CROP PRODUCTION ON RAW MUCK
LEFT AFTER THE HARVEST OF SPHAGNUM PEAT.

by

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ABSTRACT OF MASTER'S THESIS

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Crop Production on Raw Muck Left After the Harvest of Sphagnum Peat.

In the lower Fraser Valley area of British Columbia there are located considerable areas of low-lying peat lands. These lands consist of light yellowish-brown sphagnum moss, averaging three feet in depth, which is harvested and sold to the horticultural and poultry industries. Underlying this surface layer of sphagnum moss is a darker, heavier, more humified layer averaging three to four feet in depth. The material of which this lower layer is composed is known as "muck", a term used to refer to soils containing a high percentage of organic matter, but in which the original plant remains are no longer capable of being identified.

Over the period of the last twenty years the raw sphagnum moss has been removed leaving exposed the layer of heavy black muck. Since the original sphagnum moss will take many years to grow in again, these lands which have been cleared must either remain useless and vacant, or some method of reclaiming them for agricultural purposes must be found. Accordingly, research was directed toward finding the most practical and expeditious means of bringing this muck land into production.

During the summer of 1949, a field test was carried out in an effort to discover the most essential steps to be taken. Five plot
treatments were used, consisting of: control; lime only; manure only; fertilizer only; and lime, manure and fertilizer together. A number of vegetable crops were used as indicators of response and included onion, celery, corn, lettuce, cabbage, potatoes, pea, beet and tomato. The results of this field experiment were very striking and obvious. The only plot from which a good growth response was obtained was from the plot receiving the combination treatment of lime, manure and fertilizer. Other treatments were not sufficiently better than the control to recommend their use.

Following the field test, a greenhouse test was carried out during the winter of 1949 to 1950. This test consisted of nineteen different treatments in which nitrogen, phosphorous, potash, boron, copper, sodium chloride, manganese, and lime were used in various combinations. In all cases, lime gave increased yields over plots receiving no lime, no matter what the mineral treatment happened to be.

It was concluded that the most important feature in reclaiming muck soils was the use of lime to correct the high acidity, which is the primary limiting factor. Because of the low content of phosphorous and potash in muck soils, the addition of these two elements is also of great importance. From the results of these experiments, it may be said that the addition of minor elements will give no response until the more limiting factors of acidity and major element deficiency have been corrected.
ACKNOWLEDGMENTS

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AN EVALUATION OF CROP PRODUCTION, OF RAW MUCK

LEFT AFTER THE HARVEST OF SPHAGNUM PEAT

GENERAL ASPECTS OF THE PROBLEM

In the lower Fraser Valley, and more particularly on Lulu Island, are located considerable areas of low-lying peat lands. These lands consist of light yellowish-brown sphagnum moss, supporting a heavy cover of Labrador Tea with scattered scrub Jack Pine.

About twenty years ago there began the extraction of the sphagnum moss and an industry grew up, encouraged by World War II, which has now reached its climax. Virtually all the available peat land has now been opened up and production will begin to decrease.

Lulu Island peat deposits vary in depth, the average being about five feet. Only the top two to three feet of raw, undecomposed sphagnum moss is harvested and sold to the horticultural and poultry industries. Underlying this relatively undecomposed surface layer is a heavier, darker, more humified layer, averaging three to four feet in depth.

The first three foot layer of harvestable moss has been in the process of forming for a great many years. It cannot "grow back again" in one person's lifetime. The production of peat moss, therefore,
is simply the exploitation of a natural resource - and peat is mined out (not to be replaced) at such a rate that the next decade or two will see the exhaustion of all available deposits.

As a result, we shall soon have a situation in which thousands of acres of land will have been stripped of the raw moss and for which there is no immediate use. Eventually, of course, all the firms engaged in the extraction of moss will work themselves out and will be left with large land investments which must either be written off as loss or converted into useful farm land. It was the object of this research to discover the most practical and expeditious means of bringing this vacant land under cultivation.

The term "muck" is usually used to refer to those soils which contain a high percentage of organic (vegetable) matter, in a well-decomposed condition. The United States Department of Agriculture (39) states that the term "muck" is correctly applied to cultivated peat and to surface layers in an advanced stage of decomposition, in which the plant remains are for the most part no longer capable of being identified. The soil matter under consideration in this experiment meets these conditions and is the product of the decomposition of various forms of plant life, resulting in a heavy black or dark brown material which is very finely divided and possesses high colloidal characteristics. On the whole, the decomposition has reached a stage where it is impossible to identify the original plant material. In some local areas, where the original removal of the raw peat has not been complete, there is a thin strata of brighter yellow undecomposed peat but on the whole, all that
remains is the heavy black muck material.

Muck soils are among the most productive soil types used for the growing of truck crops. In some regions in the United States, such as Michigan and Florida, muck soils are extensively used for the production of such crops as lettuce, onion and celery. Eliot (11) states that there are approximately 79,000,000 acres of swamp land in the U.S., a considerable proportion of which is undoubtedly muck. Canada has a total of 22,000,000 acres of poorly drained land, much of which must be muck and peat. Not all this land will be climatically suited to the growing of crops.

Locally, in the lower Mainland area of Vancouver and at scattered points in the Fraser Valley, there is a total area of 51,000 acres of peat land (16), a good portion of which may be converted to suitable farming soil, of the muck type.

REVIEW OF LITERATURE

The conversion of muck lands to productive farming land has been found through past experience to be a highly costly venture. Harmer (14) points out that two factors limit the amount of new land opened up. One is the excessive cost involved in draining and reclaiming large acreages of bog land. The other is the remoteness from market of a large proportion of the available muck soil. Harmer was speaking of unbroken muck land found in certain areas of Michigan.

Fortunately, the situation here is not such a difficult
The clearing and draining of the land has already been taken care of and paid for through the cost of harvesting the top layer of sphagnum moss. The only additional cost will be for the removal of stumps and application of soil conditioners to convert the muck to meet growth requirements. The second problem is not serious since part of the area is located close to a large market. Lulu Island is only fifteen miles from a large metropolitan area in Vancouver. Therefore, the two main drawbacks are, in this situation, not so serious, and further investigation of the possibilities of improving this muck land might prove profitable.

Harmer (14) states that "although the agricultural development of the muck lands in the United States must be considered as only begun, that in Canada is virtually untouched." Of the large muck acreages in the United States only a very small fraction are being used for truck crop production. In many cases, muck land is simply used as pasture or meadow, without any attempt being made to improve the fertility for cropping purposes.

In certain European countries, land is scarce and all available farm land is utilized for food production. It is not surprising then, that work towards reclaiming muck lands was initiated there at a very early date. Germany, particularly, has done much work on the utilization of muck lands through the setting up of the world's first peat experimentation plant at Bremen. Holland too, where much of the land is low-lying, was early in finding methods whereby otherwise unproductive land could be reclaimed.
In fact, it was in Holland, as early as the sixteenth century, that the so-called "Fen" method of muck cultivation was developed. The subsurface layers of peat were removed for fuel and four or five inches of sand were mixed with surface material. Animal manures and city refuse were then mixed in as fertilizer. The addition of sand to peat probably added a small amount of fertilizing material but it seems more likely that the greatest effect imparted by the sand was the lightening of the muck soil, providing better aeration and tilth.

Later on, about the seventeenth century, another method was developed in which the surface layer of peat was burned over, the ash providing fertility for the following year's growth. This method was chiefly used on low-lime, less fertile mucks and since the burning was carried out each year, it was not long before the depth had been so reduced that burning could no longer be counted upon to provide the needed stimulatory effects. In modern times, this method has been prohibited by law as it is considered wasteful.

In 1862, German workers developed what is known as the "Rimpau" method. Like the "Fen" method, sand was applied, but instead of being mixed in with the muck, it was spread in a layer on top of the muck. Cultivation was limited to this layer of sand. Phosphate and potash fertilizers were applied in place of the city refuse used in the Fen method.

The Rimpau method was developed and was successful on the high lime mucks of southern Germany. It was a failure, however on the low-lime mucks of northern Germany and, as a result, there was established
the Bremen Peat Experiment Station, the forerunner of a number of similar stations on muck soils in other European countries.

