Samples dug from the treated portion indicate a yield of eight tons per acre as against the yield of five tons per acre on the untreated portion of the field. It is obvious that it would be impossible to produce a good yield by correcting a difficulty as late as the twelfth of August, but the fact that the tops grew again on the beets is sufficient evidence that phosphorous was the cause of the blight.

The literature, and especially that from Utah, describes what is termed "Late Blight," which according to the evidence presented is phosphorous deficiency blight. It is stated that late blight is very greatly favored by drought and that in past years has caused great losses to the beet growers in Utah. Drought, of course, causes phosphorous deficiency according to the ordinary laws of solubility. When moisture decreases, soluble phosphorous decreases, or in other words, phosphorous is not dissolved from the soil and hence the crop suffers for lack of this element.

Moisture affects solubility of phosphorous in still another way. Carbon dioxide is the principal means by which the phosphate in the soil is made available. When moisture is limited bacterial activity and the formation of carbon dioxide is also reduced. Furthermore the activity of the crop itself is retarded by lack of moisture and there is a corresponding decrease in the amount of carbon dioxide given off by the plant. The reduction of moisture thus causes a reduction of available phosphorous and a deficiency occurs.

The publications from Utah also state that a high pH favors phosphorous deficiency. This again is in full accord with the principles of solubility. As the pH rises or the soil becomes more alkaline phosphates are held in a more insoluble state. The deficiency is thus favored by a high pH which is according to the findings in Utah.

Phosphorous deficiency blight occurs only in extremely deficient soils. Actually such soils represent a small percentage of the total beet acreage. On these soils the crops usually do not pay more than the cost of harvest, and sometimes not even that amount. They do illustrate in the communities where they occur, how near the danger line the soils are becoming as regards the supply of phosphorous.

The symptoms of mild phosphorous deficiency cannot be detected in the plant. From an economic standpoint it is this unnoticeable handicap or deficiency that really reduces production on a large acreage. The extreme symptoms of deficiency as discussed calls to our attention the need of more watchfulness regarding the phosphorous supply in average soils or fields that have not yet become depleted to the danger line.

Note: A series of "color" photographs were shown which illustrated clearly the phosphorous deficiency symptoms of leaves and roots at various stages of development.

APPLYING FERTILIZERS TO SUGAR BEETS IN ONTARIO

H. W. Brown[1]

Sugar beets have been grown as a commercial crop in Ontario, Canada, for 40 years. It is the purpose of this short presentation, to show what part commercial fertilization plays in the production of this crop and what is the

1/Agricultural Research Dept., Canada and Dominion Sugar Co.,Ltd.,Chatham,Ont.

basis for recommendations to beet growers in regard to the use of fertilizers.

In the early days of the beet sugar industry, barnyard manure was the only fertilizer applied to the crop, but gradually the beet growers came to recognize the value of commercial fertilizers and found both the quality and the yield of beets was improved thereby.

The outline of this presentation is as follows:

1. Rates of commercial fertilizer application used by beet growers.
2. Yields obtained by "users" and "non-users" of commercial fertilizers.
3. Types or brands of fertilizer used by growers.
4. Methods of fertilizer application.
5. Soil testing and soil analyses for beet crops.
6. Research program for meeting beet crop needs as to fertilizers.

1. Rates

Records compiled from individual beet growers show a wide variation in the rate of commercial fertilizer used. The following table gives the percent of acreage upon which fertilizer was used at various rates, for all beet growers in Ontario, who number about 4000 per year:

Table 1 - Percentage of sugar beet acreage using various amounts of commercial fertilizer and average application per acre.

Year	125# or less	125#-200#	200#-300#	Over 300#	Av. application
1938	19.4%	17.9%	53.2%	9.5%	178 pounds
1937	17.8	18.2	55.9	8.1	213 "
1936	17.3	18.8	52.0	11.9	185 "
1935	4.1	32.3	58.0	5.4	195 "
1934	3.1	26.4	57.4	13.1	206 "
5 Year Av.	12.4	22.7	55.3	9.6	195 "

This table shows that the average grower applies about 200 lbs. per acre and not more than 10% use over 300 lbs. per acre. The increasing percentage with one bag or less per acre reflects the economy on expenditures as the farmers felt the depression effects more and more.

