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Bulletin No. 267 - Muck-Soil Management and Crop-Production Studies: Sanpete County Experimental Farm 1927 to 1933, Inclusive

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Fig. 1—Cabbage and barley grown in Sanpete County. Under proper management, these crops thrive in this area.

UTAH AGRICULTURAL EXPERIMENT STATION
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Muck-Soil Management and Crop Production Studies[1]

Sanpete County Experimental Farm—1927 to 1933, inclusive

LeMoyne Wilson[2]

INTRODUCTION

The muck soil area in Sanpete County, where these investigations were conducted, comprises approximately 6500 acres, 4209 of which are included in the San Pitch Drainage District. This region is located in the south end of Sanpete Valley and west of the towns of Ephraim and Manti. During part of the year the lands involved were subject to overflow by the San Pitch River. Water covered most of the area early in the winter, and during the spring months high water kept it submerged until June. Before the neighboring communities were settled by white people, this area was probably submerged the greater part of the year. As the surrounding region was developed, most of the water from the San Pitch River was diverted for irrigation purposes, which resulted in an annual decrease of water which reached the swamp.

At different times this land has been used both as hay land and as pasture land. During years of good moisture-supply, satisfactory yields of rather poor quality hay was produced and considerable pasturage afforded to range cattle; this area was thus valuable to the livestock men of the valley. With continued decrease in the water-supply, however, especially in years of drought, this section, so far as agriculture was concerned, has fast been losing its value. Weeds have taken the place of grasses; grasshoppers have made of it a breeding ground; livestock men, depending on it for grass for their livestock, have been disappointed by low yields. Some stockmen have drilled wells and have thus obtained sufficient artesian water to keep the grass growing vigorously. As it became evident that there was not enough artesian water to supply the needs of all, some of the more progressive landowners conceived the idea of draining the swamp and of putting it to more intensive use.

Actual construction of drains and canals was started in the fall of 1925, when a canal was built along the west side of the project and for about one mile along the east side. The canals joined at the north extremity for the purpose of diverting the water around the area. An open drain was dug through the center from the north end, which extended south for approximately three-fourths of a mile. As a result of this work, drainage of 300 acres was completed; more recently the east canal has been considerably extended.

It was early recognized that the problems involved in the reclamation of the area were strikingly different from those of other agricultural projects. Because of the urgent and immediate need for information concerning this area, in the spring of 1927 an experimental farm was established by the State Legislature.

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[1]Contribution from Department of Agronomy, Utah Agricultural Experiment Station.

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THE SOIL

Origin

Muck or peat soils have been developed in Sanpete County in what was originally a shallow lake with an impervious blue clay as its bottom. In the center of the area the peat reaches a depth of nearly 20 feet, gradually becoming more shallow. The water was probably never very deep and the plants making up the soil were of the marsh type (1)[3]. The more important plants were cat-tails, rushes, reeds, sedges, and true grasses. The soil was formed by an accumulating growth of these plants, the remains of which fell into the water. The water shut out the air, prevented rapid oxidation, and thus acted as a partial preservative. Mineral material was carried into the area by the river water, and at different times rather extensive floods from nearby canyons carried silt and clay which covered large portions of the swamp. The irregular placing of this material caused considerable variation in the soil. The layers of mineral soil deposited by floods vary considerably both in position and in thickness. The soil material from any given flood was deposited thickest at the edge of the swamp, gradually thinning out as it spread inward.

Composition

The soil at the Experimental Farm is classed as a muck soil. This classification is based on Dachnowski-Stokes' suggestions (2) that 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 the soil at the Experimental Farm is approximately 50 per cent. In certain areas of this swamp where limited amounts of mineral soil have been washed in, the soil contains considerably less ash and is properly classed as peat. The average chemical composition of the first and second foot of soil from samples taken at the Experimental Farm is given in Table 1.

Table 1. Chemical composition of muck soil (Results given in percentage on a moisture-free basis).

Constituents	Sample A	Sample B
	1—12[1]	12—24
Ash	49.73	52.50
SiO_2	24.06	27.48
Fe_2O_3	2.50	1.72
Al_2O_3	6.39	8.84
P_2O_5	0.32	0.32
CaO	6.60	5.42
MgO	2.54	2.69
MnO	0.045	
K_2O	0.94	1.04
S	1.51	1.09
Inorganic Carbon	0.719	0.608
Total Carbon[2]	56.90	56.07
Total Nitrogen[2]	4.227	4.021
Ratio C/N	13.46	13.94

[1]Depth in inches.
[2]Basis of 100 parts of organic matter.

[3]Numbers in parentheses refer to References, page 24.

The amounts of silica, aluminum, iron, calcium, and magnesium are all relatively high for muck soil; the high potassium content is particularly striking because most organic soils are extremely low in this element. In considering the amount of different plant-food elements in the soil it is important to bear in mind that muck soils weigh much less than mineral soils. The average weight of dry muck soil in 1929 was 17 pounds to the cubic foot; by 1931 its weight had increased to 22 pounds. It may be that the increase in volume weight was due to the pulverization and decomposition of the organic material. When dry, a cubic foot of mineral soil weighs from 70 to 100 pounds. In comparing amounts of different muck soil plant-food elements with those in a mineral soil, allowance should be made for this difference in density. Even though the muck soil and the mineral soil were similar in composition, pound for pound, the amount of plant-food in the furrow slice, within the reach of plant roots, is much less in the muck soil.

Soil Moisture

The feasibility of reclaiming this particular area depended in large measure on the water-holding capacity of the soil, since little irrigation water is available during the growing season and rainfall is entirely inadequate. Flooding the soil during the late winter and early spring months, when spring flood-water is available, is at present the only practical method of insuring a moisture-supply for the growing season. Examination of the soil in early April has shown that where the soil has not been flooded it has been moist to a depth of 4 or 5 inches from the surface (due to winter and early spring precipitation), below which there has been a dry layer of soil several inches in thickness. During dry years the Experimental Farm was thoroughly flooded in late March. When the flood water was turned on the land, dams were placed in the drains until the land was covered with water, after which they were removed and surplus water allowed to drain away. The soil was dry enough for spring seeding about the middle of April.

That muck soil has a high water-holding capacity is shown by the abundant crops grown each year in this arid region without irrigation during the growing season (this does not apply, however, to certain vegetable crops discussed later), and by actual soil-moisture determinations. Table 2 presents the average moisture content of the top foot of soil in May, immediately after the crops have been seeded, and of the first and second foot, respectively, of soil in September after the crops have been harvested.

Table 2. Average moisture content of soil at time of seeding and after harvest for soil cropped to barley, potatoes, canning peas. and for soil left fallow during the year, Sanpete County Experimental Farm.

Crop or Treatment	Percentage Dry-weight Basis		
	1st foot		2d foot
	May	September	
Fallow	149.0	108.0	145.0
Barley	138.0	44.0	144.0
Potatoes	138.0	67.0	140.0
Canning peas	151.0	45.0	164.0

These data indicate that the average moisture content of the top foot of soil in May ranges between 138 and 151 per cent. September data show that on the cropped soil the moisture was reduced from 44 to 67 per cent in the top foot and to 108 per cent on the fallow soil. The second foot of soil had a high moisture content under all conditions. The average maximum water-holding capacity of the soil is about 200 per cent.