Harmer (14) reports that the Fen and Rimpau methods have now been displaced by more recent methods. Sanding large areas of bog land is a very expensive operation, and while it may have been economical years ago in Europe, when labor was cheaper, it proves to be too expensive in America to be economically practical. Here on Lulu Island, and also in certain states in eastern United States, a modification of the Rimpau method is used for cranberry growing.

It is reported that modified Fen method is still used in the Groningen district of northeastern Holland. Lime is added to the admixture of sand and muck, as well as fertilizer. The fertilizer mixture giving best results is one high in potash, but also containing nitrogen and phosphate.

Newton (26) writing in 1934, stated that very little experimental work with peats had as yet been done in western Canada and that the best method of reclaiming such lands and bringing them under cultivation was still uncertain. He goes on to state that application of nitrogen, phosphate and potash fertilizers and farmyard manure will prove beneficial. Then, as a conclusion, he makes the statement that peats very in reaction but many of them are very acid (sic) and such peats respond to treatments with lime. Newton was dealing with the raw surface layers of undecomposed peat (that which had not become muck) and he emphasizes the fact that these overlying layers of light colored and but slightly decomposed peat require a considerably longer time after drainage to decompose satisfactorily. As mentioned before, the situation
with the muck lands here on Lulu Island is quite different, this raw overlying layer having been removed to expose the humified, dark-colored muck two to three feet deeper down. Newton states that these underlying layers of peat which are darker in color and decomposed to a greater degree are probably closer to the productive condition.

Black, (5) in reporting on extensive field trials conducted during a three-year period by the Field Crop Branch of the British Columbia Provincial Department of Agriculture says that the great majority of peat soils in this province, (in addition to being responsive to lime in correcting their general acidity), are more or less deficient in phosphates and potash. He emphasizes the need for potash by stating that fertilizers with a relatively high potash content have given good results.

According to Bear, (3) muck and peat soils are usually very high in their content of nitrogen, but quite often contain only relatively small amounts of potassium. He points out that this deficiency exists, in spite of the fact that the plant residues of which peat and muck are largely composed must have contained large amounts of this element. The reason for the resulting low level of potassium he gives as being due to leaching. Bear claims that acidic peats are also deficient in available phosphorus.

Conner (9) presents experimental data in which striking results were achieved through the use of potash-containing fertilizers on muck soils. This data is shown in Table One on page 8.
### Table One

**EFFECT OF POTASH SALTS ON ACRE YIELDS OF ONIONS ON MUCK**

<table>
<thead>
<tr>
<th>County</th>
<th>No fertilizer yield</th>
<th>N and P. # increase</th>
<th>N, P, and K # increase</th>
<th>Effect of K increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benton</td>
<td>606</td>
<td>75</td>
<td>113</td>
<td>38</td>
</tr>
<tr>
<td>Kosciusko</td>
<td>353</td>
<td>41</td>
<td>66</td>
<td>15</td>
</tr>
<tr>
<td>Whitley</td>
<td>307</td>
<td>20</td>
<td>130</td>
<td>110</td>
</tr>
<tr>
<td>Jasper</td>
<td>423</td>
<td>12</td>
<td>202</td>
<td>190</td>
</tr>
<tr>
<td>Noble</td>
<td>394</td>
<td>47</td>
<td>89</td>
<td>42</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>404</strong></td>
<td><strong>49</strong></td>
<td><strong>130</strong></td>
<td><strong>81</strong></td>
</tr>
</tbody>
</table>

* Yields in bushels per acre.*

# One thousand pounds of fertilizer per acre.

Higgins (13) further claims that higher yields with better than average quality came with intensive use of phosphate and potash fertilizers, along with new varieties that were developed specifically for muck soils.

Ellis (12) in reporting on the growing of sweet corn on muck soils in Indiana, states that it is necessary to use fertilizers containing high percentages of potash. When used alone, it increased the yield over the unfertilized check by 1.1 tons per acre.
Phosphorous, in addition to the potash, increased the yield another 1.3 tons, — showing the need for both plant-food materials. However, when phosphate was used alone, the yield of corn was depressed. When potash was used in fertilizer mixtures higher than 24%, with eight per cent phosphate, no additional increase was obtained. Phosphates higher than in 0-8-24 gave no appreciable increase. Nitrogen in 4-8-24 resulted in no increase in yield over 0-8-24.

In a report on the increasing use of Indiana muck soils for crop production, Fraser (15) states that muck soils contain an inexhaustible supply of nitrogen, and need only to be drained and potassium and phosphate added for higher yields.

Fraser's statement, however, is by no means applicable to all muck soils. More important than the addition of potassium and phosphate, at least on low-lime mucks, would seem to be the need for lime. Waksman (41) points out the need for lime on peat soils as an aid to active nitrification. In order to hasten decomposition, liming of acid soils and cultivation are probably the most economical and most widely used methods for effecting this change, according to this author. The majority of our commonly grown vegetables do not make successful growth at the acidity levels found in peat and muck soils. Watts and Watts (42) give the most satisfactory pH ranges for vegetables and these are shown in Table 2 on page 10. In view of the fact that the muck soils dealt with here have been tested as showing a pH range of 3.5 to 4.2, the necessity of liming in correcting this very acidity would seem to be of utmost importance.

That additions of lime stimulate nitrification is a well
### Table Two

<table>
<thead>
<tr>
<th>pH 6.0 to 6.7</th>
<th>pH 5.5 to 6.7</th>
<th>pH 5.1 to 6.7</th>
<th>pH 4.8 to 5.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asparagus</td>
<td>Bean, Snap</td>
<td>Carrot</td>
<td>Potato</td>
</tr>
<tr>
<td>Beet</td>
<td>Cabbage</td>
<td>Large lima bean</td>
<td></td>
</tr>
<tr>
<td>Bush lima</td>
<td>Celery</td>
<td>Radish</td>
<td></td>
</tr>
<tr>
<td>Cauliflower</td>
<td>Cucumber</td>
<td>Sweet Corn</td>
<td></td>
</tr>
<tr>
<td>Muskmelon</td>
<td>Onion</td>
<td>Sweet Potato</td>
<td></td>
</tr>
<tr>
<td>Parsnip</td>
<td>Pea</td>
<td>Tomato</td>
<td></td>
</tr>
<tr>
<td>Spinach</td>
<td></td>
<td>Turnip</td>
<td></td>
</tr>
</tbody>
</table>

After Watts and Watts (42)
-known fact. Lyon and Buckman (20), however, point out that acidity seems to have little influence on nitrification when adequate calcium is present. They claim this is particularly true of peat soils. At pH values even below five, peat soils may show remarkable accumulation of nitrates. This is because of their high total exchange capacity and the presence of unusually large amounts of active calcium despite the low percentage base saturation. Even minor elements stimulate nitrification. Phosphates are especially effective with all soil organisms, as well as nitrifiers. Competition with higher plants for this available phosphate may be set up and so it is important when bringing a muck soil under cultivation, that enough added phosphate be supplied in order to serve the needs of both the crop plant and the increasing number of soil bacteria which will build up in the soil. The same is true of potash.

Harmer's (14) findings of the relation of organic soils to low copper content are interesting. Copper has been found deficient on many soil types but more notably on those of organic origin. The importance of copper as a plant nutrient is emphasized by Harmer. In a greenhouse study of the use of copper he found that eight tons per acre of CaCO₃ and one hundred pounds per acre of (Cu)₂SO₄ gave the highest yield. Collings (8) reports that in recent years growth abnormalities of many plants produced on peat and muck soil, especially those that contain appreciable quantities of ferrous iron, have been corrected by the application of copper compounds. McMurtrey and Robinson (21) think that some of the beneficial effects derived from the application of copper compounds may be due to the influence of copper in precipitating the toxic sulfide ion of peat soils, and Willis and Piland (43) suggest that copper sulfate
may serve not only as a nutrient but as a soil amendment which decreases the availability of iron and possibly of manganese. The United States Department of Agriculture (39) state "so far as available experimental evidence indicates, the action of copper compounds is not beneficial on soils other than peats or muck."