2. Yields

Less than 10% of the beet growers will now try to grow a crop of beets without commercial fertilizer. Over the past 5 years, 90.9% of the beet acreage received some commercial fertilizer. When we compare the average yield of beets for all growers who fertilized with all those who did not use commercial fertilizer, we obtained the following results over a 5 year period:

Table II - Percentage of fertilizer users and non-users with average yields per acre

Year	Users	Non-users	Users Yield	Non-users Yield	Increase for users	Value of Extra Yield
1938	92.2%	7.8%	9.67 tons	8.64 tons	1.03 tons	$5.28
1937	91.3	8.7	7.83 "	6.72 "	1.09 "	5.06
1936	88.6	11.4	11.00 "	9.90 "	1.10 "	5.47
1935	90.0	10.0	8.53 "	7.64 "	.89 "	5.00
1934	92.4	7.6	9.89 "	8.99 "	.90 "	6.23
5 yr. av.	90.9	9.1	9.38 "	8.38 "	1.00 "	5.41

We did find that the 9.1% not using commercial fertilizer are chiefly "older" farmers who have never used it on any farm crop or those who pride themselves on the use of farm manure or clover in rotation. Despite this positive selection of the 9.1% toward good farm practice, the growers who have used commercial fertilizer have outyielded the non-users by an average of 1.0 tons per acre over a 5 year period. The increased return has been $5.41 per acre for an expenditure not over $3.00 per acre. In addition to the merit of increased returns, the fertilizer saved the land from more rapid depletion of the fertilizer elements and also had a "carry over" effect upon succeeding crops on that land.

3. Kinds

The kinds or analyses of fertilizers used on the beet crop are the outgrowth of many factors including Fertilizer Companies marketing publicity, Agricultural College bulletins, crop analyses and soil analyses. The lower analysis materials have been replaced with higher grades, and the Sugar Company has made recommendations based upon field tests and soil analyses.

The following table gives the chief fertilizer mixtures used by Ontario beet growers during the past five years:

Table III - Kinds of fertilizers used for beets by Ontario growers, given as percentage of acreage for various mixtures.

Year	2-16-6 Analysis	2-12-10 Analysis	2-12-6 Analysis	0-20-0 0-16-0	Other Mixtures
1938	64.0%	3.6%	24.2%	4.2%	4.0%
1937	58.2	4.2	28.1	5.2	3.2
1936	64.4	3.0	25.1	3.9	3.6
1935	74.4	7.9	12.0	3.5	2.6
1934	61.9	0.0	33.0	4.1	1.0
5 yr. av.	64.6	3.8	24.5	4.2	2.9

This table shows that about 95% of the fertilizers used in Ontario on sugar beets are mixed or "balanced" fertilizers. The 2-16-6 has become the most widely used fertilizer, averaging 64.6% of the crop. It was introduced as an improvement on the 2-12-6 fertilizer, which in turn was an advance over the 2-8-6. The 2-16-6 was introduced to meet the needs of the sugar beet crop on most Ontario farms. The Nitrogen content is low (2%) because Nitrogen can be incorporated into the soil more cheaply in manure and clover, but this small amount starts the crop off well. In numerous field experiments it showed a faster early growth than where it was omitted. The phosphate content is high (16%) because field trials have repeatedly shown a marked response to Phosphate application in Ontario soils. Analysis of Ontario soils (Table VI) have usually shown a low content of available phosphate. The 6% of Potash included in the 2-16-6, or 10% in the 2-12-10, has two chief merits. Firstly, it supplies part of the high Potash requirement of the beet crop, and secondly, it lessens the drain on the soil Potash supply which may be adequate at present but will be a deficiency if no replacements are made.