GROUNDWATER

Annual measurements of the groundwater level were made at frequent intervals from 1927 to 1933, inclusive, from 18 systematically distributed test wells. During 1931 and 1932, measurements were made each month in the year; Figure 2 shows the position of the groundwater for these years.

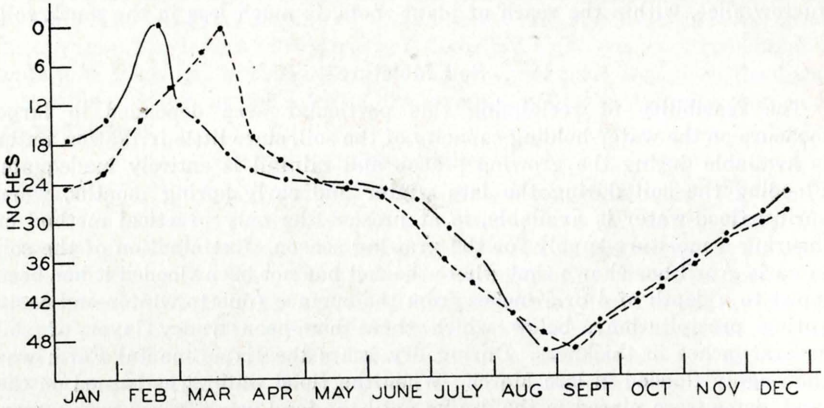

Fig. 2—Average depth of groundwater, Sanpete County Farm, from 21 systematically distributed test wells, by months, 1931 and 1932. During flooding, the water-table rose rapidly to the surface. After flooding, it rapidly receded to approximately 18 inches, continuing to recede more gradually during April, May, and early June. It receded again during late June, July, and August. During September the water-table began to rise again.

When the farm was flooded, the water-table rose rapidly to the surface; after flooding, it rapidly receded to about 18 inches, continuing to recede more gradually during April, May, and early June and receding more rapidly again in late June, July and August, when its average was approximately 48 inches from the surface. In September the water-table began to rise again, due in part, at least, to the fact that the crops had been harvested and because of cooler weather. The water-table rose gradually from September until flooding time in February or March. The water-level at the Experimental Farm is considered satisfactory.

ALKALI

Alkali occurs in varying concentrations over most of the swamp area. The salts are largely sulfates and chlorides, with only slight traces of sodium carbonate (black alkali) occurring near the edges of the swamp. As a rule, the alkali is more concentrated near the surface, decreasing in concentration at lower depths. During dry windy periods in the spring and early summer, in areas where the alkali is concentrated, it crystallizes on the surface and appears as a greyish-brown crust.

Determinations of the chloride and sulphate content of the soil have been made from samples collected three times each year, from the top foot of 36 tenth-acre plats, in May, July, and September, from 1929 to 1932, inclusive. Results are summarized in Table 3.

Table 3. Average alkali content of the top foot of soil, from samples collected on 36 tenth-acre plats in May, July, and September, from 1929 to 1932, inclusive.

	Chloride and Sulphate Salts (p. p. m.)			
	May	July	September	Average
1929				
Na_2SO_4	18,825	18,140	21,203	19,389
NaCl	4,359	3,746	4,960	4,355
1930				
Na_2SO_4	20,984	25,047	20,880	22,456
NaCl	4,603	5,882	4,500	4,995
1931				
Na_2SO_4	20,720	15,810	16,299	17,609
NaCl	4,252	3,789	3,696	3,911
1932				
Na_2SO_4	21,173	17,116	16,528	18,606
NaCl	4,306	4,218	3,445	3,990

There was considerable variation in the alkali content of the soil in different months and also from year to year; however, the relation of the amount of alkali on one plat as compared to another remained about the same. These data would indicate no definite trend of alkali movement in the top soil. Analyses of spring flood water going on to the land as well as water draining away, however, indicate that flood water carries some salt from the soil. Analytical data obtained from samples of water collected during the flooding period are presented in Table 4.

Table 4. Average total alkali content of flood water for water going onto the land and also for water draining away, 1932 and 1933 (electric bridge used for analysis).

Date of Sampling	Location of Sampling	Average Total Alkali (p. p. m.)
	1932	
March 3	Water going on to east field	1260
March 4	Water draining off east field	3754
March 17	Water going on to west field	1723
March 18	First water draining off west field	1801
March 19	Last water draining off west field	2678
	1933	
March 21	Water going on to east field	1001
March 22	Water draining off east field	1645
March 24	Water draining off east field	2037
March 25	Water draining off east field	2240
March 22	Water going on to west field	1723
March 24	Water draining off west field	1801

While these data give definite indication of alkali removal by flood water, it is probable that any appreciable reduction in soil alkali content would require continuous flooding each year for a long period of time.

The effect of barley yields on varying concentrations of soil alkali is shown in Table 5. These data indicate rather definitely that with increasing concentrations of alkali, barley yields were reduced.

Table 5. Showing yields of barley and alkali content of the top foot of soil on which the barley was grown.

Acre-yield (bus.)	Alkali (p. p. m.)		
	Sulphate	Chloride	Total
63.7	15,336	2572	17,908
47.8	18,988	6780	25,768
31.3	20,571	5260	25,830
27.3	21,788	4325	26,105
16.8	29,456	6663	36,129
6.6	31,166	10170	41,330
0	38,098	15781	54,874

These data were obtained from tenth-acre plats that had grown barley continuously for four years and which had had no fertilizer treatment. Where the soil has been properly managed, satisfactory crop yields were obtained where sulphate alkali was approximately 20,000 parts per million and where chloride alkali was approximately 4000 parts per million. Where the sulphate alkali is approximately 30,000 parts per million and the chloride alkali above 10,000 parts per million, crops are practically a complete failure. In considering these data, it should be borne in mind that the soil has a low volume weight and that a unit volume weighs only a fraction as much as does a mineral soil.

CLIMATIC DATA

Temperature

Of the climatic factors influencing crop production in this muck soil region, air temperature during the growing season is highly important. Organic soils, due to their low conductivity, are much more subject to frost than are mineral soils. An interesting illustration of this effect is described by Bouyoucos (3) as follows:

. . . "in a night during September when frost occurred, the temperature of the muck right at the surface was four degrees below freezing while the temperature of the clay was about five degrees above freezing. During the day both soils had the same temperature. Now when a soil has a high temperature at the surface during the night it helps to warm up the air above and prevent a frost. The clay, therefore, which manages to keep the surface warm will prevent a frost, while a muck which allows its surface to become cold will permit a frost. Plants, therefore, freeze more easily on muck soils than on mineral soils."