According to Sommer (37) much more copper is necessary for the correction of copper deficiency in soils of high humus content than in soils of low humus content. The addition of copper sulphate to some muck soils of New York has prevented the premature dying of onions, and in Florida and Holland it has been very helpful in preventing so-called "reclamation disease". Crop response to copper sulphate has been secured in Holland when crops were planted on newly reclaimed moor soils and on the peat soils of Michigan and Delaware in the United States. Die-back (Exanthema) of onions is now considered to be a physiological disease resulting from an insufficient supply of copper. Some truck growers in New York, Florida and Michigan have found it necessary, in order to grow lettuce successfully on certain soils which are high in organic matter, to apply copper at the rate of 25 - 50 pounds of copper sulphate per acre. Allison, Bryan and Hunter (1) as early as 1927, reported large increases in yields of a number of crops on the Everglades organic soils of Florida. Harmer (14) reports that the most responsive crops in Michigan muck soils to copper application have been carrots, lettuce, onion, potatoes, spinach and tomatoes. The same investigator claims that a response can generally be expected on mucks having a pH of 6.2 or less, provided the pH does not become greater in the second foot of soil. The recommendation on rates of application of copper sulphate very widely. Thus the Florida Everglades Station (1) states that an application of 25 to 50 pounds per acre
should be made annually. Knott (18) in reporting on onion production on muck soils in New York recommends "that 200 pounds to 300 pounds to the acre of powdered copper sulphate be used where onion scales are thin and poor in color". Harmer (14) claims that response on the more acid mucks in Michigan may be had with as little as ten pounds per acre but that it is advisable to apply at least 25 pounds and generally 50 pounds per acre, where the nature or the crop and the reaction warrant it. For spinach and lettuce he advises an initial application of 100 pounds per acre, with an additional 25 pounds per acre in the second and later years. However, on most mucks, Harmer claims that 250 to 300 pounds per acre, will completely satisfy the crop requirements, at least for several years.

Naftel (27) claims that organic soils and crops such as beets require relatively large amounts of boron. Harmer (14) states that three malnutritional diseases of muck crops - cracked stem of celery, girdle of table beets and "born deficiency disease" of sugar beets - are directly due to a lack of boron in an available form in some Michigan muck soils. He claims that 25 pounds per acre is generally sufficient to correct these conditions but that on mucks which show this trouble to any considerable extent, 100 pounds of borax mixed into the fertilizer and thoroughly mixed into the soil may be safely applied. Collings (8) claims it is generally recognized that boron can be added in larger quantities on alkaline and neutral soils without causing injury than when added to acid soils. The United States Department Agriculture (34) claims that as little as one pound per acre is sufficient to cure top rot of tobacco but that "with celery and beets the quantity necessary may be greater."
Powers (32) in some work on certain acid peat soils in Oregon reported an increase in the yields of many crops following the application of manganese sulphate. Tomatoes were increased in yield by as much as 82% following manganese application. Powers also found that manganese was needed on the basic peat soils of Oregon. It seems that in strongly acid soils the oxidation-reduction conditions favor the reduction of the manganic manganese to the manganous form. The liming of strongly acid soils to an alkaline reaction is the most common cause of manganese deficiency. Collings (8) reports that when manganese deficiency occurs in plants growing on acid soils it is thought to be a result of the leaching of soluble manganese. The U.S. Department of Agriculture (39) reports that the manganese in soils containing organic matter becomes very soluble when these soils are submerged for relatively short periods. Under these conditions the concentration of soluble manganese greatly exceeds the limits that have been found toxic to plants. Harmer (14) reports that it is the availability rather than the total amount of manganese in the soil which must be taken into consideration in studying the soil needs. He reports that muck soils are generally very low in this constituent, and that it is possible that sufficient manganese may be supplied as an impurity when fertilizing with potash. Another observed characteristic of muck soils has been the increased growth of certain crops following the application of salt (sodium chloride). Harmer (14) reports that it has long been the practice of growers of celery on muck soils to add salt along with the addition of manure. He points out that as much as 500 to 1,000 pounds per acre of salt, in addition to the regular fertilization, can be recommended for newly reclaimed muck.
METHOD AND PROCEDURES

Field Experiment

In order to obtain some indication as to the best method of converting muck soils for truck crop production, various vegetable crops were grown on five plots treated in different ways. This experiment was carried out during the summer of 1949.

The area chosen for the experiment was roughly 500 feet long and 80 feet wide. The harvestable two and half foot layer of sphagnum moss had been previously removed and the land left fairly level and clean. A considerable number of small stumps and roots of pine had been removed the previous year. Because of the fact that bog lands are slow to dry out, there was a delay in getting onto the land. Some sections of the bog were very wet and there was danger of equipment becoming bogged down. By March 15 it was possible however to use crawler type equipment on the bog.

The field was divided into five nearly equal plots measuring 80' x 90', or approximately one-sixth of an acre each. The first plot was left untreated, in its native state. The top layer of harvestable moss had been removed and the heavy black muck underlying it was thus exposed. Planting was done directly on this muck without any further treatment. This plot served as a control. Within this untreated plot a small section of approximately 100 square feet was marked out and a three inch layer of sand was spread over it and harrowed in.
The purpose of this was to test the effect of the physical lightening of the muck soil and observe its effect on growth.

The second plot received an application of agricultural lime at the rate of 3 tons per acre. This was applied on March 14, and harrowed in the next day with a 5 gang stiff-toothed harrow drawn behind an American Army-surplus Weasel, which is a small, amphibious tracked machine. An application of manure was made at the rate of approximately 20 tons per acre to the same plot and this was applied on March 25. Commercial fertilizer (4-10-10) was applied lastly at the rate of approximately one ton per acre. The plot was again harrowed and no further treatment given till seeding.

The third plot received an application of commercial fertilizer only (4-10-10) at the rate of one ton per acre. This was applied by hand as evenly as possible by the broadcast method. It was later harrowed.

The fourth plot was limed with agricultural lime, Ca(OH)₂, at the rate of 3 tons per acre. This was applied and harrowed in at the same time as that applied to the second plot.

The fifth plot received approximately 20 tons per acre of manure alone. This was harrowed in along with all the final harrowing of all 5 plots previous to planting.

The sand used to treat the small section in the control plot was obtained from large deposits which had been dredged from the Fraser River in an attempt to deepen the channel. No attempt was made to
analyze this sand but previous analysis of similar samples showed that the available mineral content was negligible.

A ten foot wide path was left to separate the various plots. Since the muck soil showed great uniformity, crops were planted in relatively the same positions in each plot. Seeding was begun about May 3rd and sowing was made directly by hand for the following: corn, beets, celery, carrots, radish, onion ( sets ), peas and beans. Cabbage, tomato, and lettuce plants were grown from transplants purchased from a commercial seed dealer. Certified seed potato was used also, being planted May 4.

The plots received no irrigation water but depended entirely on the moisture in the muck and natural rainfall. Very little cultivation was carried out and no attempt was made to control insects and diseases. This was done in order to observe the incidence of disease and infestation that might be expected on the muck soil.

**Greenhouse Test**

During the fall of 1949 and spring of 1950, further growing tests were carried out in the greenhouse at the University of British Columbia. Muck samples were taken from the bog at Lulu Island. Flats of muck soil were then treated by applying fertilizers in various combinations. The following treatments were made:

1. Boron.................100 pounds per acre.

2. 4 - 10 - 10 &..............1500 pounds per acre.
   Boron.......................10 pounds per acre.

3. Manganese.................100 pounds per acre.
4. 4 - 10 - 10 & ..........1500 pounds per acre.  
   Manganese ................ 100 pounds per acre.

5. Copper sulphate ..........50 pounds per acre.

6. 4 -10 -10 & ..........1500 pounds per acre.  
   Copper sulphate ..........50 pounds per acre.

7. Superphosphate ..........500 pounds per acre.

8. Potassium chloride ..........150 pounds per acre.

9. Muck and Sand ...........50/50 mixture.

10. Sodium chloride ..........500 pounds per acre.

11. Control ......................nothing added.

12. Lime only .................3 tons per acre.

13. Potassium chloride & ..........150 pounds per acre.  
   Superphosphate ..........500 pounds per acre.

14. Lime & .....................3 tons per acre.  
   Potassium chloride & ..........150 pounds per acre.  
   Superphosphate ..........500 pounds per acre.

