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Fertilizer Studies as Conducted on Muck Soil in Sanpete County, Utah

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2

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TABLE OF CONTENT

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INTRODUCTORY

The reclamation of muck soil is a new development in the state of Utah. Knowledge concerning the various properties and requirements of the newly-drained area in Sanpete County, Utah, is extremely limited. A need for fundamental information concerning this type of soil was the basis for the establishment of an experimental farm in this region. The fact that most organic soils respond to mineral fertilizers soon after they have been reclaimed was an important reason for starting fertilizer work on this soil as soon as it was possible to do so. This thesis reports some of the fertilizer work being conducted on the farm.

The soil on which the experimental work is being conducted seems to be fairly representative of an area of about 6500 acres located near the south end of the Sanpete Valley. The muck soil has been developed here in what was originally a shallow lake, with an impervious blue clay as the bottom. The soil was formed by the growth of marsh plants, the remains of which have accumulated and have been preserved in the water.

From the time the valley was settled with white people up until 1926, the area had been used for the production of native hay and for pasture. The native sedge sod was first broken up in this region in the fall of 1926. The drainage of the area was started in the fall of 1925 and consisted of constructing canals around the project to control spring flood water. A central drain was installed, through the bottom of the area, with sufficient small laterals to properly drain the soil. The development of the area for at least two years after breaking the sod has consisted of pulverizing the coarse sod, allowing sufficient time for the roots to decay, so that crops could be grown.

REVIEW OF LITERATURE

The literature dealing with fertilizer experiments on organic soils as a rule is of a very general nature. In many cases the experiments were conducted in cooperation with local farmers. The results obtained are usually given as a general response to a certain fertilizer without citing any particular crop. A few recent publications have dealt in considerable detail with the fertilizer requirements of a specific crop. These studies are confined primarily to truck crops such as onion and celery (1,2,3).

Two general types of organic soils are recognized in fertilizer trials, according to the lime content (4): (1) low lime or lime-deficient soils and (2) high-lime soils (soils requiring no lime treatment). A muck soil containing 1.5 per cent or mor of CaO in the form of calcium carbonate may be regarded as a high-lime soil. Fertilizer requirements differ somewhat, according to the lime content of the soil. In Germany, Fleischer (5) (as reported by Alway (4) reports that with the exception of a few high-lime much soils, potash fertilizers are necessary for all muck soils. He also considered that phosphate fertilizers are considered necessary on all low-lime soils and on most high-lime soils, but this need is not so universal as for the potash fertilizers. In Minnesota, Alway (4) found that muck soils needing phosphorus were the most common, although in some cases both potash and phosphateius were needed. In Indiana (6) the muck soils are generally deficient in potash. In Wisconsin (7), on acid mucks occurring in the western and northern sections of the state, phosphorus, as well as potash, has given a good response. In the southern part of the state where the soil is less acid, potash is usually the only fertilizer needed. There are, however, many exceptions to this rule. The Ontario (Canada) Experiment Station at Guelph (8) reports some cooperative experiments conducted on muck soil. Potash in most cases gave marked increases in yield, while phosphate was found to be less needed. Farm manure also gave as good results as the mineral fertilizers in most of the tests. From a study of the muck soils of Michigan McCool and

and Harmer (9) found that newly reclaimed mucks, if high in lime and if recently drained, seldom respond to fertilizers for from one to several years. They report beneficial effects from light application of farm manure, especially when added to new mucks which are somewhat raw and fibrous in the surface foot. Many Michigan muck areas were found to need only potash; however, on some areas both potash and phosphate fertilizers are needed.

Although farm manure gives a good response, especially to the more raw soils, it is not usually recommended for use on muck soil. This is no doubt due to the fact that manure can be used to better advantage on mineral soils.

An outstanding exception to the general fertilizer response on muck soils is found on the organic soils of the Florida Everglades (10) where copper sulphate and manganese gave outstanding responses.

DESCRIPTION OF THE SOIL

On the basis of the ash or mineral content (11), the soil on the Sanpete County Experimental farm, where these fertilizer experiments were conducted would be classed as a muck soil. As suggested by Daikuowsky (11) organic soils containing over 35 per cent mineral or ash should be classed as muck, while soils containing less than this amount of ash should be classed as peat. The average ash content of all the Fertilizer plats on this farm was about 80 per cent. If classified on the basis of the original plant tissue (12), it would be classed as a marsh muck. The plants which have gone to make up this soil include reeds, rushes, cat-tails, and sedges. When the sod was broken up it was composed for the most part of sedges, which had formed a thick mat of tough fibrous roots. The muck has an average depth of about 6 feet, under which is a thick layer of hard impervious blue clay. There is also a thin layer of clay about 1 foot from the surface, which ranges in thickness from a fraction of an inch to 3 or 4 inches.

A chemical analysis of 2 composite soil samples, taken from an area adjacent to the fertilizer plats, was made by Dr. E. V. Staker of Cornell University, the results of which are reported in Table 1.

Table 1. Analytical reprt of muck soil taken from an unfertilized area adjacent to the fertilizer plats. (Results are given in percentage on a moisture-free basis).

	Sample A	Sample B
Depth (in).	1" - 12"	12" - 24"
Ash	49.75	52.50
SiO_2	24.06	27.48
Fe_2O_3	2.50	1.72
Al_2O_3	6.59	6.04
P_2O_5	0.32	0.32
CaO	6.60	5.42
MgO	2.54	2.69
MnO	0.046	——
K_2O	0.94	1.04
S	1.61	1.09
Inorganic Carbon	0.719	0.906
Total Carbon*	56.90	56.07
Total Nitrogen*	4.227	4.021
Ratio C/N	13.46	13.94

*Basis of 100 Parts of organic matter.