Frost injury during the summer months occurred in three out of the seven years that the Experimental Farm was operated. Damage to crops occurred in 1928, 1931, and 1932. It is interesting to note that during these three years the annual precipitation was much below normal. In fact, they were years of extreme drought, especially during the growing season. Light frosts have occurred during other years, but they have occasioned only slight damage to crops.

Wherever it was possible to plow up clay and mix with muck, injury was slight as compared with straight muck. Rolling the soil with a heavy cement roller was also of considerable value in reducing the amount of frost injury.

Table 6 shows the average monthly temperature for the growing season at the Experimental Farm during the 4-year period from 1930 to 1933, inclusive; Table 7 shows the average minimum monthly temperature for the same period.

Table 6. Average monthly temperature data collected during the growing season from 1930 to 1933, inclusive.

Month	Average Monthly Temperature (°F.)				Average
	1930	1931	1932	1933	
April	50.8	44.8	45.3	35.9	44.2
May	48.8	50.2	50.5	47.0	49.1
June	58.4	60.9	57.7	61.0	59.5
July	65.7	68.0	64.9	69.1	66.9
August	66.3	65.0	62.8	63.0	64.3
September	56.5	54.9	54.4	57.8	55.9

Table 7. Average minimum monthly temperature data collected during the growing season from 1930 to 1933, inclusive.

Month	Average Minimum Monthly Temperature (°F.)				Average
	1930	1931	1932	1933	
April	33.0	26.5	30.3	26.2	29.0
May	32.0	30.7	31.7	31.3	31.4
June	36.8	39.8	37.5	37.3	37.9
July	46.0	44.0	44.4	48.0	45.6
August	49.0	43.0	41.2	39.1	43.1
September	35.8	31.2	30.0	33.9	32.7

Precipitation

The mean annual precipitation at Manti (located near the south end of the drainage district and about 6 miles south of the Experimental Farm) was 11.74 inches for the 34-year period from 1895 to 1933. Precipitation data collected at the Experimental Farm during the growing season for the 6-year period from 1928 to 1933, inclusive, are presented in Table 8.

Table 8. Precipitation during the growing season, Sanpete County Experimental Farm, for the 6-year period, 1928-1933, inclusive.

Month	Precipitation (in.)						
	1928	1929	1930	1931	1932	1933	Average
April	[1]	0.69	0.50	0.84	0.60	1.17	0.76
May	1.02	0.71	1.89	0.56	0.25	0.86	0.88
June	0.26	0.41	0.0	0.12	0.58	0.0	0.23
July	0.34	0.34	1.13	0.12	0.77	2.07	0.80
August	0.11	1.12	3.32	0.29	1.32	0.19	1.06
September	0.0	1.58	2.21	0.10	0.10	0.14	0.69
Total	1.73	4.85	9.05	2.03	3.62	4.43	4.42

[1]No record.

Summer precipitation, ash shown in Table 8, is extremely variable and generally extremely light; however, an occasional heavy rainfall does occur. Precipitation during this period comes almost entirely from local thunder storms. The driest part of the year occurs normally during June and July.

Wind

Table 9 shows the average rate per hour of wind in this section for each month during the growing season for the 4-year period, 1930 to 1933, inclusive. Prevailing winds are from the southwest. Normally there is practically no wind at night. It starts to blow in the morning between 9:30 and 10:00 and blows steadily until evening. The actual average rate per hour during the day-time is at least twice that shown in Table 9.

Table 9. Average rate per hour of wind for each month during the growing season, Sanpete County Experimental Farm, for the period 1930 to 1933, inclusive.

Month	Wind Velocity (rate per hr.)				
	1930	1931	1932	1933	Average
April	3.5	4.1	4.3	4.4	4.1
May	3.6	4.3	4.2	4.0	4.0
June	2.9	3.5	3.6	3.1	3.3
July	2.5	3.0	2.9	2.3	2.7
August	2.3	2.5	2.2	2.2	2.3
September	2.7	3.2	2.0	3.0	2.7

As shown in Table 9, April and May are much more windy than are subsequent months. Winds seldom blow hard enough to damage crops; however, severe winds did occur in May, 1931, and again in May, 1932, doing considerable damage. Within a few hours the continual bombardment of the muck particles entirely destroyed stands of young plants. The greatest damage occurred where the soil was loose and rather dry at the surface. Where the soil was moist at the surface and had been rolled with a heavy roller damage was greatly reduced. A start was made at the Experimental Farm in providing a windbreak for the protection of the crops. Golden willow, Siberian elm, and Russian olive trees were set out along the south side of the farm in the spring of 1933. All trees made a satisfactory growth during that season.

Evaporation

Evaporation records from a free-water surface were kept at the Farm during 1932 and 1933. Table 10 indicates the data for each year as well as a 2-year average.

Table 10. Monthly evaporation from a free-water surface for a 5-month period, Sanpete County Experimental Farm, May to September, inclusive.

Month	Evaporation (in.)		
	1932	1933	Average
May	7.44	4.67	6.06
June	8.39	9.54	8.97
July	8.12	9.60	8.86
August	8.03	7.46	7.75
September	5.98	...[1]	5.98

[1]No record.

TILLAGE EXPERIMENTS

Sod-Breaking

The sod encountered was largely a mat of tough fibrous roots, sedges, arrow grass, wire grass, and some true grasses. Sod-breaking was accomplished best when a special sod plow was used, which permitted the sod to be turned completely over. Experiments on sod treatment after breaking showed, in general, that an excessive amount of disking was of little value in hastening the time that crops could be grown. Merely cutting the sod into small pieces did not make conditions favorable for plant growth. It was necessary to allow sufficient time for the roots to decay and for plant-food to be made available. Where the sod was tough, it was desirable to delay cropping until the second or third year after breaking, disking often enough to keep it free from weeds. Where it was possible to turn up clay and mix with the muck or where no sod occurred, a crop of barley could be raised the first year after breaking.

Effect of Rolling

The use of a heavy cement roller for rolling the muck soil immediately after seeding resulted in increased yields of barley, oats, and canning peas, as compared to unrolled muck soil or to soil rolled with a light steel roller. Table 11 is a summary of yield data obtained at the Farm from 1929 to 1931, inclusive, for rolled and unrolled plats and represents an average of three replications.

Table 11. Summary of acre-yields, obtained on rolled as compared with unrolled plats, for 1929, 1930, and 1931.

Year	Acre-yield			Increase Due to Rolling
	Crop	Rolled	Unrolled	
1929	Oats	54.5 bu.	44.5 bu.	12.9 bu.
	Barley	42.3 bu.	16.0 bu.	26.3 bu.
1930	Oats	32.8 bu.	20.5 bu.	12.3 bu.
	Barley	58.5 bu.	48.4 bu.	10.1 bu.
Acre-yield		1560 lbs.	850 lbs.	710 lbs.
Acre-value		$42.80	$24.70	$18.10
1931	Oats	38.1 bu.	6.7 bu.	31.4 bu.
	Barley	55.7 bu.	34.6 bu.	26.1 bu.