15. 4 - 10 - 10 .............1500 pounds per acre.

16. Lime & .....................3 tons per acre.  
   4 - 10 - 10 .............1500 pounds per acre.

17. Complete plus lime  
   4 - 10 - 10 .............1500 pounds per acre.  
   Boron .................... 100 pounds per acre.  
   Copper sulphate ..........50 pounds per acre.  
   Manganese ................ 100 pounds per acre.  
   Lime ..................... 3 tons per acre.

18. Vitalerth (5-10-10) ..........1500 pounds per acre.  
   (contains Mg, Mn, Cu, B,  
   Zn, S)

19. Vitalerth & ................1500 pounds per acre.  
   lime ......................3 tons per acre.

The sand used was greenhouse bench sand, clean and sharp.  
Manganese sulphate was used as the source of manganese (80%).  Boron:  
was supplied as sodium tetraborate - 99.3% pure.  The lime used was
agricultural lime Ca(OH)$_2$. The salt used was commercial sodium chloride. Potassium was supplied as potassium chloride and phosphorous as superphosphate. The three-mix fertilizers used were commercial 4 - 10 - 10 and Vitalerth, 5 - 10 - 5 with added minor elements, the latter being the so-called ready-mixed "Complete" fertilizer. Vitalerth contains magnesium as magnesium sulphate (25 pounds per ton); manganese as manganese sulphate (15 pounds per ton); copper as copper sulphate (15 pounds per ton); boron as boric acid (25 pounds per ton); zinc as zinc sulphate (10 pounds per ton); and sulphur (50 pounds per ton). These various fertilizers were weighed out in proportionate amount at the rates stated above and thoroughly mixed in with the soil of the flat.

Morgan, Gourley and Ableiter (24) have made an evaluation of the pot method for determining fertilizer needs. Oats are used as an indicator as rapidly growing crops permit pots with a large number of soil treatments within limited space and in relatively short time. Of the results, Schreiner and Anderson (35) state that they are often directly applicable in practice, although allowances must be made for the fact that conditions of the test are different from those of the field. The soil has been disturbed, and the more uniformly controlled temperatures, moisture, and other factors modify the influence of the soil treatments themselves. About the indicator crop, it may be said that oats require a favorable amount of available nitrogen, but at a lower level than corn. Responses to phosphorous and potassium are usually less definite than for corn or wheat. The crop is not exacting in its lime requirement and does well on soils as low as pH 5.2

Oats were sown in these flats about January 15, 1950.
They were treated with a seed disinfectant and measured out in a small glass jar to ensure equal applications to all flats. The seed was sprinkled evenly over the surface of the soil and covered with a thin layer of muck soil. The flats were kept watered and all germinated well. Observations were made on the developing plants for irregularities in growth and photographs were taken about March 15. The plants were then harvested by cutting them off at the base, $\frac{1}{4}$" above the level of the soil. A pH determination was made on the soil after harvest. A sample of 25 plants taken at random from the flats were measured for length, from the tip of the longest leaf to the base of the stem. The total fresh weight of green material was then recorded immediately. The dry weight of the harvested oat plants was determined by placing duplicate 25 gm samples of fresh material in an oven at 65 degrees Centigrade and drying to constant weight.

**ASH WEIGHT**

Following this, ash weight determinations were made by placing 2½ gm. samples of dried material in an electric ashing furnace and heating to 475 degrees Centigrade for 4 hours. The resulting ash was light grey in color. Weights were recorded after cooling the crucibles in a dessicator. To get the ash into solution, it was just moistened with one or two drops of water and 2.5 cc. of concentrated HCl was added. The dissolving material was then boiled gently for a few minutes, and 10 cc. of approximately $\frac{1}{4}$N HCl was added and the whole solution was brought to the boil again. It was then filtered while still hot into a 100 cc. graduate flask, using a Whatman Paper No. 41. The small residual carbon was retained in the crucible and washed and extracted three more times with 10 cc portions of N/2 HCl, boiling at each stage. The small residue
was then transferred to the filter paper and repeatedly washed with boiling distilled water until the contents of the flask were near the 50 cc. mark. The solution was then allowed to cool and made up to 50 cc. mixed, and stored in a stoppered bottle.

**CALCIUM DETERMINATION**

This mineral was determined by the precipitation as an oxalate and titration of the latter with potassium permanganate, as recommended by Blasdale (6).

Five ccs. of the extract were pipetted into a 100 ccm. centrifuge tube. 0.2 ccm. of a 0.02% solution of phenol red were added and a solution of ammonia was run in from a microburette with constant stirring. This ammonia was of such a strength that less than 0.6 ccm. of it were used to neutralize the solution. It was prepared by making a 1-3 dilution of 0.880 ammonia. The solution which was orange at first became yellow and then purplish red. When this had happened, 0.1 ccm. of glacial acetic acid were added, or enough to make the solution bright yellow. Water was then run in to bring the total volume up to 6.5 ccm. and then 1.5 ccm. of saturated ammonium oxalate were added to precipitate the calcium.

The mixture was allowed to stand for one hour, and then centrifuged. The centrifuging was done at a speed of 2,000 r. p. m. for 7 minutes.

The precipitate was drained and washed with 5 ccm. of 1% ammonia and centrifuged again. To the washed residue in the centrifuge tube 1 ccm. of 4 N. H₂SO₄ was added, the tube heated in a boiling water
bath for a few moments, and the oxalate titrated with a solution of N/100 potassium permanganate solution. The end point appeared as a light pink and was quite permanent.

**PHOSPHOROUS DETERMINATION**

Five ccs. of the extract were diluted to 25 cc. with distilled water. One cc. of Tschopp's reagent No. 1 and 2 ccs. of Tschopp's reagent No. 2 were then added and the tube was heated in a water bath at 60 degrees Centigrade: for 10 minutes. A standard solution of phosphorous of known concentration was treated in exactly the same manner and the two tubes were placed in a colorimeter. Readings were made by adjusting the two halves of the circle of light to equal intensity and taking the readings, finding the concentration of the unknown.

**POTASSIUM** according to Pech's (27) method of determination.

Trisodium cobalti-nitrite solution is the reagent used for determining the potash content. It was made up as follows: 25 gms. of NaNO₂ were dissolved in 75 ccs. of water. Two ccs. of glacial acetic acid were then added. Lastly 2.5 gms. of Co(NO₃)₂·6H₂O were added. The solution was allowed to stand several days, filtered and diluted to 100 ccs.

Five ccs. of extract were placed in a 50 cc. beaker and evaporated to dryness. The residue was dissolved in 1 cc. of 1N HNO₃ and 10 ccs. water were added. Then five ccs. of the sodium-cobalti-nitrite solution were mixed in, and the solution allowed to stand for two hours at 20 degrees Centigrade. Asbestos was then boiled in the potassium
permanganate solution to oxidize any organic matter and the solution was filtered, after having stood two hours, through the asbestos in the Gooch crucible. 0.01 N HNO₃ was used in the wash bottle to make the transfer and the precipitate in the crucible was repeatedly washed with two cc. portions of 0.01 N HNO₃.

Fifty ccs. of standardized 0.05 N potassium permanganate solution were placed in a 400 cc. beaker, diluted with water to about 150 cc. and five ccs. of concentrated sulphuric acid added. The crucible and the precipitate were then added to the acidified permanganate solution. The whole were then heated to nearly boiling, removed from the flame and a small excess of standardized oxalic acid was added until the solution appeared colorless. The excess oxalic was then titrated with potassium permanganate. The difference between the quantities of permanganate and oxalic acid used corresponds to the quantity of permanganate reduced by the cobaltinitrite solution. The content of potassium was then calculated according to the formula:

Net ml. of KMnO₄ x normality of KMnO₄ x 7.108 = mgms. of K in sample taken.

**NITROGEN DETERMINATION** / Kjeldahl determinations.

One gram of dry material was weighed out into a Kjeldahl flask and approximately 10 grams of oxidizing mixture (K₂S₂O₇ plus CuSO₄) and approximately 25 ccs. concentrated sulphuric acid were then added. The mixture was then digested by heating under a fume cabinet for 2½ hours. After the solution had become colorless, it was cooled and diluted to 200 ccs. and allowed to cool again.

