of enough value to farmers in this county to warrant their purchase these hard times?"

For several years the staff of the Connecticut station consisted of the director and three or four chemists, whose principal work was to analyze fertilizers, soils, feeds and poisons. This does not mean that noth-

[1] Address of the president and chairman of Section O—Agriculture—American Association for the Advancement of Science, Atlantic City, December, 1932.

ing else was done, for it was during this early period that some of the most valuable agricultural research of the century was done by Director Atwater—in particular the discovery of the fixation of atmospheric nitrogen by legumes.

Just a word about the second agricultural experiment station, which was established two years later in North Carolina. Its staff consisted of a director, who was the chemist of the state board of agriculture, and three assistant chemists. Like the Connecticut station, its work for several years consisted principally of its analyses of soils, fertilizers and feeds and the examination of seeds.

In his first report Director Ledeaux says: "The Board of Agriculture has wisely refrained hitherto from ordering any field tests to be made at the station for the following reasons: (1) These experiments are very expensive. (2) They need to be conducted through a series of successive years to be worth anything. (3) Owing to the extreme diversity of soils in this state most results obtained would only benefit those farmers who lived near Chapel Hill, or had soil of similar character to ours."

The above statement is also repeated in the third annual report.

With a change in station directors the fourth year, we find the new director saying in his annual report: "Experience shows that chemical manures are used to best advantage only when their application is determined strictly by the results of experiments upon the land." However, no permanent field experiments were started by the North Carolina station until four years later, when a "strictly scientific station, not a model farm," to quote the language of Director Dabney, was established.

So much for the early setting of the agricultural experiment station.

The early distrust of field experiments, as voiced by Jordan, when at the New York station, Ledeaux and others was perhaps warranted. Attempts to draw conclusions from one or two years' work conducted on land that gave every evidence of a lack of uniformity, and without sufficient controls and replications, were very properly discredited.

At a later date—some 12 or 13 years ago—C. B. Lipman and Linhart, of California, gave perhaps the most severe criticism of field experiments made before or since. They concluded that "even when fertilizer experiments were properly planned and the results adequately studied by statistical methods, our present knowledge of the enormous variability of all soils and plants renders the data from any given fertilizer plot of value only on that plot, no matter how near the experimental one." And Lipman further concludes that such experiments are not worth "the large expenditure of money, time and energy involved."

In view of these and other criticisms of field plot work, the question arises, what is the attitude of present-day experiment station workers toward field plot experimentation? In order to secure definite information regarding this matter the following question was submitted to the agronomists of 15 representative experiment stations: "What has been the trend regarding field plot experimentation at your experiment station during the last 25 years? Has your station been increasing or decreasing this line of work in your state?"

These agronomists responded as follows:

From the Connecticut station: "There has been a marked increase in the amount of field plot work at this station during the last 25 years. In spite of the many weaknesses inherent in field plot work, still it can not be entirely dispensed with, and while our greenhouse and laboratory studies have also expanded we expect to continue field work."

From the North Carolina station: "During the past 25 years there has been a material increase in field plot experiments in this state."

From the California station: "In general our field plot work has increased quite materially during the past 25 years."

From the Kentucky station: "Twenty-five years ago this station had very little field plot work. At the present time we have in soil management, fertilizer and crops work approximately 2,900 plots. We do not have any sympathy with the idea prevailing in some quarters that field work has little or no value."

From the Michigan station: "The number of field plot experiments has greatly increased in recent years. We are very much interested in greenhouse experiments and laboratory studies. However to our mind the final test is the result given under actual field conditions."

From the Kansas station: "The general trend in this state at the present time is to increase the use of field plots in our soils experimental work. We believe that some types of work may be done successfully on very small areas and under greenhouse and laboratory conditions, but that field plots are also essential in many phases of our work."

From the Alabama station: "We have very definitely increased our experimental work using field plots as a means of securing more or less practical answers to more or less practical questions. It is our opinion that there is no other way to secure answers to many of our most important questions except through the use of field plots."

From the Minnesota station: "Minnesota has greatly increased the plot work with soils and crops out in the state, both on the sub-stations and on fields leased by the university. On the university farm plot work has been decreased as this soil represents only a very small part of the state."

From the Tennessee station: "We have quite materially increased our plot work in the last 25 years. I consider work of this kind very important; in fact I would not know how to get along without it."

From the Wisconsin station: "Our faith in the value of the field plot as a medium of experimentation is increasing rather than decreasing. The trend, however, is more and more in the direction of a combination of field, greenhouse and laboratory work."

From the New York station (Ithaca): "The soil at Ithaca lacks uniformity to a rather unusual degree. This difficulty has led us to substitute what we call 'frames' for ordinary field plots. We also use the greenhouse for certain experiments, but I think that the extent to which a greenhouse may be substituted for field experiments is rather limited. We have not curtailed in any way the work on our outlying experiment fields."

From the Illinois station: "The trend in plot experimentation was distinctly upward until the cost of operation began to be almost unbearable. We had our peak in the number of crops and soils fields in 1919—forty fields. I suspect the number will be smaller than it has been in the past. We are emphasizing our laboratory research more than used to be the case. We must find a good balance between the two."

From the Indiana station: "During the last 25 years the field-plot experimental work of this station has increased many fold. All our experience tends to strengthen the view that the results of carefully conducted and long-continued experiments on a reasonably representative field of any distinct type of soil will apply to other areas of the same type wherever found under similar climatic conditions. We hope to add to our permanent experimental fields until we have one on every important soil type in the state."

From the Iowa station: "The area on which we are now carrying experiments is five or six times as large as formerly. Too much emphasis can not be put on the value of field plot experimental work in soils and crops."

From the Pennsylvania station: "There has been a continued increase in our field plot experiments year by year up to the present time."