These data show that in 1929 and again in 1931 the increase in yield of barley, due to rolling, was much larger than in 1930. The heavy rains which occurred immediately after seeding were probably responsible for the comparatively high yields obtained on the unrolled plats in 1930. In 1931, an extremely dry year in which spring frosts and hard winds did considerable damage, the effect of rolling was outstanding for both barley and oats. In 1932 those plats which, in previous years, had been unrolled were rolled with a light steel roller, weighing approximately 100 pounds to the linear foot, which is about one-sixth the weight of the cement roller. Comparative yield data for barley, oats, and canning peas are presented in Tables 12 and 13.

Table 12. Yield data for barley and oats obtained on plats rolled with a heavy cement roller as compared with yield from plats rolled with a light steel roller, 1932.

Plat No.	Acre-yield (bus.)		Increase in Heavy over Light Rolling
	Heavy Roller	Light Roller	
Barley			
137	79.8	69.9	9.9
141	53.4	36.0	17.4
143	50.2	32.3	17.9
172	53.0	36.2	16.8
Average	59.1	43.6	15.5
Oats			
138	81.3	41.3	40.0
140	70.9	28.8	42.1
171	56.9	54.7	2.2
173	56.9	36.9	20.0
Average	66.5	40.4	26.1

Table 13. Yield data for canning peas obtained on plats rolled with a heavy cement roller as compared with yield for plats rolled with a light steel roller, 1932.

Plat No.	Acre-yield (bus.)				Increase in Heavy over Light Rolling
	Heavy Roller		Light Roller		
	Acre-yield (lbs.)	Value ($)	Acre-yield (lbs.)	Value ($)	Value ($)
139	2587	55.62	2467	53.04	2.58
170	4144	89.10	4102	88.19	.91
136	4136	88.92	3169	68.13	20.79
Avg.	3622	77.88	3246	69.79	8.09

In every case yields were higher on those areas rolled with the heavy roller than on adjacent areas which had been rolled with the light steel roller.

It is highly important that a heavy cement roller be used where the soil is highly organic since it compacts not only the surface soil but also the underlying layers. Light rollers and cultipackers compact the surface to some extent and are especially useful where the soil contains considerable clay or silt. Compacting of the lower layers of soil is important because it closes large air spaces in the soil, thereby giving the roots of the growing crop a better opportunity for penetration and development; at the same time it allows the soil moisture from below to move more rapidly upward. As a result of improved moisture conditions, frost injury is much less where muck soil is rolled with a heavy cement roller. Rolling is most effective when the soil is fairly moist; otherwise, when either too dry or too wet, the compaction is only temporary. The heavy cement roller should not be used where the soil contains considerable clay or silt since it renders this type of soil hard and impervious.

The roller used at the Experimental Farm was constructed of cement. It is 30 inches in diameter and 3.5 feet in length, with an estimated weight of approximately 600 pounds to the linear foot. In constructing this roller, mower wheels were used at the ends. The mower shaft was left in place and used for the roller shaft. Four-inch boards were placed around the mower wheels and held in place with wires. After the cement had hardened the boards were removed and a frame was constructed for pulling the roller.

PLOWING AND SEEDBED PREPARATION

Plowing and seedbed preparation tests were conducted during the 5-year period from 1929 to 1933, inclusive. The following treatments were included: (1) Fall-plowed with fall seedbed preparation, (2) fall-plowed with spring seedbed preparation, (3) not plowed, and (4) spring-plowed in 1930. Three replications of each treatment were included in this test. Barley yield data for the 5-year period, 1929-33, inclusive, are summarized in Table 14.

Table 14. Five-year summary of barley yields, obtained from plowing and seedbed preparation test, Sanpete Farm, 1929 to 1933, inclusive.

Treatment	Acre-yield (bus.)				
	1929	1930	1931	1932	1933
Fall-plowed, fall seedbed preparation	72.3	76.4	65.0	77.3	83.1
Fall-plowed, spring seedbed preparation	68.5	67.8	72.6	68.9	85.8
Not plowed	66.0	70.7	45.5	59.8	68.8
Spring-plowed	....	51.8	....	....	....

Spring-plowing data were obtained only for 1930. The harmful effects of spring plowing were so obvious that no further attempts were made to plow the soil in the spring. In 1929 and 1930 there was no significant difference in barley yield data for the other treatments; however, during the following three years (1931, 1932, and 1933) the yields were much higher on fall-plowed plats than on unplowed plats. Data indicate that barley yields are considerably reduced on land left continuously unplowed. When possible the land should be plowed in the fall; however, if, during certain years, fall-plowing is not possible it may be more desirable to leave the soil unplowed the following spring. Cropping the soil for more than one year without plowing should be avoided.

Seedbed-preparation data indicate that there is no advantage in preparing the seedbed in the fall as compared to preparing it in the spring. In preparing the seedbed in the spring care should be taken to avoid excessive stirring of the soil, so that the top soil will not dry out too rapidly. In general, the desirable practice seems to be to prepare the seedbed, sow the seed, and roll the soil within a short period of time.

CROP ADAPTATION

Crops vary considerably in their adaptability to different parts of the swamp. In general, there is a wider range of adaptation where appreciable quantities of clay or silt have been mixed with the organic material; there is a limited range, however, on the more organic soil, especially where the soil is high in alkali.

At the time the Experimental Farm was established (1927), practically no information was available in regard to crops that might be grown here. In order to find crops adapted to this type of soil, a large number of the more promising crops commonly grown in the state were tested. It was soon evident that this area was not adapted to long-season, non-hardy crops because of late-spring and early-fall frosts as well as the possible danger of summer frosts.

Results with Field Crops

Barley—Table 15 gives the annual and average yields of six varieties of barley grown in the barley variety nursery during the 3-year period, 1931 to 1933, inclusive. Only those varieties which possessed outstanding promise were included in this test, conducted according to "Latin-square" requirements.

Table 15. Annual and average acre-yields of barley varieties, Sanpete Farm, for the 3-year period, 1931 to 1933, inclusive.

Variety	Acre-yield (bus.)			
	1931	1932	1933	Average
Trebi	88.5	96.0	96.3	93.6
Coast	69.6	101.7	83.8	85.0
Atlas	84.7	101.7	107.3	97.9
Sacramento	68.0	90.4	94.8	84.4
Colo. 3192	64.5	107.4	95.2	89.0
Colsess	50.2	93.9	89.3	77.8

As shown by Table 15, the highest 3-year barley average was with Atlas, with Trebi second. In 1933 Atlas outyielded Trebi by 11 bushels and in 1932 three varieties (Atlas, Colorado 3192, and Coast), all earlier in maturity than Trebi, outyielded that variety. On an average, Atlas matures about one week earlier than Trebi. Although tests have not been conducted sufficiently long to be considered conclusive, they do indicate that Atlas, and possibly other early-maturing varieties, offers considerable promise in this region. Because of the short frost-free growing season, it is highly desirable to have early-maturing crops.