Half a teaspoonful of pumice powder and a small piece of wax:
were added to the flask along with some glass beads and finally 100 ccs. of concentrated NaOH were added. The ammonia was distilled over and caught in 20 ccs. of N/10 HCl to which methyl red indicator had been added. The distillation was continued until about 100 c.c. had come over.

The distillate in the receiving flask was then back-titrated with N/10 NaOH. The per cent of nitrogen in the sample was then calculated.

**CARBOHYDRATE DETERMINATION**

According to the Lane and Enyon method (2).

Two and a half grams of dried material were weighed out into an Ehrlemeyer flask and slowly heated in a reflux condenser for 2½ hours with 50 ccs. of 10% HCl. The mixture was then cooled and filtered through a Gooch crucible. Because the resulting solution was too dark to titrate successfully, it was found necessary to clear by heating for two minutes with ½ teaspoonful of carbon and then filtering a second time.

Five ccs. of Fehlings A solution and five 8ccs. of Fehlings B solution were then placed in a small Ehrlemeyer along with ½ ccs. of methylene blue. The Fehlings solution was kept constantly boiling and titrated until the blue color of the bubbles disappeared. The filtrate of the plant extract was run in from a burette. The carbohydrate content was then calculated.
The results of the trial carried out on the muck plots during the summer were very striking and obvious. The control or untreated plot was characterized by an almost total absence of growth. The cabbage transplants failed to develop beyond the fourth or fifth leaf stage, and remained at about the same size as they came from the nursery flat. In spite of the fact that very poor growth was made, there was seldom complete dying out of these plants. They remained green and stunted throughout the summer. On July 5th, the field notes contain the observation that the potatoes were showing no tops, and that the seed pieces, on being dug showed few sprouts and no tuber development. The radish seed had germinated, but the plants remained stunted and only a few developed, and these not to any extent. The seedlings as they developed were very dwarfed, "tight" and stiff looking and had an unnatural deep-blue color. In most cases they didn't grow more than one inch in height. Peas sown in the control plot germinated well but made very poor growth. None grew more than six inches in height and they were yellow in color. Some few plants, however, bore seed pods which failed to fill out normally and soon dried out and withered. Beans showed much the same development as did the peas. There was no fruiting and none grew over four inches in height. Corn germinated poorly and the resulting growth was very depressed. The tomato transplants failed to make any further growth beyond the transplant stage. They took on a deep blue color and most of them died out completely. The small section of this control plot which was treated with sand proved to be of great interest and showed striking results. The most obvious effect was an earlier
germination and a more advanced stage in the development, although total growth was not appreciably greater than in the unsanded portion.

In sharp contrast to the control, the plot receiving all three treatments (i.e. - lime, manure and fertilizer) showed excellent growth. This was the only plot which gave any harvestable crop. The corn produced on this plot, while not the best grade, formed ears which were usable. The radishes made excellent growth, which was very rapid, and produced tender well-developed roots. The cabbage plants headed up well, and were a good marketable crop. There was a high degree of infestation by cabbage worm, but as mentioned before, no attempt was made to control the insects or diseases. The tomato plants set numerous fruits, but these remained small and failed to color properly. The fruits themselves showed a mottling distributed very uniformly over the surface and affecting all fruits equally. This mottling is very suggestive of a calcium or potassium deficiency in the soil. The onions produced here grew very well. While they were young they made excellent bunching onions and later they developed into large, well-formed cooking onions. There was a certain amount of die-back amongst some, suggesting a possible copper deficiency. The beets formed roots which were small, hard and showed severe and very obvious symptoms of boron deficiency, indicating "girdle of beet" - a nutritional trouble. The potatoes formed large healthy tops which even seemed to be excessive in size. The foliage was of good color and stood up well, but the tubers formed were small and showed evidence of flea-beetle injury. The tubers were also badly colored and the muck soil clung tenaciously to them, making drying difficult. They were very variable in size and poor in shape. One hundred and fifty pounds were harvested from the 80 foot row. The peas grew large mounts of vine, and bore a heavy crop of
well-filled pods. On eating, they were sweet and tender. The bean, also produced well, and the wax butter beans were about five inches in length and hanging in clusters. The celery grew to a height of about five inches but failed to develop into a marketable head. This was the only plot on which any growth was obtained from celery.

Growth on the fertilizer only plot was even more depressed than it was on the control plot. The cabbage transplants, instead of remaining stunted but green as they did on the control plot, turned yellow and died off completely. There was a very slight amount of growth following germination on the corn. The tomato transplants failed completely. The peas germinated and made a feeble growth but failed to produce pods. None of the other seeds planted germinated. There was no evidence of aerial portions of potato development and on examining the seed-pieces, they were found to have sent out only small feeble rootlets. The entire surface of this plot was observed to have a whitish cast, presumably from the crystallization of the salts of the fertilizer. This would suggest that there may not have been a sufficient amount of dissolution of the fertilizer salts, in spite of the rain and the very wet nature of the muck soil in the early part of the spring when the fertilizer was harrowed in.

The limed plot showed the greatest response in growth when compared to any other single treatment. There was even here not enough crop produced with any of the vegetables to make a harvest possible and the crop compared to that produced on the lime-fertilizer-manure plot was insignificant. However, peas developed pods which filled out and bore peas, though the total growth was still very small. Potatoes produced sufficient growth to appear above ground and produced tubers about the
size of marbles. The cabbage transplants made additional growth and produced small, loose heads. The lettuce on this plot was very soft and lacked crispness, but a small head was formed, the color lacking the healthy green of the lettuce on the all-three plot. The tomato plants produced one or two small fruits but most of them were depressed and died off. The onions made some green growth but did not reach a marketable stage.

Response of the vegetable crops grown on the manured muck plot was about equal to that of the growth produced on the control. The cabbage transplants again failed to make any additional new growth although they did not completely die off. The seed-pieces of the potatoes failed to develop tops or tubers. Peas germinated, as did beans, but in both cases the following growth was very restricted. There was no growth of corn beyond the seedling leaf stage and the tomato transplants died off completely. In this plot, and also in the plot receiving the manure, lime and fertilizer there was a considerable amount of weed growth, unlike the other three plots which were almost entirely free of weed growth. From these observations, calcium was evidenced as the most pronounced lack, but there is evidence of a multiple soil deficiency also.

RESULTS OF GROWTH OF GREENHOUSE OATS

Visual Symptoms of Growth.

Boron -- Figure 1.

Growth was more depressed in this flat than in any of the others. Evidently the rate of application of boron proved decidedly toxic. Leaves were the shortest of any of the flats, and averaged about 2", the longest
being slightly over 3 inches. There was very obvious absence of chlorophyll with bleached white areas showing at the margins of the leaves and yellowing and browning of the tips very evident. In the most advanced stage, the leaves appeared to be dying out. In others, there were pale, light green areas showing in the centre of the larger leaves, which were as wide as \( \frac{1}{4} \)" in some cases. A general washed out whiteness seemed to be very typical of all plants.

4-10-10 plus Boron — — Figure 2.

There was extreme die-back on the tip leaves, which were showing curling and whitening. There was browning farther down on some of the other leaves and these were collapsing. The remainder of the leaves appeared not to be affected and were stiff standing. The leaves for the most part were broad and remained green longer along the veins. The growth was thin and spindly at the base of the plants. Nitrogen deficiency indicate possibility of inability of the plant to absorb because of the low pH.

Manganese — — Figure 3.

The general appearance of this flat was good. The leaf blades were standing very stiff and showed no browning except with some of the older leaves which were showing die-back, not from the tip but slightly back of the tip. There seemed to be evidence of a calcium deficiency with the possibility of a secondary nitrogen deficiency. The manganese seems to have given a slight stimulation of growth.

4-10-10 plus Manganese — — Figure 4.

The growth was very poor and depressed, much more than in the
manganese alone plot. There was a large amount of die-back from the tips and from the margins of the leaves inward. Nitrogen deficiency was evidenced and again it was probably a matter of too low pH affecting the ability of the plant to absorb. The younger leaves were very long and narrow, while the older leaves were fairly broad.