Such is the testimony of representative agronomists of the United States.

The greater use which is apparently being made of field plots in the solution of soils and crops problems, as indicated above, is probably in large part due to improved methods in field experimentation. With more replications and controls, with a greater appreciation of the possibility of experimental error and a technique adapted to the measurement of such error, results are being secured to-day that were not to be had in some of the earlier work.

Not only have methods been improved in field plot experimentation, but there has been a general refinement in methods along all lines.

It is not so long ago that our workers with animals were content to use from one to five animals in feeding tests and to draw conclusions therefrom regarding rations and gains. Now, from 20 to 100 animals on each ration are regarded as quite essential, and the work must be repeated several times. Numbers, replications and controls are exceedingly important.

There is, I think, a rapidly growing tendency to break down departmental lines in research institutions in joint attacks upon research problems, both in planning and carrying them forward. Much more valuable results are to be had from such cooperation. And similar cooperative attacks may be and are being carried on between different experiment stations and between state stations and the Federal department of agriculture.

While many of our experiment stations got under way without any help from the Federal Government, the Hatch Act of 1887, the Adams Act of 1906 and the Purnell Act of 1925 have proved a great stimulus to research work. In the expenditure of Adams funds a higher type of research was insisted upon.

Some 7 per cent. of the projects of the agricultural experiment stations of the United States is listed by the Office of Experiment Stations as Adams projects, and 12 per cent. as Purnell projects. The latter act especially encouraged research in agricultural economics, home economics and rural sociology. Approximately one half of the projects supported by Purnell funds are in these three lines of work.

The field of the agricultural experiment station is an ever broadening one. Beginning largely in an effort to protect the agricultural public from fraudulent practices in the manufacture and sale of commercial fertilizers, feed stuffs, seeds, etc., the experiment station has taken over the vast fields of soils and crops, animal production, dairying, horticulture, forestry, agricultural and biological chemistry, plant and animal nutrition, plant and animal pathology, economic entomology, bacteriology, genetics, agricultural economics, agricultural engineering, home economics, food technology, rural sociology, textiles and clothing.

As one looks backward over these 50 years of experiment station work, he is impressed with the contribution the stations have made to our material progress—the hundreds of new varieties of farm and horticultural crops which have been developed;

The many new legumes which have been discovered and introduced, some of which will be found adapted to our widely varying conditions;

The discovery and development of economic methods for combatting insects and diseases which have made relatively certain the production of crops and animals which was previously a gamble;

The improved methods of breeding and feeding all kinds of live stock for increased production in milk, meat and eggs;

The economic use of commercial plant foods and soil amendments;

The invention of the Babcock test and its consequent influence on all dairy practices—not to mention other contributions.

Up to 10 or 12 years ago it was the fashion to descant upon the grave dangers confronting this country and the world at large from our rapidly growing population overtaking our production of food and fabric materials. We hear none of this to-day.

But back of and leading up to these practical results are more permanent contributions to our fundamental knowledge which will bear fruit in the decades to come, for our experiment stations have not been content with knowing "what," but have pressed on to the "how" and the "why."

What of the future?

The financial situation in which many of our experiment stations now find themselves is discouraging. A reduction of state appropriations is very general. What course Federal appropriations will take is uncertain at this writing, but in spite of our tremendous financial depression it is hardly conceivable that the Federal Government will scrap an organization which it has been slowly building up for the last 40 years.

A reasonable support of these institutions would seem to be assured.

QUANTUM MECHANICS AND CHEMISTRY WITH PARTICULAR REFERENCE TO REACTIONS INVOLVING CONJUGATE DOUBLE BONDS[1]

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THE universally accepted conception of atoms as positive nuclei surrounded by electrons make it obvious that some sort of mechanics of such particles will properly describe their chemical behavior. The success of quantum mechanics in atomic physics where it gives quantitative agreement with experiment shows us clearly enough the general means to be employed. From this point of view it is convenient to regard the Schrodinger equation as our point of departure. Among the solutions of the Schrodinger equation which satisfy the supplementary quantum conditions only those which in addition obey the Pauli principle, *i.e.*, only those solutions which change sign when two identical particles are interchanged need be considered as having physical reality. Our scheme, though complete, is still much too difficult to proceed with. We must find other simplifying conditions. The first simplification is a familiar one. Because of the much greater mass of atoms than electrons the atoms travel relatively much more slowly so that in calculating the potential energy of any system from the Schrodinger equation we neglect the motion of the atoms without introducing serious error. The result is that we obtain a potential energy for the system under consideration as a function of the distance between the atoms, and this, as we shall soon see, provides just the necessary information for estimating rates of reactions. London was the first to point out that such a scheme probably provided a way for calculating activation energies. We next consider the nature of an activation energy. Consider the reaction $H_2 + I_2 = 2HI$. This is a well-known bimolecular reaction. For the rate of formation of HI, we can write

$$\frac{d(HI)}{dt} = f\,S\,e^{-E/RT}\,(H_2)\,(I_2).$$

The parenthesis around a formula indicates the concentration of that substance. Thus S (H_2) (I_2) is the number of collisions between molecules of hydrogen and iodine in concentration units and can be calculated from kinetic theory, while the expression $e^{-E/RT}$ is the chance that in a particular collision the two molecules collide with an energy E in a form to permit reaction. The energy E is called the activation energy and has for this reaction a value of 40,000 calories. The precision of activation energy measurements is seldom better than one large calorie; so that activation energies are ordinarily specified in large calories. The proper fraction f in our rate expression approaches one for most simple reactions.

[1] Based on a paper presented before the Section of Chemistry of the American Association for the Advancement of Science at its Atlantic City meeting for which the anunal prize of the association was awarded.