Trebi barley has been the only variety grown in the area on a commercial scale and as such has given general satisfaction. As a first crop to use after the sod is broken, barley is especially adaptable; it is also probably adapted to a larger part of the swamp than any other crop. There is definite need for additional barley variety tests, however, before any variety can be recommended to replace Trebi. It is suggested that farmers plant a limited amount of Atlas for comparison with Trebi under general field conditions.

Oats—Annual and average yields of six varieties of oats grown in the oat variety nursery during the 3-year period, 1931 to 1933, inclusive, are given in Table 16. This test included only such varieties as were considered as having outstanding promise; this test also was conducted according to "Latin-square" requirements.

Table 16. Annual and average acre-yields of oat varieties, Sanpete Farm, for the 3-year period, 1931 to 1933, inclusive.

Variety	Acre-yield (bus.)			
	1931	1932	1933	Average
Markton	51.9	102.1	79.0	77.7
Swedish Select	41.5	98.6	79.7	73.3
Victory	29.7	102.0	82.2	71.3
Idamine	46.2	91.4	81.8	73.1
Golden Rain	30.1	97.7	72.4	66.7
O. A. C. 144	37.9	89.6	92.7	73.4

These data show Markton to be the high yielder in 1931 and 1932 as well as the variety with the highest 3-year average. In a number of tests conducted throughout the state, Markton is reported as being an outstanding yielder. The grain of Markton has an objectionable quality in that it has a yellowish cast, and for this reason is not as desirable on the market as are other varieties. However, this discoloration should not be objectionable when the grain is fed by the grower.

Victory yielded as high as Markton in 1932, while in 1931 it was the lowest yielder in the group. O.A.C. 144 was the highest yielder for the first time in 1933. These facts indicate the danger of drawing conclusions from results of a limited number of years and suggest the need for continuing the test for a number of years so that definite recommendations might be made.

In certain areas of high alkali content, oats have done well where barley was almost completely killed out. However, where barley grows well it generally outyields oats.

Wheat—Dicklow wheat has outyielded five other varieties in a wheat-variety test conducted at the Sanpete Farm during the 2-year period, 1932 and 1933. Included in this test were varieties commonly grown in the state as well as especially promising strains which have been developed at the Central Station at Logan. The test was conducted to meet "Latin-square" requirements. Table 17 gives the acre-yield (in bushels) for each year as well as the average yields for the 2-year period.

Table 17. Annual and average acre-yields of wheat varieties, Sanpete Farm, for the 2-year period, 1932 and 1933.

Variety	Acre-yield (bus.)		
	1932	1933	Average
Dicklow	77.0	79.0	78.0
Federation	68.0	60.0	64.0
Q-80 (Hd. Fed. x Dick.)	70.0	65.0	67.5
Q-227 (Hd. Fed. x Dick.)	64.0	62.0	63.0
Baart	59.0	46.0	52.5
01-24 (Fed. x Dick.)	61.0	64.0	62.5

In the 2-year average Dicklow outyielded Q-80, the next high yielder, by more than 10 bushels, and outyielded Baart, a commonly-grown variety, by more than 25 bushels. This wheat was grown on an area where the muck soil contained considerable silt. Wheat grown on more organic muck soil has not given satisfactory yields.

Flax—Flax was first seeded in the muck soil in the spring of 1931, the crop being severely damaged by wind and frost in May of the same year. Those plants which did survive made a poor growth and when mature were no more than 8 inches in height. In 1932 and 1933 variety tests with five different varieties of flax were conducted on clay soil near the edge of the swamp. These tests were also conducted according to "Latin-square" requirements. The flax was irrigated several times during the growing season with water obtained from an artesian well. Yield data for 1932 and 1933 and the 2-year average are given in Table 18.

Table 18. Annual and average acre-yields of flax varieties, Sanpete Farm, for the 2-year period, 1932 and 1933.

Variety	Acre-yield (bus.)		
	1932	1933	Average
Linota	16.1	21.1	18.6
Bison	17.7	21.0	19.4
Redwing	11.8	20.3	16.1
Buda	17.3	19.1	18.2
Rio	18.9	20.3	19.6

When mature, the average height of the flax was 26 inches. As indicated in Table 18, there is no significant difference in the yield of any of the varieties grown. Satisfactory yields apparently can be obtained on clay soil bordering the swamp, provided sufficient irrigation water is available.

Potatoes—During the 5-year period, from 1927 to 1931, inclusive, Irish Cobbler potatoes outyielded six other varieties in the potato-variety tests conducted at the Farm. For this period the average acre-yield for Cobblers was 123 bushels and for Bliss Triumph 80 bushels. Similar yields were obtained for Blue Victor and Early Ohio varieties. Varieties which failed to produce marketable potatoes were Idaho Rural, Russet Burbank, and Brown Beauty. During the first two years of the test, yields were low because of unfavorable soil conditions. During the more favorable years of 1929 and 1930, the average acre-yield of Irish Cobblers was 259 and 213 bushels, respectively.

Potatoes were grown on a wide range of soil types. During years when summer frosts occurred, best yields were obtained where from 4 to 6 inches of clay had been mixed with the organic soil. During frost-free growing seasons better yields were obtained where the soil contained little clay. However, because of the possible occurrence of summer frosts, it is advisable to grow potatoes only where clay or silt layers have been mixed with the soil. The best time to plant potatoes is apparently about May 25. If planted much earlier than this, the plants are often damaged by late-spring frosts. Immediately after planting, the soil should be rolled, using a heavy cement roller on the more organic soil and a light steel roller on the heavier soil.

Alfalfa and Sweet Clover—Small-seeded crops, such as alfalfa and sweet clover, cannot be grown successfully in coarse and soddy soil. Attempts to secure stands proved a failure until a firm moist seedbed was secured. Satisfactory stands of both crops were first obtained in the spring of 1930, the fourth year after the sod had been broken. Yields for the following two years were disappointing. Continued cold weather during April and May of both 1931 and 1932 greatly retarded growth, making the first crop almost a complete failure; because no irrigation water was available, only a light second crop was obtained. Results from sweet clover plantings were more satisfactory than for alfalfa. In 1933 an excellent crop of sweet clover was obtained on muck soil, the alkali content of which was too high for successful barley growing.

In the spring of 1932 an alfalfa variety test was begun in which 24 varieties and strains were used. This experiment was located near the edge of the swamp where the soil was largely clay with only a few inches of organic material on the surface. Yield data from two crops of hay were obtained in 1933, the average acre-yield of the highest yielding variety (Italian) for these two crops being 2.16 tons. The four highest yielding varieties were Italian, Cossack, Hardistan, and Dakota Common No. 12.