**Copper sulphate** -- -- Figure 5.

This element seemed to give some response as evidenced by the growth. The growth tended to be less upright than in the sand-muck 50/50 plot treatment but the appearance was very similar. About 25% of the plants showed a browning of the tips - about one inch back from the tip, suggesting a secondary potash deficiency, and a possible excess of copper. The average height of the leaves was slightly greater than in the sand-muck flat and the leaves averaged about \( \frac{2}{3} \) in width.

**4 - 10 - 10 plus copper** -- -- Figure 6.

There was a great amount of browning - especially on the older leaves, which were also broader than the younger leaves. The general appearance was very similar to that of the 4-10-10 plus Boron plot. The growth for the most part was thin and spindly. White tips were also apparent, though only to a limited extent.

**Superphosphate** -- -- Figure 7.

There was evidence of potash deficiency, caused by excess phosphorous. The leaves showed the deficiency first at the growing points. In almost all cases, the first leaf had turned a light straw brown color - along its entire length to the stalk. Later leaves showed a healthier
green color for the greatest part of the blade but at the tip there was
evidence of a similar dying back of the leaf points. The leaf blades
were narrow, about one-eighth of an inch in width. The general appearance
of the flat as a whole was depressed. The plants appeared stunted and
spindly and had stiff, wiry, and dried out looking leaves. Some of them
were badly curled and twisted and were reddish-pink in appearance.

**Potassium chloride** -- Figure 8.

Growth here showed a tendency toward nitrogen deficiency.
There was also evidence of multiple deficiency symptoms. The green color
had appeared faded. The plants as a whole had a stiff wiry appearance. Th
There was some twisting and inward rolling of the leaf edges. Older
leaves had taken on a marked straw color. Younger leaves were beginning
to show this evidence starting at the tips. The leaves were narrow --
some only one-sixteenth of an inch in width while none were over five
thirty-seconds.

**Muck and Sand** -- Figure 9.

Growth here was fairly good. Individual leaves are healthy
green and standing upright. The extreme tips of some of the older leaves
were showing browning. Individual leaf blades are wider on the average
than those in the superphosphate treated flat. This flat shows evidence
of potash deficiency but of a milder degree than that of the superphosphate
flat.

**Sodium chloride** -- Figure 10.

The meristematic growing points were killed by this treatment.
The tips were showing a white, bleached color and were dying back. The
green color had faded to a light yellow color. The yellowing seemed
more general here and not so localized and specific as in other cases.
The larger leaves were falling over, while the younger leaves were very
stiff.

**Control** - - - Figure 11.

The growth was very rigid, and the plants had a stiff, stark
look to them. The green color appeared quite normal, but about half way
down the leaves were showing tip die-back, which was extending down the
margins of the leaves. This would suggest that the nitrogen source avail­
able in the muck had been depleted and there was not sufficient to meet
growth requirements. The growth was thinner and not so well developed as
in the plot receiving KCl, Phosphate and lime.

**Lime only** - - - Figure 12.

The growth here appeared very good. There was no die-back
of the tips or leaf margins. The leaves were a lush green color. This
was one of the best plots. Most leaves were three-sixteenths of an inch
wide and the stalks of the plant were stout and firm. It would seem to
indicate that here was good healthy growth to a point where the nitrogen
become limited.

**Potassium chloride and phosphorus** - - - Figure 13

This flat was characterized by a stiff, upright, more spindly
type of growth. The older leaf blades tended to be very wide, while the
young ones were narrow and spindly. The tips were showing slight discolor­
ation.
Growth in this flat appeared roughly equal to that in the copper sulphate treated flat.

Potassium chloride, phosphorous and lime — Figure 14.

Growth made under this treatment was very good. There was no evidence of lack of nitrogen. The stalks of the plants were stout and healthy. The leaves were not broad, the average being one-sixteenth of an inch to three-sixteenth of an inch. Nitrogen in the muck was evidently being utilized, since the addition of lime would allow more active nitrification.

4 - 10 - 10 — Figure 15.

There seemed to be no strength in the plants grown in the plot receiving the three major elements. They tended to collapse and the color was an unnatural light green. The bases of the plants were very thin and spindly. The older leaves were broad and yellowed. Nitrogen shortage was very evident in spite of the fact that this element had been added. The low pH of the soil had probably prevented nitrification.

4 - 10 - 10 plus lime — Figure 16.

This plot stood up very well. The growth was good, although there was some slight amount of tip- "die-back". The leaves were a healthy green color. More growth on this plot dried the soil out at a faster rate than occurred in other flats.

Complete (N,P,K, plus B, Cu, & Mn) plus lime — Figure 17.

Growth on this plot was equal to that on any of the other plots.
Length of stalk growth was very good and the bases of the plants were stout and the leaves a healthy green color, with no evidence of developing deficiencies.

Vitalerth -- Figure 18.

Evidence of lack of nitrogen showed as a paler green, probably caused by the lack of calcium. There was a tendency for the leaves to fall over badly. There was dying - a straw color developing from the tip downward, following the inter-veinal spaces and also along the edges of the leaves.

Vitalerth plus lime. -- Figure 19.

Excellent growth was evidenced here. There was no tip browning and no evidence of nitrogen deficiency. The plants as a whole appeared healthy and normal. The correction in the pH probably has much to do with this more normal growth.

In all the plots receiving lime, it was noticed that there was a tendency for the muck soil to dry out faster. This would lead one to infer that the limed plants were transpiring more water and making better growth and as a result had a higher demand for water.
Figures One to Nineteen,

showing the growth resulting after treatment of muck soils as indicated.
THE EFFECT OF TREATMENTS ON THE CHEMICAL COMPOSITION OF PLANTS
### Table 3

<table>
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<tr>
<th>TREATMENT</th>
<th>Fresh Wt. (grams)</th>
<th>Percentage Dry Wt. (Fr. Wt.)</th>
<th>Percentage Ash Wt. (Fr. Wt.)</th>
<th>Av. length (inches)</th>
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<td>Potash cont. (mgs/100 gm fresh wt.)</td>
<td>Calcium cont. (mgs./100 gms fresh wt.)</td>
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Laboratory Analysis of Growth

It is a particularly noticeable fact that any plot receiving an application of lime (with or without other minerals) produced a much higher fresh weight than did any other treatment, without lime. Thus, the highest fresh weight was produced on the limed muck plot, followed closely by the complete (N,P,K plus minor elements) treatment. The lowest fresh weight was produced on the boron-treated plot, while the majority of the remaining treatments were intermediate in their production of fresh weights.

Dry weight results showed that single element treatments resulted in highest dry weights. Thus, superphosphate gave a dry weight count of 26.3%. The fresh weight produced by the treatment, however, was one of the lowest. The lowest dry weight produced was that of the sodium chloride treated plot which have a reading of 12.8%. It is interesting to note that the best growth produced dry weights intermediate between these extremes - thus, the greatest yield was produced by plants having a dry weight of 14.4%. It would seem that extremely high or low dry weights are not desirable.

The highest percentage ash weight (which reflects the high mineral content) was produced by the 4-10-10 plus lime plot. The lowest ash weight resulted from the growth of oats on muck soil used as a control. This low content of mineral in the muck soil was borne out by the low ash weight obtained from the limed plot, the plot which had the highest fresh weight. The majority of the other elements gave ash weight percentages higher than control and lower than the 4-10-10 plus
lime plot.

The plots receiving the three major elements and lime gave the greatest length of oat plants. The control gave a length of 4.75 inches while the boron-treated plot showed the evidences of the toxic concentration of this treatment, with a length of only three inches. The lime only plot gave a high length reading, while the majority of the other treatments were much lower.

The nitrogen content of the harvested plants showed wide variations. Thus, the highest content of nitrogen was obtained, not on the limed plots, but on the Vitalerth plot, followed closely by the superphosphate and boron plots. The lowest nitrogen content was produced by the copper sulphate treated plot. The control plot proved to have a higher nitrogen content than the N, P, K plus lime plots.

Phosphorous content was directly reflected by the fertilizing treatment. Thus, the highest phosphorous content was produced in the plants treated with superphosphate. Other treatments involving phosphorous also gave high contents of phosphorous in the analyzed plants. Thus, plants from the Vitalerth, NPK plus single elements, and the complete plus lime plots were quite high in phosphorous content. The lowest phosphorous content produced proved to be that of control and control plus lime.