The amount of silica reported is high as compared with other muck soils. The silica, together with other mineral elements, no doubt has been washed in by flood waters which are not unusual in this region. The amount of aluminum, iron, calcium, and magnesium are all relatively high for muck soil. The high potassium content is highly striking because most organic soils are extremely low in this element. Table 2 taken from Lyon and Buckman (12), gives a partial analysis of certain representative organic soils. In all analysis which they reported, the potassium content of the soil was extremely low. The phosphorus content of the Utah muck is similar to that reported in trials from other parts of the world. When muck soil is compared with an average mineral soil on the basis of the phosphorus content, the phosphorus usually is as high or higher in the muck soil. In making this comparison, it should be remembered that the volume-weight of the muck is much less than that of the mineral soil. A furrow slice of muck soil would contain only about one-fourth of the phosphorus contained in a similar slice of mineral soil of the same phosphorus content.

Table 2. Chemical analysis of certain representative organic soils.

	Organic matter	N	P_2O_5	K_2	CaO
Minnesota (Low Lime)	93.0	2.22	.18	.07	.40
Minnesota (High Lime)	79.3	2.73	.24	.10	3.55
Michigan (Low lime)	77.8	2.10	.26	—	.16
Michigan (high lime)	85.1	2.08	.25	—	6.80
Minnesota (low organic)	59.7	2.35	.56	.17	2.53
Minnesota (high organic)	94.0	1.70	.16	.04	.51
Florida muck	68.4	2.63	.20	.17	—
Canadian muck	74.3	2.19	.20	.16	—

The total phosphorus content of the soil of the Sanpete Experimental Farm as reported in Table 1, is 0.32 per cent. It should be remembered that this figure is based on the mineral portion of the soil exclusive of organic matter. For the entire sample, this figure would be considerably reduced.

The pH value of soil, as determined on the soil of the experimental plats, was fairly uniform. The average pH for all determinations was 7.21. The maximum value obtained was 7.5 and the minimum was 7.

EXPERIMENTAL METHODS

Fertilizer treatments.- The fertilizer work consisted of applying those fertilizer materials which have commonly given a response on muck soil. The applications were made to soil that had recently been broken from sod and on which no previous cultivated crop had been grown. The plats were one tenth-acre in size, and were separated by 7-foot alleys. The experiment consisted of two series of plats--one manured and one unmanured. The commercial fertilizers were applied on both series. The arrangement of the plats and the fertilizers used is shown in Figure 1. The rate of fertilizer application, together with the number of applications, is given in Table 3.

Table 3. Fertilizers used together with the rate and number of applications.

Fertilizer	Rate of Application (per acre)	No. Applications.
Superphosphate	250 (lbs.)	3
Potassium Chloride	120 "	3
Ammonium sulphate	200 "	3
Raw rock phosphate	3000 "	1
Lime	500 "	3
Gypsum	500 "	3
Farm manure	10 (tons)	3

Due to the raw condition of the newly-broken sod no attempt was made to crop the area in 1927. In 1928 the plats were seeded to Trebi barley, but, due to a low germination, the crop was practically a complete failure. The first successful crop of barley was obtained in 1929, the third year after breaking the sod. The plats were all seeded to barley again in 1930. In 1931 only half of each plat was seeded to barley, and the other half was planted to potatoes. The barley yields were obtained by harvesting 6 square-yard areas from each plat.

Manured Series	Unmanured Series
Check	Check
Lime	Lime
Gypsum	Gypsum
Superphosphate	Superphosphate
Raw Rock Phosphate	Raw Rock Phosphate
Check	Check
Potash and Superphosphate	Potash and Superphosphate
Potash and Rock Phosphate	Ammonium Sulphate
Potash	Potash
Check	Check
Lime	Lime
Gypsum	Gypsum
Superphosphate	Superphosphate
Raw Rock Phosphate	Raw Rock Phosphate
Check	Check
Potash and Superphosphate	Potash and Superphosphate
Potash and Rock Phosphate	Ammonium Sulphate
Potash	Potash

Figure 1.- Showing plat arrangement and fertilizer used.

PART 1 — STUDIES OF YIELD DATA ON FERTILIZER PLATS

Results of Fertilizer Treatments

Barley yields obtained in 1929 are given in Table 4. It should be noted that the probable error for each treatment is extremely high. These high probable errors are the result of large variations in the yields of the plats of each treatment. In the case of certain treatments there was a deviation from the mean of the particular treatment of as much as 62 per cent. The large variation is also expressed in the probable error of a single treatment for the whole experiment which was 20.3 per cent. It is evident from the results given in Table 4 that none of the fertilizer treatments[3] gave significantly better or poorer yields than the checks (plats receiving no fertilizer treatment.) The yields and corresponding treatments are shown graphically in Figure 2. The high points in the graph seem to indicate that there has been a slight response to superphosphate and to superphosphate and potash combined. This is especially evident on the unmanured series. Due, however, to the extreme variation, no significance can be attributed to the results.

In 1930 the plats were again seeded to Trebi barley. The yield data for this year are presented in Table 5. It was evident from observation early in the summer that the barley was more vigorous and was making a better growth on the manured series than on the unmanured series. However, on the unmanured series, those plats which had received applications of superphosphate

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[3]In the column headed Diff./ P.E., each value obtained is the result of obtaining the difference between each yield and of the checks, and dividing the difference by the probable error of the difference.
The figure obtained must be at least 3 before the difference in yield is regarded as having significance.

