Fertilization of Sugar Beets

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NEARLY EVERYONE in this room has at one time or another been confronted with the problem of sugar beet fertilization in a given region, on a certain farm, or on a particular piece of land on a farm. This fact puts us all on the same common ground, and I am sure each of us has some ideas on how to fertilize a beet crop, at least in some particular area. After I had been asked to talk on the subject of fertilization of sugar beets, and had reviewed a number of papers, I asked myself, "What do we know about sugar beet fertilization?" Not what are our ideas, or suppositions, but what do we know? I was reminded of an example given by a certain professor of Colorado A & M College at the 26th annual meeting of Colorado Seedmen's Association at Fort Collins, December of 1947. The professor was discussing the fertility problems in Colorado. When the question was raised as to what was known about the fertility problems of Colorado and their solution, the professor raised this bulletin and said, "This small bulletin contains all we know about the fertility problems in this state." He then raised this bulletin and said, "This bulletin contains all we are willing to guess on." And raising his hand above the desk about two feet he said, "This bulletin, which hasn't yet been written, contains all we do not know about the fertility problems in this state." I believe we are in about the same position with respect to our knowledge on fertilization of sugar beets.

To be sure there is a tremendous amount of experience, experimentation, and research back of us. A great deal of information and knowledge has been obtained from this past effort. But when we compare this with what we do not know, the difference is great.

What are the important soil fertility problems of the sugar beet producer? They are numerous and if broken down in detail would require several pages for their listing. Most of the specific problems, however, would be combined in a typical answer which a farmer would give if we were to ask him to state his problems in regard to fertilization of sugar beets. He would say that he wanted to know how to fertilize his particular piece of land in order to get a maximum economic return from his investments, including his labor. In other words, the practical problem is to be able to tell every farmer what fertilizers to apply, how to apply them, and the correct amount to apply.

How can these questions be solved? There are at least two ways of approach. First, we could conduct experiments on every farm and even every soil type on every farm in the sugar beet growing areas to try to obtain the correct answers. Second, we could develop some means of

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analyzing the soil to predict fertilizer needs for various crops under different conditions. Let us consider first the approach of conducting field experiments on all of the farms. We know from past experiences that no two farms are alike, and that information obtained on one farm cannot be translated to another farm without considerable information on the soil, most of which we do not know how to obtain. Even if we were to conduct fertility experiments on every piece of land that was to be put in sugar beets the results at any particular spot would vary from year to year depending upon past treatment, previous crops, etc. Of course, we know that we do not have money enough to attempt such a program and that it would be an unwise approach if we did have the money. I am sure no one has ever tried or anticipated such a program. Field experimentation is necessary, however, and a certain amount of it must be done.

Let us look at some data from fertility experiments, conducted in Colorado by the Great Western Sugar Company and the Colorado Agricultural Experiment Station (3)[2]. These results were presented and discussed Monday afternoon in the Irrigation and Fertility Section. The fertility experiment I am referring to had various treatments, but included were three levels of nitrogen at the following rates: 0, 66, 132 pounds of nitrogen per acre and two levels of P_2O_5 at 0 and 120 pounds per acre. This experiment was conducted at 37 locations. Of these 37 locations, 70 percent gave increases in sugar per acre from the added phosphorus. Variations in apparent response varied from a minus 1,100 to a plus 1,300 pounds of sugar per acre. There were 2 farms on which the added P_2O_5 apparently reduced the yield by 1,100 pounds of sugar per acre and 2 farms on which the added P_2O_5 increased the yield of sugar by 1,100 or more pounds per acre. Part of these differences may be due to errors inherent in field experiments. For plots receiving 66 pounds of nitrogen per acre there were 51 percent on which yields were apparently decreased and about 49 percent on which yields were apparently increased. Variations associated with this treatment were from minus 700 pounds to a plus 1,700 pounds of sugar per acre. When nitrogen was added at the rate of 132 pounds per acre but in combination with phosphorus and potassium, 57 percent of the locations gave increases and 43 percent gave decreases in sugar production. Variations were from a minus 1,900 to a plus 1,700 pounds of sugar per acre. Certainly different responses at different locations were expected from the various treatments by the people who designed these experiments. They do serve, however, to illustrate the fact that the mere conducting of field experiments will not completely answer the problem of how to fertilize sugar beets. I know that the Colorado people and others connected with this experiment just referred to are making laboratory and greenhouse studies in an attempt to obtain more information on these soils and reasons for the type of responses obtained.