The potash content results were similar to those found for phosphate. Thus, the KCl, Phosphorous plus lime plot gave the highest reading of potash in the plants. Potassium chloride alone gave the second highest reading. The lowest reading was produced on the sodium chloride treated plot. The control was only a little higher. The NPK plus minor elements plots, with lime, gave high potash readings, though not so high
Calcium content was highest in those plants grown on limed muck soils. Thus the Vitalerth plus lime and the 4-10-10 plus lime plots gave the highest content of calcium in the harvested plants. The KOI plus phosphorous plots gave a fairly high calcium reading. The control and superphosphate plots gave the lowest calcium readings. The other treatments produced plants intermediate in their calcium content.

Carbohydrate content varied widely between the different treatments. Thus, high carbohydrate content was associated with reduced nitrogen content in the case of the complete (NPK plus minor elements) plus lime treatment. On the other hand, higher nitrogen was also associated with lower carbohydrate to give less growth, in the case of the superphosphate treated muck. There seems to be no definite pattern or relationship between the carbohydrate and nitrogen content as one might expect there should be.

The acidity readings made on the soil after growth of the oat plants fell into two divisions. Thus, the pH of the muck soil in the plots which had been limed tested 6.6 to 6.7. The pH readings on the plots receiving no lime ran from 4.6 to 4.8 except in the case of the Muck/Sand flat in which the pH reading was 5.0.
DISCUSSION OF RESULTS

Field Test

Of field tests, Schreiner and Anderson (35) state that for direct evaluation of fertilizer requirements, taking into account all factors affecting crop production, field trials remain the ultimate criteria. By means of field tests, different fertilizers and cultural treatments may be tested under essentially the same conditions as prevail in practice. Unlike greenhouse pot culture methods, the results obtained in the field reflect the effect of all climatic and other influences to which the crop and soil are subject during the season. They are directly indicative of the results to be anticipated in practice under the same or similar conditions.

Results of the field test very obviously indicate the need for liming of muck soils as a necessary prerequisite of successful vegetable culture. The extremely high acidity of the muck soil was shown by previous readings taken in which the acidity varied from pH 3.5 to 4.2. High pH would thus appear to be the basic limiting factor in growth response. The high soil acidity evidenced here would be expected to retard or entirely prevent the uptake of plant nutrients. As pointed out by Morgan, Gourley and Ableiter (24), the degree to which nitrate and ammonium nitrogen may be assimilated by the plant is a function of the acidity or basicity of the soil solution. Thus, for the maintenance of a satisfactory supply of available nitrogen, a reaction of pH 6 to 8 is most favorable. The availability of phosphorous is affected by the soil reaction. Another feature of soil reaction is the degree of microbial activity. Most soil
bacteria function best when the pH of the soil solution is neutral or only slightly acidic. Certainly soil microbial activity would be very restricted at pH 4. The field results bear out the fact that these conditions must be satisfied. Of the single treatments, lime alone gave the greatest response. It is true that total growth was still very low, but plants made a better start on the limed plot than on either the manured or fertilized plots. It has been found, according to Miller (25) that a pH of 4.8 definitely stops the growth of roots of alfalfa, while they grow well in a medium with a pH of 5 or higher. This need for liming of acidic soils would seem to make clear the reason for lack of response to a complete chemical fertilizer application to the muck soil. That certain fertilizers tend to increase soil acidity has been realized for a long time (39). When the nitrogen source used is ammonium sulphate there is a tendency for the soil acidity to increase. On the other hand, calcium cyanide and sodium nitrate have the opposite effect. Thus the use of fertilizer materials which tend to increase soil acidity should be avoided. As a result of work by Pierre (31), more attention is now being given to compounding fertilizers that will give the most favourable reactions for the particular soil conditions. In some sections of the country fertilizer companies are now putting out special mixes specifically adapted to muck soils. Besides the possible increase in soil acidity caused by the addition of the fertilizer salts, there is also the principle of antagonistic effects produced which may also partly explain the reduced growth. This is shown more clearly in the results of the greenhouse test and will be discussed at greater length in dealing with those tests.

The plot receiving manure alone proved that the answer to reclamation of muck soils does not lie here. Cattle manures are known to
contain large amounts of available nitrogen, but are low in phosphorous and in potash. One of their chief advantages lies in their ability to inoculate the soil with large numbers of bacteria which aid in making the plant nutrients more available. However, muck soils possess much the same features. That is, muck soils tend to be well-supplied with nitrogen (though not all is available immediately) and are very low in phosphorous, and particularly in potash. Therefore the wisdom of applying cattle manure to muck soils is not obvious. There would occur simply the increasing of the nitrogen content which is already fairly high, with no large increase in the phosphorous and potash contents, which are lowest. Another benefit of manure, that is, its humus content, would not be so advantageous here as on a mineral soil since muck soils are largely humus in character anyway. The bacteria added to muck soil d find very unsuitable conditions for growth. Ruschmann (33) states that peat used as litter contains 1-9 million organisms per gram, as against 31 million in sawdust and 116 million in straw. In addition to their bacteria and major element content, manures are of course valuable for their minor element content (Mn) and hormone containing substances. This latter feature is probably the best argument for their use on muck soils. The contrast in results achieved between the control plot and the plot receiving all three treatments (lime, manure and fertilizer) points the way to best management of muck soils. The lime applied to the all-three plot, first of all, corrected the extremely acidic conditions, giving a more ideal media for soil bacteria and secondly adjusted the pH of the soil solution to a point where more minerals would be brought into solution. Calcium was also supplied as a necessary mineral element. The deficiency of phosphorous and potash was made up through the use of the complete chemical fertilizer, while a more quickly available
source of nitrogen in the mix gave added stimulus to growth. This added nitrogen content is necessary when addition of manure is made, since if there is not sufficient nitrogen available, the organisms contained in the manure will compete with the higher plants for the available nitrogen present. In addition to the bacteria and nitrogen of the manure, certain other constituents prove useful in promoting growth. Creatinine (36) is one of these. B-indolylacetic acid, a powerful stimulant of root growth is also present; and chemically related skatole and hydrogen sulphide are also said to have growth stimulating properties. (34). In addition, to these direct effects of organic constituents of manure there are possible indirect effects. The reducing action of manure decomposing in the soil undoubtedly aids in making iron and manganese available. Salter and Schollenberger (34) think that the soluble organic matter supplied by manure aids in keeping iron and phosphates in solution, thus promoting their movement through the soil, and tending to have a favorable effect upon mineral colloids. The control plot, as might be expected, showed very limited growth, low availability of nitrogen, limited content of phosphate and potash, extremely high soil acidity, and low bacterial population all combining to give extremely repressed plant growth.

In dealing with productive capacity of muck soils, one important consideration is the content of humus and its breakdown. Mucks are formed from the decomposition of organic matter. Myer and Anderson (25) point out that decomposition of organic matter in bogs and swamps under conditions which are largely anaerobic, results in the production of relatively large quantities of humus. Muck soils, therefore, will be made up largely of humus materials. Humus is composed principally of the degradation products of the cellulose and lignin derived from plant remains.
When excessive amounts of organic matter rich in cellulose are added to soil, the fertility is reduced until the excess cellulose is decomposed. Newton (26) points out that it is doubtful if peat will form a satisfactory soil for common crops until the excess of cellulose has been decomposed. Myer and Anderson (25) point out that decomposition under these conditions is largely effected by fungi. Bacteria and purely chemical decomposition may also help to aid in breakdown but organic matter under these decidedly acidic conditions is largely decomposed by fungi. In studies of the biological decomposition of plant materials, Norman (26) found that in general, all substances in straw but lignin were attacked by fungi to a degree relatively proportional to the apparent total losses of organic matter. Newton (26) working on the utilization of peat soils and their decomposition found that fungi are more important than bacteria in the decomposition of cellulose. He found also that nitrogen, phosphorous and potash (the three main elements in fertilizer mixes) did not produce rapid decomposition of cellulose but that the addition of all "essential" elements (magnesium, sulphur and calcium) did produce rapid decomposition. It would seem, therefore, that anh practice hastening the further decomposition of the muck would also make possible the early successful culture of muck soil. Since fungi are more important in producing these breakdown products than are bacillius, animal manures may not be of such great value in effecting this change. Minor elements in conjunction with the three major elements speed the growth of fungi which cause breakdown and therefore it would appear desirable to these minor elements to a muck soil along with the fertilizer.
The most obvious point to be drawn from the results of the greenhouse experiment was that lime had the greatest influence on the production of high fresh weight. Thus, no treatment by fertilizers without the use of lime gave as high a fresh weight of material as did the use of lime alone or with added mineral salts. The highest yield as shown in Table 3 was obtained through the use of lime added to muck soils, where the fresh weight produced was nearly twice that produced on the control plot. Following in yield very closely was the complete (NPK plus minor elements) plot and the limed plot. Because these plants were harvested before full maturity, it would appear that possible exhaustion of the food supply had not had time to occur, and so the plants in the lime only plot were still making good growth. However, it seems reasonable to assume that deficiencies would show sooner in the limed plot than would be the case in the fertilized plus lime plot and that total growth would be greater in the latter. Longest length of stem growth was evidenced in the Vitalerth plot, which also had the third greatest fresh weight.