Table 4. Barley yields obtained in 1929 from plats receiving various commercial fertiliser treatments with and without farm manure*

	Acre-yield of Barley(bus.) P.E.	diff./P.E. Compared with Checks
	Manured Series	
Checks	65.0 ± 10.8*	1.70+
Lime	47.2 ± 9.6	1.25
Gypsum	51.3 ± 10.4	0.91
Superphosphate	58.9 ± 11.9	0.38
Raw Rock Phosphate	35.5 ± 7.2	2.27
Potash and Superphosphate	82.4 ± 16.7	0.88
Potash and Rock Phosphate	76.6 ± 15.5	0.61
Potash	62.4 ± 12.7	0.16
	Unmanured Series	
Checks	43.7 ± 6.3	—
Lime	57.6 ± 11.7	1.06
Gypsum	62.5 ± 12.7	1.33
Superphosphate	74.8 ± 15.2	1.87
Raw Rock Phosphate	49.6 ± 10.1	0.50
Potash and Superphosphate	72.4 ± 14.7	1.80
Ammonium Sulphate	49.1 ± 10.0	0.46
Potash	58.3 ± 11.8	1.09

* Probable errors were obtained by the "Deviation of the mean" method. The probable error, in bushels, of a single determination for the entire experiment is obtained by applying the formula $P.E. = \pm .6745 \sqrt{\frac{S(d)^2\,n}{N(n-1)}}$

The probable error obtained is converted into percentage of the mean of all plats. To obtain the probable error of a single treatment, the percentage probable error is applied back to the mean of the treatment.

The probable error in percentage for each treatment in 1929 based on the whole experiment was 20.3 per cent.

+ The first figure in this column is the result obtained by comparing the unmanured checks with the manured checks.

Table 5. Acre-yields of barley obtained in 1930 from plats receiving various commercial fertilizer treatments with and without farm manure.

	Acre-yield of Barley(bus.) P.E.	Diff./P.E. Compared with Checks
	Manured Series	
Checks	66.0 ± 6.94	3.34*
Lime	64.1 ± 8.26	0.21
Gypsum	68.7 ± 8.55	0.28
Superphosphate	75.7 ± 9.75	0.93
Raw Rock Phosphate	77.3 ± 9.96	1.07
Potash and Superphosphate	72.7 ± 9.37	0.67
Potash and Rock Phosphate	64.1 ± 8.26	0.21
Potash	71.4 ± 9.20	0.55
	Unmanured Series	
Checks	39.8 ± 5.65	—
Lime	56.5 ± 7.46	2.01
Gypsum	59.2 ± 7.63	2.28
Superphosphate	67.9 ± 8.75	3.00
Raw Rock Phosphate	60.5 ± 7.79	2.41
Potash and Superphosphate	72.4 ± 9.33	3.26
Ammonium Sulphate	53.2 ± 6.86	1.73
Potash	52.4 ± 6.75	1.65

* The first figure in this column is the result obtained by comparing the unmanured checks with the manured checks.

Table 6. Acre-yields of barley obtained in 1951 from plats receiving various commercial fertilizer treatments with and without farm manure.

Treatment	Acre-yield of Barley(bus.) P.E.	Diff./P.E. Compared with Checks
	Manured Series	
Checks	58.7 ± 3.63	5.84+
Lime	49.3 ± 4.37	1.65
Gypsum	46.5 ± 4.11	2.24
Superphosphate	52.9 ± 4.70	0.98
Raw Rock Phosphate	60.1 ± 5.53	0.22
Potash and Superphosphate	68.9 ± 6.12	1.45
Potash and Rock Phosphate	52.5 ± 4.86	1.05
Potash	57.5 ± 5.10	0.19
	Unmanured Series	
Checks	34.1 ± 2.14	—
Lime	21.0 ± 1.86	4.63
Gypsum	40.3 ± 3.58	1.48
Superphosphate	58.9 ± 5.25	4.39
Raw Rock Phosphate	36.7 ± 5.26	0.67
Potash and Superphosphate	62.2 ± 5.52	4.75
Ammonium Sulphate	31.1 ± 2.76	0.88
Potash	31.4 ± 2.78	0.77

+ The first figure in this column is the result obtained by comparing the unmanured checks with the manured checks.

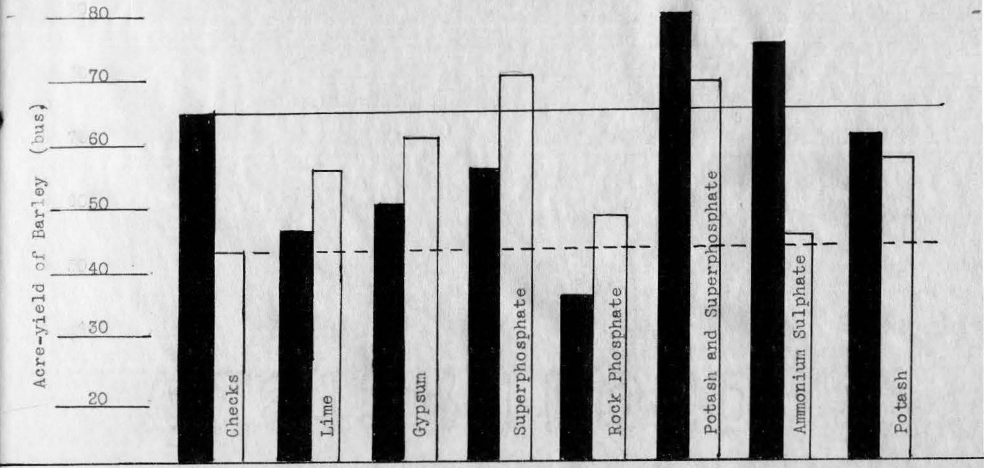

Fig. 2.- Barley yields obtained in 1929 from the different fertilizer treatments, on the manured and the unmanured series.