Grasses and Clovers—Experiments with grasses and clovers were begun in 1932 to determine, if possible, the most desirable varieties for the thousands of acres of clay soil which border the swamp and which now produce only weeds and a few unpalatable grasses; an effort was also made to determine desirable varieties for muck soil areas where the alkali content is too high for general cropping. In 1932 twelve varieties of grasses and clovers were seeded in clay soil near the edge of the swamp. Additional promising varieties were seeded in the spring of 1933 in the clay soil as well as on muck soil of a high alkali content. Tests were not conducted sufficiently long to obtain dependable results. Varieties which appeared to give promise on the clay soil area were smooth brome grass, Reed canary grass, crested wheat grass, and alsike clover. Smooth brome grass, slender wheat grass, and sweet clover proved to be the most promising varieties on muck soil of high alkali content. A firm moist seedbed is highly essential for securing stands of grasses and clovers. A number of attempts to secure stands of small-seeded grasses, such as Kentucky bluegrass, proved to be failures, mainly because the surface soil dried out before the plants had become established.

Results with Vegetable Crops

For the first few years after the sod was broken, the soil was too coarse and too soddy for the successful production of vegetable crops. From numerous tests conducted with vegetable crops, indications are that there are few possibilities of commercial importance of vegetables in this area.

Asparagus—Mary Washington asparagus crowns were set out in the field in the spring of 1928. During the next two years plant growth was not satisfactory, due in all probability to the soddy condition of the soil. Additional crown plantings in 1931 and 1932, under more favorable soil conditions, made a much better growth. Asparagus sprouts were harvested from the first planting during 1931, 1932, and 1933. Because of continued frosts during April and May, the spring months of 1931 and 1932 were unfavorable to asparagus production, resulting in a slow sprout growth. The spring of 1933 was much more favorable, and high-quality sprouts were harvested approximately each alternate day for a period of about five weeks. Available information does not warrant making definite conclusions. It is evident, however, that commercial plantings should not be made until more information is available concerning various phases of production.

Celery—Investigations indicate that a high-quality product can be grown on selected areas of muck soil. In general, celery has grown best on soil which is not only highly organic but which is well-decomposed and low in alkali content. The cool summer nights of this section are especially favorable to the production of high-quality celery.

Irrigation tests have shown that it is necessary to irrigate the soil at the time the plants are set out as well as a number of times during the growing season. Successful celery production depends on the development of an adequate water-supply, best obtained by digging wells and installing pumping plants. Small artesian flows are considered undesirable for the irrigation of celery, because they are easily neglected and allowed to over-irrigate the area near their source.

Available data on time of setting celery plants in the field indicate that they should be set out much earlier in this region than is necessary in other celery-growing sections of the state because of the short growing season and the danger of severe fall frosts, making it hazardous to leave the crop in the ground after the first of November. Best results were obtained when sturdy plants had been planted on or about May 25.

Preliminary experiments with fertilizers indicate a marked response by celery to applications of farm manure and of superphosphate.

Cabbage and Cauliflower—Cabbage and cauliflower investigations indicate that best results are obtained when well-hardened, stocky plants are set in the field about the first of June. Soil and irrigation requirements apparently are about the same as for celery. Variety test data indicate that Golden Acre cabbage is the best early variety to grow and that Danish Ballhead is the best late variety. Early Snowball appeared to be the most promising variety of cauliflower.

Carrots and Table Beets—Muck soil, well decomposed and with a low alkali content, was ideal for the production of carrots and table beets. When the soil contained a sufficient amount of alkali to form a crust on the surface practically all seedlings of these crops were killed in the spring. Muck soil is desirable (1) because it permits root crops, such as carrots and beets, to grow straight, smooth, and symmetrical and (2) because satisfactory yields are obtained without irrigation. Results of a variety test conducted in 1933 are given in Table 19.

Table 19. Yield data for three varieties of carrots, Sanpete Farm, 1933.

Variety	Acre-yield (tons)			
	No. Replications			Average
	1	2	3	
Chantenay	17.6	20.9	19.8	19.4
Red-cored Chantenay	15.2	16.7	16.0	15.9
Danver's Half-long	17.4	19.5	18.6	18.5

Onions—Experiments indicate quite definitely that this area is entirely unsuited to the production of onions from seed. This is due in part to the short growing season and to unfavorable spring weather. Successful production of onions from sets and from seedlings was possible at the Farm only on selected areas and where sufficient irrigation water was available for weekly irrigation.

Peas—Where layers of clay or silt have been mixed with organic material, canning peas have been grown on the Sanpete Farm with marked success. Perfection, the most commonly-grown variety, outyielded all other varieties in tests conducted. Dwarf Telephone proved a desirable pod variety; the pods were large, easy to pick, and the entire crop was harvested in two or three pickings; acre-yields as high as 8000 pounds were obtained. Late July or early August offers the best market for pod peas.

CROPPING SYSTEMS

Experiments were conducted to determine, if possible, the best cropping systems for this area. Because of soil variation in different parts of the swamp, due in part to the irregular placing of clay and silt, and further because of varying amounts of soil alkali, it is impossible to recommend a cropping system applicable to the entire area.

During 1932 and 1933 only was it possible to obtain data on this problem. Definite rotations were started in 1928, but because practically no information was then available as to what crops to include and further because of the rough soddy condition of the soil, it was impossible to obtain reliable data. It was observed that where barley had been grown continuously on the same soil for a number of years, a marked decrease in yield generally occurred for each succeeding crop. This was especially true on the more organic soil containing considerable alkali. In some instances farmers have broken the sod, prepared a good seedbed, and have grown one good crop of barley, following which extremely poor crops of barley have been grown. An example of a similar effect is shown in Table 20, where in 1932 a series of plats, located on highly organic soil which had produced little in previous years, was seeded to barley. In 1933, one-third of each plat was planted to barley, one-third to potatoes, and one-third to canning peas.

Table 20. Barley yield data on a series of plats whose soil was highly organic, Sanpete Farm, 1932 and 1933.

Plat No.	Acre-yield (bus.) 1932	Acre-yield (bus.) 1933
226	69.5	60.7
227	68.3	48.7
228	76.4	37.0
229	54.2	56.4
230	41.6	53.6
231	57.6	27.5
232	58.4	18.9
233	49.6	35.1
234	87.6	47.5
235	65.0	34.8
Average	62.8	41.9

Barley yields for 1933 are shown to be much lower than for 1932, even though the 1933 growing season was much more favorable. Canning peas following barley on these plats were a complete failure and potatoes were poor in comparison with yields obtained on other plats. The average 1933 barley yield on an adjacent series of plats, which had been planted to potatoes in 1932, was 70.3 bushels; for barley following canning peas on a third series it was 71.7 bushels. Best yields of potatoes were obtained where potatoes followed canning peas; satisfactory yields of canning peas were obtained following either potatoes or canning peas.

Canning pea yield data for 1933, where peas were grown on soil containing a mixture of muck and clay and where different crops had previously been grown, are presented in Table 21.

Table 21. Canning peas yield data on plats having different previous cropping arrangements, Sanpete Farm, 1933.

	Acre-yield (lbs. and value of No. 1 grade peas)		
	Series		
	B	C	D
Previous Crops			
1931	Sweet clover	Barley	Barley
1932	Barley	Barley	Canning peas
Yield Data 1933			
Plat No.			
1	4289	3340	3563
2	2145	1597	1743
3	1810	1352	1787
Average	2748	2096	2364
Value	$57.71	$44.02	$49.64

Best yields of canning peas were obtained where peas followed barley grown for one year, the next best where peas followed peas, and the poorest where barley had been grown for two years previous to peas.