In 1945 Bion Tolman (4) of the Utah-Idaho Sugar Company conducted an experiment with uniform treatments at 55 locations. These

[2]Numbers in parentheses refer to literature cited.

tests covered an area of four states—Utah, Idaho, South Dakota, and Washington. The chemical treatments were 0, 200, and 400 pounds of ammonium sulfate and treble superphosphate each in all combinations at every location. For our purpose we shall consider these as treatments 1 to 9 and observe the data with respect to uniformity of response to any one treatment. The data as summarized by Tolman indicate the most profitable treatment for each location. The individual locations were broken down into states and in most cases into districts. Some typical examples are given. In the Gunnison District of Utah there were 8 locations. The highest percentage of fields for most profitable treatment came in the Number 1 treatment, no added fertilizer, and in treatment Number 3, 400 pounds of ammonium sulfate per acre. Thirty-seven and one-half percent of the farms were in each of these two treatments. For the West Jordan District there were 10 farms; the highest percentage of farms in the treatment being most profitable was 30 percent. For Idaho there were 5 districts. The Blackfoot District had 4 farms and 2 of these had the most profitable response from the same treatment, making 50 percent in one treatment. For the Valley District there were 3 farms and all 3 fell in separate treatments for the one most profitable. There were other locations in Idaho but summing up the 21 locations in Idaho, the most profitable treatment was most profitable 38 percent of the time. For South Dakota there were 8 farms. The no added fertilizer was most profitable on the greatest number of farms for a total of 37.5 percent. In the Yakima Valley in Washington there were 8 farms. The 400 pounds ammonium sulfate plus 200 pounds treble superphosphate was the most profitable on 5 of these farms, or 62.5 percent of the time. Summing up all of the 55 locations, there was one treatment that was most profitable on 27.3 percent of the farms; all of the rest were less.

A summary of the data in the manner just given is somewhat different from the summary given by Tolman and may be somewhat misleading insofar as practical application is concerned. For instance, often the differences between treatments in a test were not fundamentally different. There were cases where the 200 pounds of ammonium sulfate plus 200 pounds of treble superphosphate was better than the 400 pounds of ammonium sulfate plus 200 pounds of treble superphosphate and vice versa. At the same time both of these treatments may have returned $4 to $6 for each dollar spent, and this may have occurred on 70 to 80 percent of the farms of a given district. Certainly the benefits to be derived from such experimental work are obvious, and the results of this type of information should be brought to the farmer as quickly as possible.

While the information obtained in the two experiments referred to above is certainly valuable and gives us a better knowledge of the fertility problems in certain areas, it is not the final goal in our desire to obtain information on the fertility problems of sugar beets or fertility problems in general. More information is needed. Why is there such variation in response to treatments? The answer is that there are any number of factors that affect yield. Some of the first thoughts center around such things as past cropping history. Were such crops as alfalfa and other legumes grown? Has the land received large applications of manure or other fertilizer treatments? What about soil type, etc.? Was moisture a limiting factor?

A factorial experiment (2) at the Utah Station was conducted on land that was thought to be quite uniform with respect to fertility level. The variables were moisture, spacing, manure, and commercial fertilizer treatments. This experiment has shown that if one is to obtain a maximum return from added, high amounts of nitrogen it is necessary to have a sufficient number of plants to utilize more fully the large amounts of nitrogen added. For instance, in this experiment, compare the yields of sugar from plots which received no added nitrogen with those from plots which received 160 pounds of nitrogen at each of the three spacing treatments. On the no-added-nitrogen plots the yields of the 12-20 inch and 20-inch spaced rows yielded the same—about 3.4 tons of sugar per acre—but for the plots receiving 160 pounds of nitrogen the yields increased for the 24, 20, and 12-20 inch spacing as follows: 3.35, 3.95, and 4.25 tons sugar per acre respectively. Likewise, there was not a sufficient number of plants on the 24-inch spacing to benefit from the extra 80 pounds of nitrogen in the 160-pound treatment versus the 80-pound treatment. In the nitrogen treatments at the various moisture-stress levels it was found that for the 160-pound nitrogen treatment the low stress (or high moisture) yielded 4.25 tons sugar, the intermediate or next driest treatment yielded 3.4 tons sugar per acre and the driest treatment yielded 2.9 tons sugar per acre. In this experiment it was very obvious that nitrogen was an effective fertilizer only if moisture did not become limiting, and it was more effective the greater the number of plants per acre. In other words, if one is to obtain a maximum yield or a maximum economic use of fertilizer it is necessary to have all of the other factors that affect plant growth at as near optimum as possible. If any one of the factors affecting plant growth is limiting maximum yields will not be obtained. This experiment has shown highly significant interactions between moisture level, spacing, and fertility treatments, and points out the tremendous importance that moisture level or spacing of plants may have on fertilizer response and yield of beets.