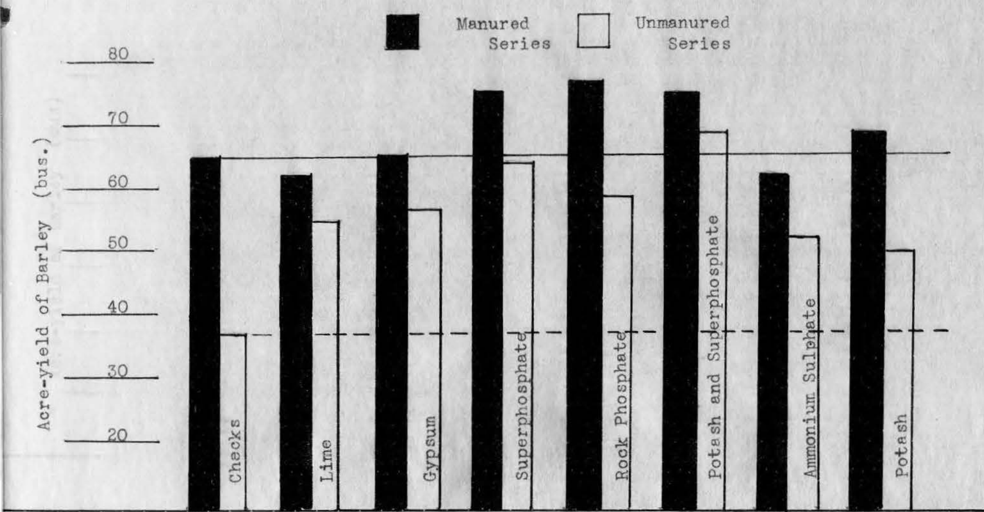

Fig. 3.- Barley yields obtained in 1930 from the different fertilizer treatments, on the manured and the unmanured series.

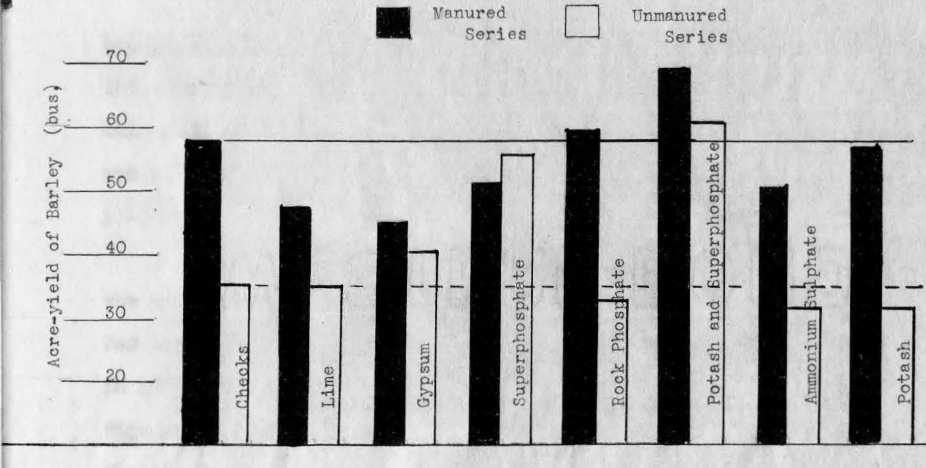

Fig. 4.- Barley yields obtained in 1931 from the different fertilizer treatments, on the manured and the unmanured series.

and superphosphate and potash combined yielded nearly as well as did the manured plats. The yield data obtained were in accord with the observations. The yields on the manured series were uniformly high and were all significantly better than the checks of the unmanured series as shown in table 5. In the manured series, manure alone gave as good results as when other commercial fertilizers were added. In the unmanured series, those plats receiving either super-phosphate alone or superphosphate and potash combined gave significantly higher yields as compared to the checks. Since potash alone gave no response, it is safe to assume that the response on the plats receiving both super-phosphate and potash was due to the superphosphate alone. This is substantiated by the fact that the plats receiving both fertilizers gave no higher yields than where superphosphate alone was applied. Figure 5 shows graphically the yields obtained from the different treatments.

In 1931 only half of each plat was seeded to barley, the other half being planted to potatoes. The barley yield data are presented in Table 6. The observations and yield data were similar to those obtained in 1930, the main difference being that the response to farm manure and to superphosphate was more pronounced in 1931. An apparent detrimental effect from the application of lime was obtained for the first time on the unmanured series.

From a comparison of the probable errors of a single treatment for the whole experiment for the three years, it should be noted that the error has been substantially reduced each year. It was reduced from 20.3 per cent in 1929, to 12.89 per cent in 1930 and 8.88 per cent in 1931. From these figures it is evident that the plats in general are becoming more uniform. The effect is probably due not alone to the fertilizer treatments but to a large extent to the fact that the soil is becoming more uniformly decomposed, coarse soddy spots having been almost entirely eliminated.

The yield data obtained from potatoes are not presented because the yields were extremely low, due to adverse weather conditions and an apparent lack of fertiliser response.