Some data on relationship of clover and manure of the Ontario beet crop is important to the picture being presented. The following table shows how these Nitrogenous materials are related to the beet crop:

Table IV - Percent of sugar beet acreage with clover and manure.

Year	Manure Applications			Clover in Rotation	
	Same Year	Previous Year	Tons per Acre	Previous Year	2nd Yr. Back
1938	5.3%	23.9%	13.6	13.1%	30.0%
1937	4.7	27.6	13.5	16.5	29.2
1936	3.1	25.9	14.2	1.1	15.7
1935	3.3	27.4	13.7	0.3	15.5
1934	5.8	31.7	12.4	0.3	27.4
5 Yr. Av.	4.4	27.3	13.5	6.3	23.6

This data shows the relatively small percentages of beet acreage being manured or clovered at a time likely to increase the Nitrogen content for sugar beets. With only about 30% of the acreage getting a direct effect of clover and manure, the tonnage yields of sugar beets are relatively low on many Ontario farms. This is one of the main reasons for the wide variations in yield often found on neighboring farms.

4. Application

The methods of applying fertilizer to sugar beets are the direct outcome of the type of equipment sold to growers for seeding their beets. The combined seed and fertilizer drill was introduced nearly 20 years ago, and the fertilizer has been applied with the seed on at least 90% of the acreage receiving any fertilizer. The beet drills now used by practically every Ontario grower deliver the seed and fertilizer into one tube and let them mix while dropping from the separated seed and fertilizer boxes.

The mixture of seed and fertilizer drops into a shallow furrow made by a pair of discs or a runner shoe and is left there at a depth from 1/2 inch to 2 inches below the surface. The soil texture and pressure put upon the discs or shoes regulates the depth of seed and fertilizer. The intimate contact of seed and chemical fertilizer has both benefits and disadvantages for the beet crop.

On the positive side, the young seedling is assured of adequate plant nutrients in the early stages of growth, if there is sufficient moisture to dissolve the fertilizer elements. In S. W. Ontario, where the sugar beets are grown, there is an average rainfall of 29.0 inches, of which more than 5 inches occurs in April and May while seeding is being done. Under normal conditions the beet seedlings obtain adequate nutrients, as our plant tissue tests or chemical analyses of seedlings show. Unfortunately, there are abnormal seasons and every year there are abnormal districts where the rainfall is just sufficient to form a very concentrated nutrient solution which injures or kills the tender seedlings.

Numerous case histories have shown injury to seedlings by fertilizer, and the stand in some cases has been seriously lowered. Yields have been reduced as they are at J. R. Shuel's in 1939 when "No Fertilizer" yielded 12.7 tons per acre while with 500 lbs. of 2-12-6 the yield was only 12.0 tons per acre and the "set-back" was noticeable all spring. At H. Maitre's, stand counts were reduced 13% where fertilizer was applied with the seed, and some growers have torn up beet crops where the stand was too poor, apparently because of fertilizer burning.

The rate of fertilizer application becomes very important when the fertilizer is applied in contact with the seed. Field experiment results with triple superphosphate, double strength 2-12-6 and Ammo-Phos brands showed that they could not be safely applied at the rates commonly used. With the analyses now used, the rates must be held to 250 pounds or less to avoid damage to the seedlings and injury may occur even then under certain moisture conditions.

To increase beet yields and ensure a profitable crop, it is often necessary to apply more than the amount which can be safely mixed with the seed. Two alternative methods of application are being adopted and should be encouraged, despite the use of more complex machinery or additional work at seeding time. One new method in Ontario is to use a drill with separate fertilizer delivery tubes which will place at least part of the fertilizer away from the seed, and the second is the application of part of the fertilizer at a different time.

Every bit of complexity in the beet drill not only increases its cost, but increases the mistakes in uniform seeding by unmechanical or careless farmers. Even the "split shoe" drill, which is the simplest separate seed and fertilizer adaption, increases seeding mistakes. In this drill there are twice as many tubes to "go wrong" and a number of our growers had difficulty in the tubes "plugging".