Where the soil contains considerable silt or clay which has become mixed with organic material, the common practice of farmers has been to grow canning peas more or less continuously. Satisfactory yields of peas have been obtained each consecutive year for as many as four years of continuous cropping. The chief danger of this system is that disease organisms may become more readily established in the soil. In 1933 a number of fields in which canning peas had been grown continuously for four or five years were badly infested with root rot (*Aphanomyces euteiches*), which has materially reduced yields, especially of late plantings of peas. Crop rotation is the only practical method of control.

While experimental work has not proceeded sufficiently far to definitely recommend the most desirable cropping system, a suggested system, based on limited available data, as well as on observations made on the Sanpete Farm during the years of its operation, would include the following: Canning peas, 1 year; potatoes, 1 year; canning peas, 1 year; and barley, 1 year. This plan makes possible the growing each year of canning peas on one-half the land adapted to this crop; the potato crop provides a needed cultivated crop, which could be supplemented with carrots and mangel beets.

Certain areas of the swamp are not well-adapted to the production of canning peas and potatoes. Where soil is deficient in clay or silt, these crops are more susceptible to summer frost; neither do canning peas and potatoes thrive where this type of soil contains an appreciable amount of alkali. Under such conditions barley or oats, and possibly sweet clover, offer the best possibilities. Where the soil is still soddy and the establishment of a sweet clover crop is difficult, it is more desirable to maintain a clean summer fallow, alternating with barley or oats.

FERTILIZER EXPERIMENTS

Plat Treatments

Fertilizer experiments on the Sanpete Farm were confined mainly to barley. Fertilizer materials were used which have commonly responded on muck soil in other sections of the country. The first fertilizer experiments, started in 1928, were located on two series of tenth-acre plats on soil that contained an average of 50 per cent mineral material or ash, by weight. One series of plats was manured. Commercial fertilizers were applied to both series, the application rate of which is given in Table 22.

Table 22. Fertilizers used, together with rate and total number of applications, 1928.

Fertilizer	Rate of Application (per acre)	No. Applications
Superphosphate	250 lbs.	5
Potassium chloride	120 lbs.	5
Ammonium sulphate	200 lbs.	3
Raw rock phosphate	8000 lbs.	1
Lime	500 lbs.	3
Gypsum	500 lbs.	3
Farm manure	10 tons	3

Because of the raw condition of the newly-broken sod, no attempt was made to crop the area in 1927. In 1928 it was seeded to Trebi barley, but because of poor 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. In 1930 the plats were again seeded to barley; in 1931 one-half of each plat was seeded to barley, the other half being planted to potatoes.

There was considerable variation in the 1929 yield data and little indication that barley had responded to any of the treatments. In 1930 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. However, on the unmanured series those plats which had received applications either of superphosphate alone or of superphosphate and potash combined were as vigorous as the manured plats. Yield data obtained were in accord with field observations. Yields on manured series were uniformly high and were significantly better than were the checks of the unmanured series. Manure used alone gave as satisfactory results as when combined with commercial fertilizers. In the unmanured series, those plats receiving either superphosphate alone or superphosphate and potash combined gave significantly higher yields than did untreated check plats. Since potash alone gave no response, it is probable that response on plats receiving superphosphate and potash combined was due to superphosphate alone.

In 1931 observations and yield data were similar to those obtained in 1930, the main difference being that response to farm manure and to superphosphate was more pronounced. No yield data were obtained for potatoes. Barley yield data for 1930 and 1931 on the use of fertilizers are summarized in Table 23.

Table 23. Acre-yields of barley obtained from plats receiving various commercial fertilizer treatments with and without farm manure, Sanpete Farm, 1930 and 1931.

Treatment	Acre-yield (bus.)	
	1930	1931
Manured Series		
Checks	66.0	58.7
Lime	64.1	49.3
Gypsum	68.7	46.3
Superphosphate	75.7	52.9
Raw rock phosphate	77.3	60.1
Potash and superphosphate	72.7	66.9
Potash and rock phosphate	64.1	52.5
Potash	71.4	57.5
Unmanured Series		
Checks	39.8	34.1
Lime	56.5	21.0
Gypsum	59.2	40.3
Superphosphate	67.9	58.9
Raw rock phosphate	60.5	36.7
Potash and superphosphate	72.4	62.2
Ammonium sulphate	53.2	31.1
Potash	52.4	31.1

In 1932 a few changes were made in some of the treatments. Fallow treatments were substituted for fertilizer treatments where no response

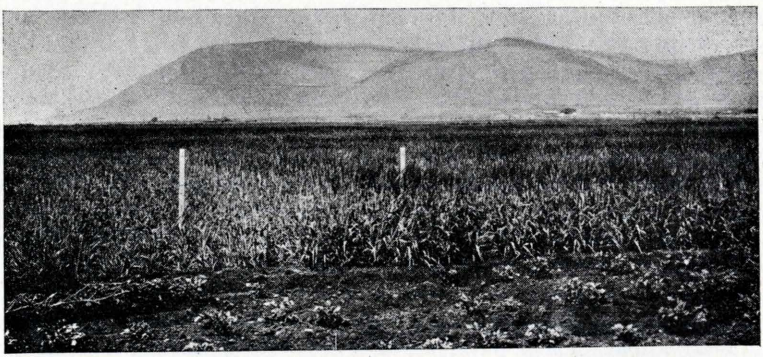

Fig. 3—Trebi barley in the fertilizer test. The stake at the left is in a check plat which received no fertilizer treatment. The stake at the right is in a plat treated with superphosphate.

had been obtained. The 1932 planting order was reversed from the 1931 planting, so that barley followed potatoes and potatoes followed barley. Yield data for barley were somewhat irregular and inconsistent in comparison with data obtained for the two previous years (1930 and 1931), due in the main to severe wind injury in the spring and to summer frosts.

In 1933 all plats, with the exception of fallow plats, were seeded to barley. Due to the fact that in 1932 half of each plat was planted to potatoes and half to barley, the 1933 data were collected from each half plat so that the effect of previous crops might be studied. Barley yield data for 1933 are summarized in Table 24.

Table 24. Acre-yields of barley obtained from plats receiving various fertilizer treatments and also different cropping treatments, Sanpete Farm, 1933.

Treatment Crops grown in 1932	Acre-yield (bus.) South Half Barley	Acre-yield (bus.) North Half Potatoes
Manured Series		
Checks	50.5	77.5
Superphosphate	59.7	80.3
Potash and superphosphate	72.5	82.8
Potash	70.0	80.6
Average	63.2	80.3
Unmanured Series		
Checks	42.5	65.4
Superphosphate	59.8	59.0
Potash and superphosphate	66.4	72.9
Potash	55.0	68.0
Average	55.9	66.3

Barley yields were uniformly high on all plats of the manured series where barley followed potatoes, the average yield being 14 bushels higher than the average for the corresponding series of unmanured plats. The last application of manure was made in 1930. Response to superphosphate was outstanding on only part of the plats on which it was applied. On check plats, where barley followed barley, the grain made an extremely poor growth, especially during the early part of the season, and a large number of weeds became established. The grain on these plats was late in ripening and was difficult to cut because of the heavy growth of weeds.