Results of Fallow Treatment

Alley-ways between the plats were maintained free from all plant growth up until 1951, when they were all seeded to barley. It was noticed early in the summer that the barley on the alleys was much more vigorous than the barley on the adjacent plats. This vigorous growth continued throughout the growing season. The barley on the alleys ripened on an average six days earlier than on the plats adjacent to them. The average yields of the alleys and of the plats are given in Table 7.

Table 7. Average yields of alleys and plats on the manured and the unmanured series.

Treatment	Acre-yield (bus.)
Manured Series	
Average yield of alleys	77.4
Average yield of plats	56.1
Average yield of check plats	58.7
Unmanured Series	
Average yield of alleys	58.8
Average yield of plats	38.9
Average yield of check plats	34.1
Average yield of plats receiving superphosphate	60.5

Yields from each alley and plat are shown in detail in Figures 5 and 6. These graphs indicate that yields from the alleys were consistently higher than were those on the adjacent plats. It should be noted that in the manured series the alleys received the same manure treatment as did the plats but received no fertilizer treatment. Apparently, maintaining the alleys in a summer fallowed condition for two years was about as effective in increasing the productivity of the soil as was either manure or phosphorus fertilizer.

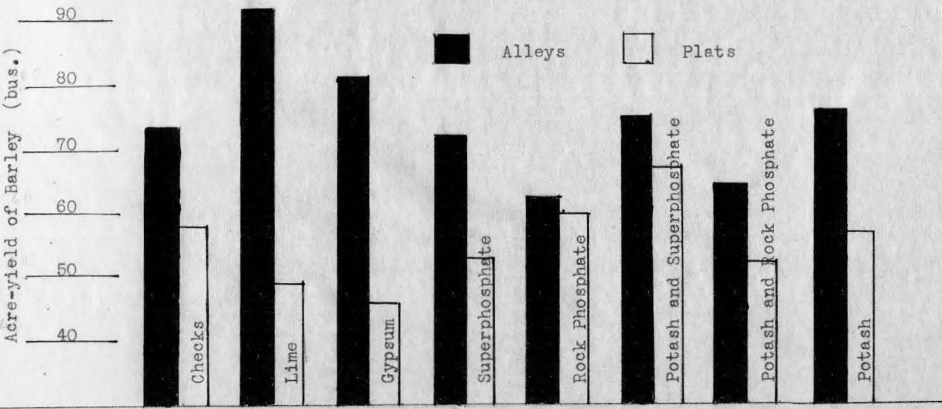

Fig. 5.- Barley yields on the manured series for 1931, showing the difference in yield of the plats and the adjacent alleys, for the different fertilizer treatments.

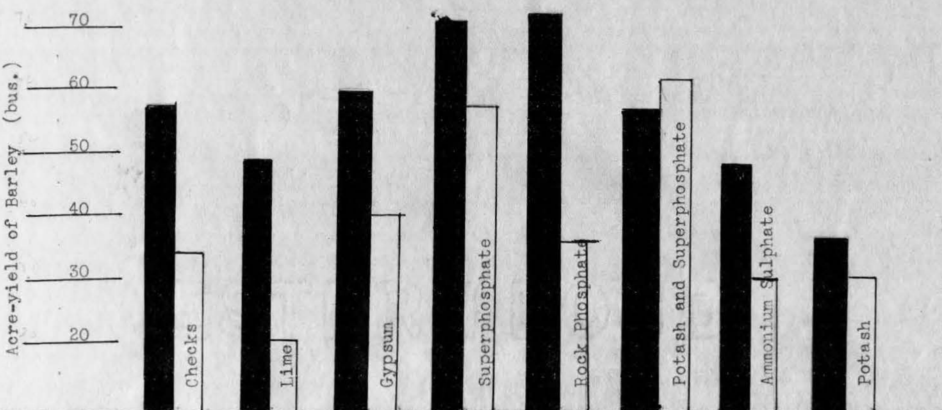

Fig. 6.- Barley yields on the unmanured series for 1931, showing the difference in yield of the plats and the adjacent alleys, for the different fertilizer treatments.

Fig. 7.- General view of the fertilizer field, showing potatoes in the fore-ground and barley in the back-ground. This picture was taken August 1, 1931.

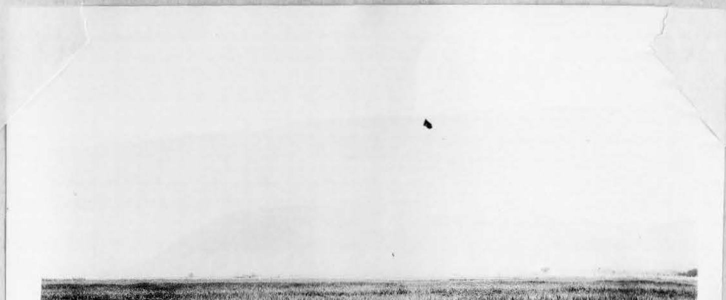

Fig. 8.- In this picture the stake at the left is in the check plat, and the one at the right is in an adjacent alley. The plat on the right of the alley has received superphosphate.

PART 11

SOIL STUDIES MADE IN CONNECTION WITH THE FERTILIZER EXPERIMENTS

The Care of Soil Samples and Methods Used in Determining Their Physical and Chemical Properties

Soil samples were collected from each plat, three times each year, during May, July, and September, respectively. The samples were taken with an auger and the first and second feet of soil we kept separate. Nine borings were made from each plat. The soil was placed in a paper bag and thoroughly mixed. The bags were left open and the soil was stirred occasionally until it had become thoroughly dry. The samples were then stored away until the following winter, when the analytical work was done in the College Soil Laboratory.