Calcium has been said to play the following three roles, by Miller (23). As an antidoting agent it may play a part through the calcium magnesium ratio and it may function in the neutralization of organic acids. Work by Lipman (19) has disproved the theory that there is a definite calcium/magnesium ratio. Parker and Truog (29) in connection with the neutralization of acids within the plant believe there is a close relationship between the calcium and nitrogen in plants. Other functions of calcium are structural materials of the middle lamella and and translocation of carbohydrates.
The increased calcium content of the plant tissue was clearly shown in the additions of lime to the muck soil. Thus, the five plots which were limed showed the highest yield of calcium in the plant tissues. The low calcium content of muck soils was reflected in the 30 mg. per 100 grams fresh weight of the plant. There is a direct correlation between the calcium content, the pH of the soil after growth, and the fresh weight of material produced.

Beeson (4) reports that lime added to soil represses the solubility of iron and aluminum and converts insoluble phosphorous compounds to more soluble forms. He states that liming affects yield more than it does the phosphorous content. This would certainly be true of the results obtained here in which yield was more than doubled while phosphorous content was only slightly changed. Beeson goes further by stating that lime and phosphate combined have more effect on the concentration of phosphorous in the plant than either material alone.

Liming and intensive fertilization under conditions of limited supply of micronutrients such as boron, manganese, iron and cobalt have been found by Beeson (4) to further reduce the amount of these elements. This fact should be borne in mind when adapting muck soils for crop production. Already limited amounts of minor elements present in the muck soil may be further reduced by the addition of the large amount of lime necessary to correct the extreme acidity.

So far as mineral contents are concerned it would seem from the results that application of mineral salts are necessary and have a direct influence on the content in the plant. The element showing this most clearly was potash, which gave a direct increase in every case in
which it was applied. Thus, potash, phosphorous and lime applied together
gave the highest content of potash in the plant tissue - 1218 mg/100 grams
fresh weight. All other cases show a direct correlation between addition
of potash to the soil and subsequent higher quantities in the plant tissue.
The limed and control muck plots reflect the low potash content of muck
soils. The same was true of phosphorous, applications to the soil being
reflected directly in the plant tissue. Thus, superphosphate applied alone
gave a content of 531 mg/100 gms. of fresh weight. This is surprising in
view of the fact that its extreme acidity would be expected to make the
phosphorous unavailable to the plant. The second highest phosphorous con­
tent was exhibited by the Vitalerth plot. It is noted that the boron
treated plot showed a high content of phosphorous in the plant. This would
seem to be in agreement with results reported by the U. S. Plant, Soil and
Nutrition Laboratory (40). They reported some highly significant re­
lationships with boron. An increased boron supply resulted in significant
increases in the manganese, iron, phosphorous and cobalt contents of plant
tissues. Boron's function seems to be the regulation of the intake of
other ions. Various investigators have reported certain ratios between
quantities of boron taken in by plants and the intake of such elements as
calcium and potassium. It is known that calcium affects the intake of
certain other elements, so if boron affected calcium intake it would in­
directly affect the intake of all ions affected by calcium. Boron occurs
mostly as a constituent of the mineral "tourmaline" and in organic matter
(10). Total quantity in the soil is of little importance, availability
is. Boron deficiencies occur on soils high in lime. It is possible to
induce boron starvation by applying lime in excessive amounts to an acid
soil. Boron is usually not needed on soils that need lime, according to
Beeson (4). However, it is doubtful if this would apply to muck soils. As might be expected, the low content of phosphorous in muck soils gave a correspondingly low reading in the case of untreated muck, limed muck and muck plus sand. In work done on vegetable crops by Cornell University it has been found that in increased supply of boron in association with increased supplies of N, K, and Ca resulted in an increased nitrogen content. Results of the greenhouse tests here bear this out, in part. Thus, the highest content of nitrogen was given by an application of a "complete" plus minor element fertilizer in which boron is a constituent. However, a similar plot in which calcium was included as lime showed lowered nitrogen content. A straight N, P, K fertilizer gave a higher nitrogen content than one with lime. Nitrogen content of plants treated with complete fertilizers and lime were not the highest. In fact, the nitrogen content was higher in the control than in the complete plus lime plots. In all other cases where nitrogen was not added, the addition of other elements lowered the nitrogen content below that of the control. An interesting point is the fact that boron alone gave a very high nitrogen content and so too the straight 4-10-10 gave an increase in the nitrogen content. Yet, when these two fertilizers were combined, the nitrogen content was considerably reduced, even below that of the control.

A point of nutrition illustrated here which has been previously demonstrated is that with the addition of more salts, the uptake of any one element is reduced. Thus the addition of single elements reduced plant growth and gave lowered fresh weight readings than did the control. The inference drawn is that the soil solution was unbalanced and uptake of nutrients present in the native muck was retarded. Thus, as pointed out by True (38), solutions of certain single salts are toxic to living
organisms but in mixed solution of these salts, organisms function normally and are not injured. This phenomena is called "antagonism", a term used to designate the hindrance that a given salt has upon the toxic action of another salt. Thus, sodium chloride when applied alone gave a lowered fresh weight of material, but when applied in combination with other fertilizer elements and lime, the fresh weight was considerably increased over control, and the toxic property of the salt was decreased.

The physical effect of lightening the muck soil by the addition of sand was shown to increase the growth of crops both on the field plot and in the greenhouse test. However, it is doubtful if the slight increase in growth would justify the high expense entailed in spreading sand over a large area of muck.

From an appraisal of the results obtained here it would appear that the addition of minor elements is not of as great importance in making muck soils productive as certain other consideration. The addition of certain minor elements such as boron and copper may give increased growth but until more important limiting factors are corrected, minor elements cannot be expected to prove beneficial.

Correction of the extremely acidic conditions found in muck soils through the use of lime is the primary consideration for successful reclamation.

Because of the low content of phosphorous and potash in muck soils, the addition of these two elements is of great importance. While total nitrogen is plentiful in muck soils, a quickly available added source will prove beneficial.
SUMMARY

The utilization of raw muck left after the harvest of sphagnum peat from the surface of bog lands on Lulu Island is becoming increasingly important. In order to determine the best method of putting these muck soils into truck crop production, a search of the literature was made and field and greenhouse tests were carried out. The field tests consisted of five plot treatments each involving: 1. control; 2. lime; 3. manure; 4. fertilizer; 5. lime, fertilizer and manure. The greenhouse tests involved the use of nineteen treatments including lime, and major and minor elements in various combinations on muck soils. The survey of literature showed that the principal method of reclaiming muck in the past had been through the use of cultivation and liming practices, supplemented with additions of the three major elements, nitrogen, phosphorous and potassium. In certain cases, the addition of minor elements such as copper and boron to muck soils have given great responses.

Results of the field test clearly demonstrated that liming was the most important operation to be considered in the reclamation of muck soils. This fact was borne out in the greenhouse study in which highest yields were obtained when lime was used in any treatment, regardless of the mineral element used.
LIST OF REFERENCES


(38) True, R. H. Antagonism and balanced solutions. Sci. 41: 653-656. 1915.