Fertilizer tests with other crops were started in 1932 and 1933 but no significant results were obtained. However, there were indications of increased yields of canning peas, potatoes, and celery on plats receiving either manure or superphosphate; a better response was usually obtained for manure than for superphosphate.

Fallow Treatments

Beneficial results from maintaining a clean firm summer fallow were first observed in 1931, when alleyways between fertilized plats which had been maintained free from crop growth the previous year were seeded to barley. It was observed early in the summer that barley in the alleyways was much more vigorous than on adjacent plats. This vigorous growth continued throughout the growing season and, on the average, the grain ripened six days earlier than on the plats. Average yields for alleyways and plats are given in Table 25.

Table 25. Average acre-yields of alleys (previously summer-fallowed) and of adjacent plats, Sanpete Farm, 1931.

Treatment	Average Acre-yield (bus.)
Manured Series	
Alleyways	77.4
All plats	56.1
Check plats	58.7
Unmanured Series	
Alleyways	58.8
All plats	38.9
Check plats	34.1
Plats receiving superphosphate	60.5

In 1932 regular fallow plats were laid out in connection with the fertilizer experiment. Barley yield data were obtained in 1933 following the 1932 summer fallow. On an average, these yields were over 30 bushels higher than those when barley was grown for the second consecutive year.

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SUMMARY

Origin of Soil—Muck soil on the area where the Sanpete County Experimental Farm was located was formed by an accumulating growth of marsh plants, the remains of which have been partially preserved in the water. Mineral material was carried into the area by the river water and at different times extensive floods from nearby canyons carried silt and clay, which covered large portions of the swamp. The irregular placing of this material is one cause of soil variation.

Soil Composition—The average ash content of muck soil on this area is approximately 50 per cent. The amount of silica, aluminum, calcium, and magnesium are all relatively high for muck soil; the high potassium content is striking because most organic soils are extremely low in this element.

Soil Moisture—The average maximum water-holding capacity of muck soil was approximately 200 per cent. The average moisture content of the top foot of soil in May was approximately 150 per cent. Flooding the soil during late winter and early spring months is the only practical known method of insuring a moisture-supply for the growing season.

Groundwater—After the soil is flooded, the groundwater-table rapidly recedes to about 18 inches from the surface and continues more gradually during April, May, and early June, receding more rapidly again in late June, July, and August, when it averages approximately 48 inches from the surface. The water-table rises gradually from September, until flooding time in February or March.

Alkali—Alkali occurs in varying concentrations over most of the swamp area. The salts are largely sulphates and chlorides, with only slight traces of sodium carbonate (black alkali) occurring near the edges of the swamp. As a rule, the alkali is more concentrated near the surface, decreasing in concentration at lower depths.

Temperature—Muck soils are more subject to frost during the summer months than are mineral soils. Where clay or silt has been mixed with organic soil there is less injury from summer frosts. Compacting the soil is also beneficial in avoiding frost injury. Frost injury in the summer months occurred during three out of seven years.

Sod-breaking—Sod-breaking was best accomplished when a special sod plow was used, making it possible to turn it over completely. Where the sod was tough, an excessive amount of disking proved of little value in hastening the time when crops could be grown; it was generally desirable to delay cropping until the second or third year after breaking, disking only often enough to keep the land free from weeds.

Rolling—The use of a heavy cement roller for rolling the muck soil immediately after seeding resulted in increased yields of barley, oats, and canning peas, as compared to unrolled muck soil or to soil rolled with a light steel roller.

Plowing and Seedbed Preparation—Fall-plowing of the muck soil proved much more desirable than spring-plowing or to not plowing at all. No advantage was apparent in preparing the seedbed in the fall as compared to preparing it in the spring. In preparing the seedbed in the spring, to prevent the top soil from drying out, it was necessary to avoid excessive stirring of the soil.

Crop Adaptation—Crops were found to vary considerably in their adaptability to different parts of the swamp. In general, there was a wider range of adaptation where considerable clay or silt had been mixed with the organic material, with a more limited range of adaptation on the more organic soil, especially where the alkali content of the soil was high. Because of the late spring and early fall frosts as well as because of possible danger of summer frosts, this area is not adapted to long-season non-hardy crops.

Cropping Systems—A marked decrease in yield each succeeding year was apparent where barley had been grown continuously on the same soil for a number of years. In 1933 fields on which canning peas had been grown continuously for four or five years were badly infested with root rot. Where barley was grown for two or more consecutive years, the crop following was generally poor. However, crops following canning peas and potatoes usually did well.

Fertilizers—On plats receiving either superphosphate or barnyard manure, barley yields were significantly higher than on unfertilized checks. Manure alone gave equally satisfactory results as when combined with commercial fertilizers. Indications of increased yields of canning peas, potatoes, and celery were apparent on plats receiving either manure or superphosphate. A better response was usually obtained for manure than for superphosphate.

Fallow Treatment—Greatly increased yields of barley were obtained when a clean firm summer fallow was maintained during alternate years.

DISCUSSION AND RECOMMENDATIONS

Experimental work conducted from 1927 to 1933, inclusive, at the Sanpete Experimental Farm clearly shows that muck soil, if properly managed, will produce satisfactory yields for a number of crops. However, under existing conditions it will probably be desirable for farmers to grow only a few of the more promising crops. To reduce danger of disease and to maintain a high level of production, it is recommended that some system of crop rotation be adopted. Where the soil contains considerable clay, the following rotation is suggested: Canning peas, 1 year; potatoes, 1 year, canning peas, 1 year; and barley, 1 year. Where the soil is lacking in mineral soil material, a shorter rotation is suggested: Barley or oats, 1 year; sweet clover, 1 year; or, barley or oats, alternating with a clean firm summer fallow.

Experimental work with celery and cabbage indicates that these crops can now be grown successfully on selected areas of muck soil. Commercial production of these crops, however, depends upon the development of an adequate water-supply, as well as upon a satisfactory market. Further experimental work with asparagus is necessary before definite conclusions can be drawn regarding the commercial production of this crop.

Experimental work with pasture grasses and clovers was conducted for such a short time it was impossible to offer reliable recommendations. This phase of the work warrants consideration in any future research program. There is definite need for information concerning varieties which can be grown successfully not only on high alkali muck soil but also on the thousands of acres of heavy clay soil that border the swamp and which now produce little except weeds.

In general, fertilizer treatment results indicate that in addition to some rotation to maintain crop yields on a high level, farm manure or the commercial fertilizer, superphosphate, is necessary. However, because of soil variation, it is suggested that at the beginning farmers try these fertilizers only on a small scale. A satisfactory test can be made by applying the fertilizer used in strips through the field.

(College Series No. 500)

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