The moisture content of the soil was determined on a moisture-free basis. Immediately after collecting the soil sample and thoroughly mixing it, 100 grams were weighed out and placed in a soil-moisture can. The soils were dried for 48 hours in an oven at a uniform temperature of 110 degrees and weighed again.

The volume weight of the soil was determined in the field by pressing a cylinder into the soil and obtaining an undisturbed core of soil. The volume and the weight of the soil were determined. After determining the amount of water the soil contained, the weight was corrected to a dry basis. Dividing this weight by the weight of an equal volume of water gave the figures for volume weight.

The pH value of the soil was obtained by the use of a potentiometer with a quinhydrone and a calomel electrode. A proportion of about 5 parts of soil to 8 parts of water seemed to give the most consistent results.

Nitrate nitrogen of the soil was determined colorimetrically by the phenodisulphonic acid method (14).

The organic matter of the soil was determined by the rapid approximate method of Schallenberger (15).

Total nitrogen determinations were carried out according to the official Gunning-Hibbard modification of the Kjeldahl method (16).

The chloride content of the soil was determined by titrating with a standard silver nitrate solution, using potassium chromate as the indicator. The results were expressed as sodium chloride.

Sulphate determinations were made according to the common gravimetric method, in which barium chloride is used to obtain an insoluble barium sulphate precipitate. The amount of barium sulphate obtained was calculated to sodium sulphate.

Attempts were made to determine the soluble phosphorus content of the soil, according to Pittman's (17) modification of the Coeruleo-Molybdate method of Atkins. Considerable difficulty was encountered in obtaining a clear soil extract. This was finally overcome by using a clarifying solution composed of 5 c.c. of silver sulphate, 1 c.c. of a normal copper sulphate solution, and 0.1 gram of calcium hydroxide.

The Nitrate Nitrogen of the Soil.- In an attempt to determine changes, if any, that were taking place in the soil, in connection with the fertilizer treatments, soil studies have been made. An attempt has also been made to determine to what extent the different fertilizer treatments were influencing these changes. The nitrate nitrogen of the soil was determined in this connection.

The results of the nitrate determinations of the soil show a rather high nitrate content. Figure 9 shows the average nitrate content for the 3-year period for the months of May, July, and September. In 1929 the p.p.m.

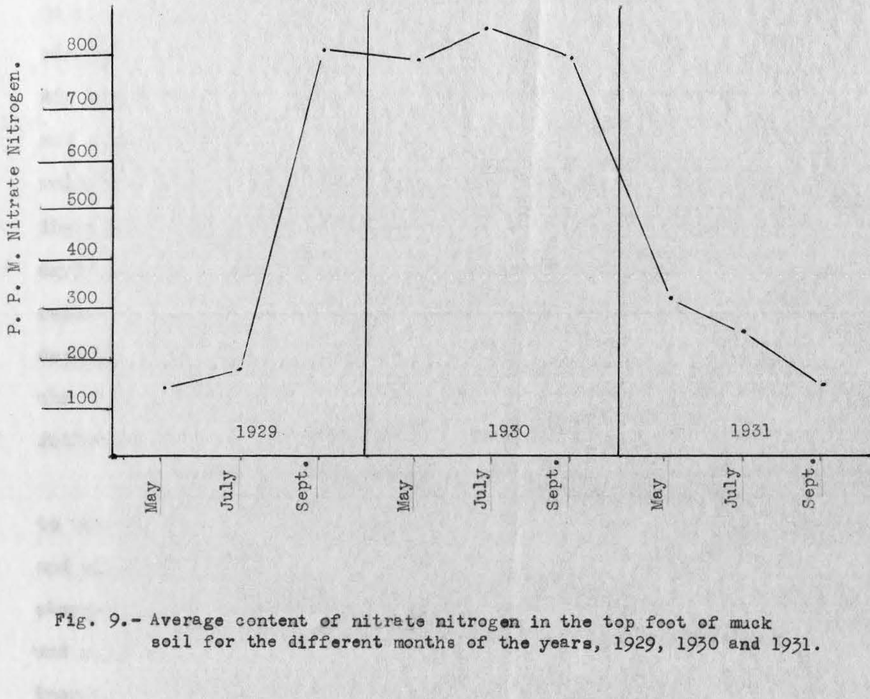

Fig. 9.- Average content of nitrate nitrogen in the top foot of muck soil for the different months of the years, 1929, 1930 and 1931.

of nitrates increased from about 200 to over 800; this high average was maintained throughout the following year. However, in 1931 there was a substantial drop in the nitrate content; this drop continued until the end of the season. It is probable that the results obtained can best be explained on the basis of the moisture content of the upper few inches of soil, since nitrification takes place most rapidly near the surface of the soil and since it is dependent on a relatively high soil moisture content. The rainfall records give the following information in this regard: In 1929 there was little rain during the summer months and the top soil was extremely dry; however, in September after the grain was harvested there was considerable rain. In 1930 rain was general and was fairly heavy throughout the growing season. In 1931 there was little rain and the top soil was dry again during the entire season. The rainfall for the summer months of the 3-year period follows the nitrate content of the soil very closely.

In Table 8 the July nitrates of each year are summarized according to the fertilizer treatments. The average nitrate content of the manured and unmanured series was practically the same in 1929, but in 1930 it had changed somewhat. In 1931 the average nitrate content of the manured series was consistently higher than the unmanured series. The manure apparently increased the nitrifying power of the soil.