The second alternative to injuring the germination with fertilizer is to apply part of the material, broadcast, as a side-dressing or with a grain drill. Our experience in Ontario with side-dressing the beet rows, has not proven marked benefit for this practice over pre-seeding applications of the same fertilizer. Side-dressing after thinning means considerable work with extra equipment, and the increases in yield have usually only paid the additional expense. Nitrogen applications after thinning often increase the tonnage, but give a lower sugar content crop which about balances the value of increased yield. Our best results in Ontario have come from a generous application of Phosphate with the grain drill just before seeding, and the use of a balanced fertilizer like 2-12-10 at 125 - 250 lbs. per acre with the seed. There is scope, however, for improvement in machinery and further research upon deeper fertilizer application and its effect upon the seed bed. Our experience indicates that any benefits derived from deeper placement of fertilizer are nullified if the seed bed is disturbed under the row.

5. Crop Needs and Soil Contents

The fertilizer application should depend upon the soil content of available plant food and the particular crop needs. We have made analyses of Ontario beet roots and beet tops as well as followed the crop through the season with tissue tests. The crop needs for a 10 ton per acre crop of Ontario beets, as published in the Society's report of the Detroit meeting in 1939, involve 97 lbs. of Nitrogen, 23 lbs. of Phosphorous, 129 lbs. of Potash and 44 lbs. of Lime, found in 5550 lbs. of dry matter including crowns and leaves. These fertilizer elements would be found in approximately 500 lbs. of Sulphate of Ammonia (20% N), 115 lbs. of Superphosphate (16% P_2O_5) and 215 lbs. of Muriate of Potash (60% K_2O). It would take 2000 lbs. per acre of a fertilizer mixture approximating an analysis of 5-2-7.

Fortunately for the sugar beet growers, the beets are grown in soil, not in a solution, and the soil is able to supply most of the crop demands. Unfortunately for our problem, the total fertilizer ingredients in the soil are not available to the growing plants, and the old method of "Total Analysis" of a soil does not give the right answer to fertilizer requirements. Our methods of estimating "Available" plant nutrients are constantly changing and every year we have "better and better" methods thrust upon us.

Our laboratories have used the Azotobacter Test, Morgan's, Brya's, Truog's, Thornton's Method and the Neubauer Test as well as several modifications of our own. The following soil analyses of typical sugar beet growing soil will show the general conditions in Ontario.

Table V - Analyses of typical sugar beet soils in Ontario.

Soil Type	Soil Series	x-Total Org.Matter	xx-Active Org.Matter	O.M.Rates A/T	Thornton's Phosphate	Truog's Potash
Clay	Brookston	6.3	3.9	64%	116#	546#
Clay Loam	"	5.3	3.1	57	87	323
Sandy Loam	"	4.9	3.1	65	73	273
Clay	Clyde	11.6	6.3	57	117	361
Silt Loam	"	10.4	6.0	58	50	226
Clay Loam	Thames	5.8	3.3	56	84	438
Clay	Haldimand	3.4	2.5	74	17	263
Clay Loam	Perth	5.1	4.0	79	5	341

x Method = Potassium dichromate under special heat.
xx " = Sodium " under heat of reaction.

Soil Type	Soil Series	H-ion pH	Total Nitrogen	Neubauer phosphate (P_2O_5)	Neubauer Potash (K_2O)
Clay	Brookston	7.1	.282	83#	896#
Clay Loam	"	7.3	.288	64#	564
Sandy Loam	"	7.3	.257	42#	552
Clay	Clyde	7.4	.512	57#	421
Silt Loam	"	7.6	.291	58#	356
Clay Loam	Thames	7.6	.241	46#	529

x = Hydrogen ion by quin-hydrone. xx = Total Nitrogen by Kjeldahl digestion.