All of these factors we have been discussing are important, but let us raise the question: What is it we really need to know before we can intelligently lay out a fertilizer program for sugar beets in any given area? First we must know the nutritional requirements of sugar beets. We must know for the various periods of their physiological development the nutritional requirements of the various elements, or for instance: What are the needs of beets for phosphorus each week, or month, from the time they are planted until they are harvested?

The total amount of the various elements for certain yields of beets has been determined at various locations for specific conditions. For instance, in a recent paper Gardner (1) has given values for a 15-ton crop of beets and a 3,200-pound crop of beet tops as follows: 134.6 pounds of nitrogen, 18.2 pounds of phosphorus, and 201 pounds of potassium. Figures are also given for calcium, magnesium, sulfur, iron, manganese, zinc, copper, and boron. While such information may give the total amount of a given element needed for a certain yield, under a given set of conditions, it does not tell the rate of uptake and the specific needs at various periods of the plants' development. Such information can be determined for specific conditions, with our present knowledge.

Second, how much of the various nutritional elements are available in the soil for growth of sugar beets? How much will become available over the growing season? And at what rates? If there is not a sufficient amount of a given nutritional element, how much will need to be added? When some is added, what happens to it? How much will remain available? How much will be fixed in an unavailable form, leached, or become unavailable in some other way? At what rate will it become unavailable? With this type of information, the amount of a given nutritional element required for maximum economic sugar beet production could be added to a given soil. Obviously, we cannot answer these questions at the present time. One of the main reasons for our inability to answer these questions is that we do not know the property of the various elements that is important insofar as plant growth is concerned. Take phosphorus, for instance. Is it total soil phosphorus, water-soluble phosphorus, some acid or alkali extractable phosphorus or some other property that is important insofar as plant growth is concerned? I believe this is one of the first questions to solve. It is not an easy one. Contrast our knowledge on fertilizer elements with that of soil water. We believe now that we know the property of soil water that is important insofar as plant growth is concerned. That is, namely, the total equivalent stress. It was not very many years ago that soil moisture was reported, for various moisture experiments, as so much percentage moisture without any relation to total stress or moisture potential. As we all know, some soils may be at "field capacity" at a moisture percentage of 10 percent while others may be approaching the wilting percentage at values of 15 to 20 percent.

Obviously we could not correlate and integrate various results if our only knowledge of the soil moisture was that of percentage moisture. But once the important property of soil water in relation to plant growth was established, it has been possible to begin to determine the effects of variations in this property on plant growth. These effects will be the same for various soils and various locations providing other factors affecting plant growth which would cause interactions with soil-moisture stress do not vary. We need some such property for the various fertilizer elements—a property that we could determine, the value of which would not vary, insofar as plant growth is concerned, for various soil conditions.

A considerable amount of experimental work should be under way on these fundamental problems. I doubt if there is any one of us who would say that he could even set up an experiment that would definitely give answers to these questions. This, however, should not discourage us from tackling the problem. Many people have worked on these problems and much information has been obtained. It is becoming obvious, however, with the accumulation of more and more data that these problems are large, and that no one person is going to solve them. Their solution requires more money and more effort than any one or small group of people will be able to put into it. It requires the best and coordinated efforts of all concerned. Developments in the past few years have shown considerable progress.

The establishment of the Beet Sugar Development Foundation indicates a coordinated attack on the research problems by the sugar companies. A similar coordinated approach on soil research problems is indicated by the recent development of a Western States Soil Management Committee which helps to coordinate the efforts of the various state and federal research agencies. This type of coordinated effort makes possible a much more vigorous attack on specific problems. Even with such cooperative approaches, most frequently there is not sufficient technical manpower and funds to undertake the type of research which is known to be needed for the solution of certain specific problems such as the fertilization of sugar beets. I feel certain that we shall not be satisfied with our knowledge on the problems of fertilization of sugar beets until such a time comes when we can analyze a farmer's soil and tell the farmer how much of the given nutritional elements he should add for maximum economic production, where to place them, when to add them, etc. These answers will come only through continued cooperative research, and a redoubling many times of our efforts will be necessary before we obtain the final solution.

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