The July nitrate contents were correlated with the barley yields. In 1929 a correlation of $-.473 \pm .103$ was obtained. In 1930 this negative correlation was $-.423 \pm .081$, and in 1931 it had changed to a small positive correlation of $.231 \pm .104$. The correlations obtained in 1929 and 1930 indicate that high nitrates had a slightly detrimental effect on barley yields. The correlations are, however, too small to be considered very significant. Since the nitrates are correlated with the organic matter, it is probable that high organic matter content is the important factor limiting crop growth in 1929. The change from a negative in 1929 to a positive correlation in 1931 was probably due to the fact that on the manured series the nitrates were higher than on the unmanured series only in 1931, and since the barley yields were also highe on the manured series in 1929 the correlation changed to a slightly positive value.

The occurence of high nitrates is reported from Indiana (19), where on some unproductive areas the nitrate content of the soil was found to be 0.34, while on productive areas .1 per cent was common. Wilson and Townsend (19) in New York reported nitrate determinations of over 1290 p.p.m. No Detrimental effect on crops was reported by them.

Organic Matter and Total Nitrogen of the Soil.- Studies of the organic matter and total nitrogen of the soil were made on the different fertilizer plats. The determinations were made only on the July soil samples each year. Table 9: The results of the determinations for 1929 and 1931 are summarized in Table 9. It is evident from these data that during the 3-year period there has been no significant change either in the organic matter or in total nitrogen content of the soil. The data in Table 9 indicates that fertilizer treatments, have apparently had no significant effect in changing these factors.

The results of correlating these factors with the barley yields are indicated in Table 10.

Table 8. Summary of the nitrate nitrogen content of the soil, as determined on the july soil samples for 1929, 1930, and 1931

	Nitrate Nitrogen in p.p.m.		
	1929	1930	1931
	Manured Series		
Checks	218.0	1016	464.0
Lime	174.0	1712	577.0
Gypsum	190.0	826	584.0
Superphosphate	202.0	906	336.0
Raw Rock Phosphate		629	378.0
Potash and Superphosphate	180.0	522	366.0
Potash and Rock Phosphate		882	380.0
Potash	222.0	960	172.0
Average	177.7	951.6	403.5
	Unmanured Series		
Checks	152.0	570	260.0
Lime	228.0	255	376.0
Gypsum	212.0	1616	305.0
Superphosphate	217.0	650	280.0
Raw Rock Phosphate		2019	224.0
Potash and Superphosphate	134.0	882	352.0
Ammonium Sulphate	111.0	536	360.0
Potash	167.0	498	172.0
Average	174.3	879.1	291.1

Table 9. Summary of Organic matter and total nitrogen content of the soil for 1929 and 1931

6	Organic Matter			Total Nitrogen		
	1929	1931	Increase or decrease in 2 years	1929 1929	1931	Increase or decrease in 2 years
			Manured Series			
Checks	48.1	46.0	-2.1	1.75	1.75	0
Lime	51.8	52.4	± .6	2.06	1.76	-.30
Gypsum	57.1	56.7	-..5	2.39	2.16	-.23
Superphosphate	52.6	52.0	- .6	2.16	2.01	-.15
Raw Rock Phosphate		48.0	---		1.86	---
Potash and Superphosphate	45.9	45.5	- .4	1.70	1.75	±.05
Potash and Rock Phosphate		49.8	---		1.80	---
Potash	48.4	49.4	±1.0	2.08	1.94	-.14
Average	50.7	49.97		2.02	1.88	-.14
			Unmanured Series			
Checks	53.7	48.3	-5.4	2.00	1.79	-.21
Lime	45.9	48.5	±2.6	1.82	1.79	-.03
Gypsum	54.9	48.9	-6.0	1.79	2.03	±.24
Superphosphate	53.0	47.8	-6.2	2.09	1.79	-.30
Raw Rock Phosphate		47.2	---		1.80	---
Potash and Superphosphate	55.7	51.1	-4.6	1.88	1.89	±.01
Ammonium Sulphate	44.1	50.4	±6.3	1.72	1.87	±.15
Potash	39.4	50.9	±11.5	1.81	1.89	±.08
Average	49.50	49.13		1.87	1.86	

Table 10. Correlation coefficients (r) obtained when barley yields were correlated with organic matter and total nitrogen

	Year		
	1929	1930	1931
Organic Matter	-.457 ± .107	-.266 ± .104	.0095 ± .112
Total Nitrogen	-.601 ± .085	-.030 ± .112	--

The negative correlations obtained in 1929 indicate that when the soil had a high organic matter or nitrogen content there was a tendency for the yield of barley to decrease. It is highly probable that the orgainc content of the soil was much more responsible than the nitrogen in influencing the yields in 1929. The soils that were high in orgainc matter, as a rule, were rather coarse and fibrous and afforded a poor environment for the growing crop. That there was a tendency for higher yields on the more compact soil is indicated by the 1929 correlation obtained when the yields were correlated with the volume weight of the soil. In 1930 and 1931 the correlations were almost negligible for both factors, indicating that the differences obtained in organic matter and nitrogen content of the different plats are not important in accounting for the yields obtained in these years.

The Volume Weight of the Soil.- One of the most outstanding physical characteristics of muck soil is the light weight of the dry soil. Determinations of the volume weight of the plats were made in May of each year. The results of these determinations are summarized, according to the fertilizer treatments in Table 11. It is evident from a study of this table that the volume weight has increased each year. The results were not corrected for differences in volume due to different moisture contents, but the average moisture content for all the plats, was nearly equal in 1929 and 1931. The increase in volume weight has apparently not been at the expense of the

Table 11. The volume weight of the soil from 1929 and 1931 determinations, summarized according to the fertilizer treatments.