These analyses indicate that the soils on an average contain sufficient of these elements for the beet crop if it were all obtainable by the plants. However, the root system is not able to penetrate every inch of soil and only a fraction of it is within reach of the crop. Insufficient moisture also prevents the plants obtaining what is in available form since plants can only take in food when it is in solution. Such soil analyses as the above have to be interpreted in terms of the plant response and field trials enable us to set limits of low, high or deficient contents. Thus, when a soil shows less than 100 lbs. of available Phosphate, we know that the beet crop will respond to that element in a fertilizer. The Potash content is apparently from 5 to 10 times that of the Phosphate soil content, so that the fertilizer applications should contain more Phosphate, in order to keep it from being a limiting factor in root development.

6. Research Program

Soil analyses must go hand in hand with field experimentation to find the levels of fertilizer response for each soil type. In our Ontario soils the sugar beet crop generally responds to Phosphate, but the Potash content must not be neglected or it soon will become a limiting factor. The wise farmer adds some Potash to his field each year to maintain a high Potash level, particularly for sugar beets which use so much of it.

Our research program in regard to fertilizers involves a record of the crop history for each field where beets are grown and an attempt to interest the farmer in the fertility level of that field. We collect soil samples from each locality and encourage farmers to send in soil samples for free testing and fertilizer recommendations. Soil maps are of considerable help in locating soil types sent in, and these soil types have plant food characteristics which help in recommending fertilizers. Due to wide variations in the soil types, the soil analyses, even with a field kit such as Thornton's, are valuable in estimating the crop needs on special fields. The farmer's cropping system, if he used clover crops in good rotation series, have marked effects upon the fertility level and modify the fertilizer recommendations.

Unless there are special qualities of a soil proposed for sugar beets, our recommendations are for a 5 year rotation to include clover the second year preceding beets, with a heavy manure application on the crop preceding the beets. If the mineral elements are low, then fertilizers are recommended to build up those elements near the deficiency level. Clover and manure can supply most of the Nitrogen needed, but the Phosphate level in Ontario soils is usually so low as to need special application of superphosphate, in addition to the "balanced" fertilizer recommended to go in with the seed. Potash applications do not usually show much response in the beet crop, but the plants use it to a degree which merits some addition to the soil growing beets.

Cooperative field experiments are placed in various localities each year and these act as demonstrations of fertilizer benefit as well as furnish data on the field response of sugar beets to the analyses under test. We feel that much still remains to be done in persuading farmers to stop burning straw, to adopt better rotations and apply more fertilizer for this special cash crop. The general production can be raised much higher apart from disease control, and more productive seed types, if the proper fertilizer analyses are used in the proper quantities and put in the right place.

THE EFFECT OF SOIL STRUCTURE ON SUGAR BEET GROWTH

by

R. B. Farnsworth and L. D. Baver[1]

The sugar beet producing region of Ohio is located in the northwestern quarter of the state. The sugar beet enterprise is, however, concentrated in the Maumee Basin or the old Glacial Lake Plain. The soils of this area are of lacustrine and glacial origin and are mostly of a very heavy nature.

The Paulding, Toledo, and Brookston series comprise the major soil groups of the area (I). The Paulding constitutes a large portion of the flat area west of central Henry and Putnam counties, and nearly all of Paulding county. The soil is principally a heavy clay, exhibits a high moisture-holding capacity, and has a high organic matter content. The Toledo clay is almost as heavy as the Paulding, has almost the same content of organic matter, and is highly retentive of moisture. This clay with the associated classes: silty clays, silty clay loams, and clay loams make up the soils of the beet producing area of eastern Lucas, north central Sandusky, and Ottawa counties.

The Brookston soils overspread the area eastward from the Paulding soil and intersperse the area of the Toledo soils. They are less heavy than the Paulding clay, slightly gritty but almost as dark. The principal soil classes, in addition to the clay, are silty clay loam, silty clay, and silt loam. Throughout the above areas are several light-colored soils ranging from sandy to heavy with respect to texture.

During the last few years evidence has been brought out which indicates that beet yields in these areas are frequently limited by unfavorable physical conditions of the soil. In a recent publication (II) data from the Agricultural Statistics of the U.S.D.A. were presented which show a gradual decrease in acre

---

1/ Research assistant and Professor, Dept. of Agronomy, Ohio State University