	Volume Weight		
	1929	1931	
Manured Series			
Checks	0.28	0.35	.07
Lime	0.29	0.32	.03
Gypsum	0.22	0.32	.10
Superphosphate	0.27	0.31	.04
Raw Rock Phosphate	—	0.35	—
Potash and Superphosphate	0.30	0.36	.06
Potash and Rock Phosphate	—	0.36	—
Potash	0.29	0.35	.06
Average	0.28	0.34	.06
Unmanured Series			
Checks	0.29	0.36	.07
Lime	0.28	0.38	.10
Gypsum	0.28	0.39	.11
Superphosphate	0.26	0.37	.11
Raw Rock Phosphate	—	0.35	—
Potash and Superphosphate	0.25	0.37	.12
Ammonium Sulphate	0.27	0.37	.10
Potash	0.28	0.39	.11
Average	0.27	0.37	.10

organic matter, since, as shown by Table 9 no significant decrease in organic matter has occurred. It is probable that the increase in volume weight was due to the pulverization of the organic material, thus decreasing the air space in the soil. In considering the effect of fertilizer treatments on the volume weight, it appears that none of the fertilizers have affected the volume weight as compared to the checks, although the unmanured series has apparently increased somewhat faster than the manured series. This difference is probably not enough to be considered significant.

The correlation coefficients obtained, when the volume weight was correlated with the barley yields gave the following values: 1929, + .301 ±.118; 1930, .147 ± .125; and 1931, -.234 ± .106. From the values obtained it appears that the differences in volume weight of the different plats were of little importance in accounting for the yields obtained. It is the writer's opinion that the volume weight was more important in 1929 than is indicated by the correlation value. It is possible that the method used in obtaining the volume weights was not sufficiently accurate, or it may be that other factors tend to conceal the effect.

The Alkali Content of the Soil.- The alkali content of the soil was studied in connection with the fertilizer experiment to determine, if possible, the effect of alkali on the barley yields. Alkali is not considered as being altered by the fertilize treatments. Determinations of the sodium chloride and sodium sulphate content of the soil were made three times each year, during May, July, and September, respectively. These determinations show a high content of both salts in the soil. These results also show that the alkali is more concentrated near the surface. The top foot contained an average of 20 per cent more alkali than did the second foot. There was considerable variation in the alkali content in the different months and also from year to year; however, the relation of the amount of alkali on one plat as compared to another remained nearly the same.

The July determinations of both salts were correlated with barley yields each year. Corelations were obtained separately on the manured and on the unmanured series. They were also made on the unmanured series with the plats receiving superphosphate eliminated. The results are given in Table 12. The correlations obtained for 1929 were all high negative correlations. The alkali content of the soil was no doubt an important factor in limiting the yield of barley in that year. This may in part explain the lack of correlation between yield and fertilizer treatment in 1929. The values obtained in 1930 and 1931 were much less than in 1929. It would appear from these results that the alkali content factor was not so important in 1930 and 1931, as it was in 1929. In considering the correlations for the unmanured series, the values obtained when the plats treated with superphosphate were eliminated were consistently slightly higher than the complete series. This result was not significant when considered in terms of the probable error. The increased yields on the plats receiving superphosphate appear to be a factor in reducing the correlations on the complete series, as shown by these results.

Table 12. Correlation coefficients (r) obtained when barley yields were correlated with p.p.m. of NaCl and Na_2SO_4 of the soil from the July soil samples.

	1929		1930		1931	
	NaCl	Na_2SO_4	NaCl	Na_2SO_4	NaCl	Na_2SO_4
Manured Series	-.787±.083	-.855±.052	-.506±.116	-.558±.135	-.368±.134	-.327±.138
Unmanured Series	-.799±.065	-.650±.104	-.368±.134	-.397±.130	-.263±.145	-.254±.145
Unmanured Series (with plats receiving superphosphate eliminated)	-.885±.046	-.723±.101	-.555±.125	-.495±.136	-.331±.160	-.295±.165

SUMMARY AND CONCLUSIONS

This paper presents the results of fertilizer studies with Trebi barley at the Sanpete County Experimental Farm, on newly-reclaimed muck soil, for a period of 3 years — 1929, 1930, and 1931. No significant response was obtained during the first year to any of the fertilizer treatments, which seems to have been partly due to the influence of alkali that year. In 1930 and 1931, however, the barley yields on plats receiving either superphosphate or barn yard manure were significantly better than on the unfertilized checks. Manure alone gave as good results as when other commercial fertilizers were combined with it. Superphosphate alone gave as good results as when combined with potash.

Maintaining the alleys in a summer-fallowed condition for two years was about as effective in increasing the productivity of the soil as was either manure or superphosphate on cropped land. The nitrate content of the soil was consistently higher on the manured series in 1931 than on the unmanured series.

The data indicates that the organic matter and total nitrogen content of the soil were not materially altered by any fertilizer treatment during the course of the experiment.

Correlation coefficients obtained when organic matter and total nitrogen were correlated with barley yields, indicated that when either of these factors were high in the soil, there is a tendency for the yield to decrease. The correlations obtained in 1930 and 1931 are too small to be significant.

The data indicates that the volume weight of the soil increased consistently throughout the course of the experiment. The fertilizer treatments had no significant effect on the rate of increase in volume weight. It is thought probable that the increase in volume weight was due to the pulverization of the organic material.

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