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Bulletin No. 224 - Muck Soil Investigations: Progress Report, Sanpete County Experimental Farm 1927-30, Inclusive

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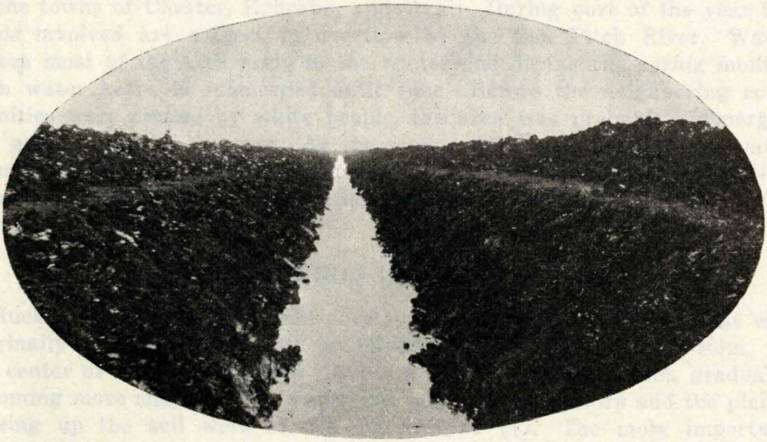

Section of open drain in muck soil. The drain is 7.5 feet deep with a bottom width of 5 feet.

Courtesy, R. A. Hart.

Utah Agricultural Experiment Station

Utah State Agricultural College

LOGAN, UTAH

Muck Soil Investigations[1]

PROGRESS REPORT, SANPETE COUNTY EXPERIMENTAL FARM, 1927-30, Inclusive

LeMoyne Wilson and George Stewart[2]

The estimated area of muck or peat soil in Utah is approximately 21,000 acres. The muck occurs in many valleys of Utah. The largest areas are in the Sanpete and Utah Lake Valleys. The area in the former is estimated at 6500 acres and the Utah Valley area at 9000 acres; the other areas, all more or less significant in size, are scattered throughout the state.

Investigations reported have been confined entirely to the Sanpete area which is located near the south and bottom end of the valley and is west of the towns of Chester, Ephraim, and Manti. During part of the year the lands involved are subject to overflow by the San Pitch River. Water covers most of the area early in the winter and during the spring months high water keeps it submerged until June. Before the neighboring communities were settled by white people, the area was probably submerged the greater part of the year. As the section developed, most of the water from the San Pitch River was diverted for irrigation purposes, resulting in an annual decrease of water which reached the swamp.

ORIGIN OF SOIL

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 about 20 feet, gradually becoming more shallow. The water was probably never deep and the plants making up the soil were of the marsh type (1). 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 ex-

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

[2]Superintendent, Sanpete County Experimental Farm, and Agronomist, respectively. Publication authorized by Director, March 17, 1931.

tensive floods from nearby canyons carried silt and clay which covered large portions of the swamp.

Type of Vegetation. The type of plants has changed since the entrance of the pioneers into the valley. The early settlers describe the area as being covered with cat-tails and with rushes growing taller than a man and so dense that it was practically impossible to penetrate them. With a decrease of the water-supply the vegetation changed to a predominance of sedges, arrow grass, wire grass, and a few true grasses; during dry periods alkali plants came in and in certain parts replaced some of the grasses.

Former Use of Land. At different times the land has been used as hay land and as pasture land. During years of good moisture supply, satisfactory yields of rather poor quality hay were produced and considerable pasturage was afforded for range cattle. The area was thus valuable to the livestock men of the valley. With continued decrease in the water-supply especially in years of drought this section, as far as agriculture was concerned, was fast losing its value. Weeds took the place of grasses; grasshoppers made it a breeding ground; livestock men depending on it for grass for their livestock were being disappointed with the low yields obtained. Some of the stockmen began drilling wells and obtained enough fresh artesian water to keep the grass growing vigorously. As it was soon evident that there was not enough artesian water to supply the needs of all the land owners, to some of the progressive owners came the idea of draining the swamp and putting it to more intensive agricultural use.

DRAINAGE

A major portion of the swamp west of Ephraim to the south end of the valley and west of Manti, representing a total of 4209 acres was surveyed. In December, 1925, a progress report was isued by the engineer in charge (2). In the first part of this publication it was proposed to build a canal along each side of the project, joining them at the upper extremity for the purpose of diverting water around the area. It was thought that a drain through the lower portion of the area would also be required.

Actual construction of canals and drains was undertaken late in the fall of 1925. The west-side canal has been completed. A canal on the east side extended only about a mile; an open drain was dug through the center of the area, reaching south for about three-quarters of a mile. As a result of this work 300 acres were drained. It was decided at this time to use this area for experimental work, the plan being to investigate the agricultural possibilities of the area before completing the drainage system.

ESTABLISHMENT OF EXPERIMENTAL FARM

Due to the unusual conditions involved in the project, the board of supervisors of the district asked the Utah Agricultural Experiment Station to undertake investigational work on the 300-acre tract. During the 1927 session of the Utah Legislature a bill was passed authorizing the establishment of an experimental farm and at the same time appropriating funds for its support. The Experiment Station was authorized to have direct charge of the farm. In the spring of 1927 officials of the Experiment Station met with the board of supervisors of the drainage district and selected a 40-acre tract in the southeast corner of the 300-acre drainage tract located three miles west of Ephraim. Experimental work was started immediately.

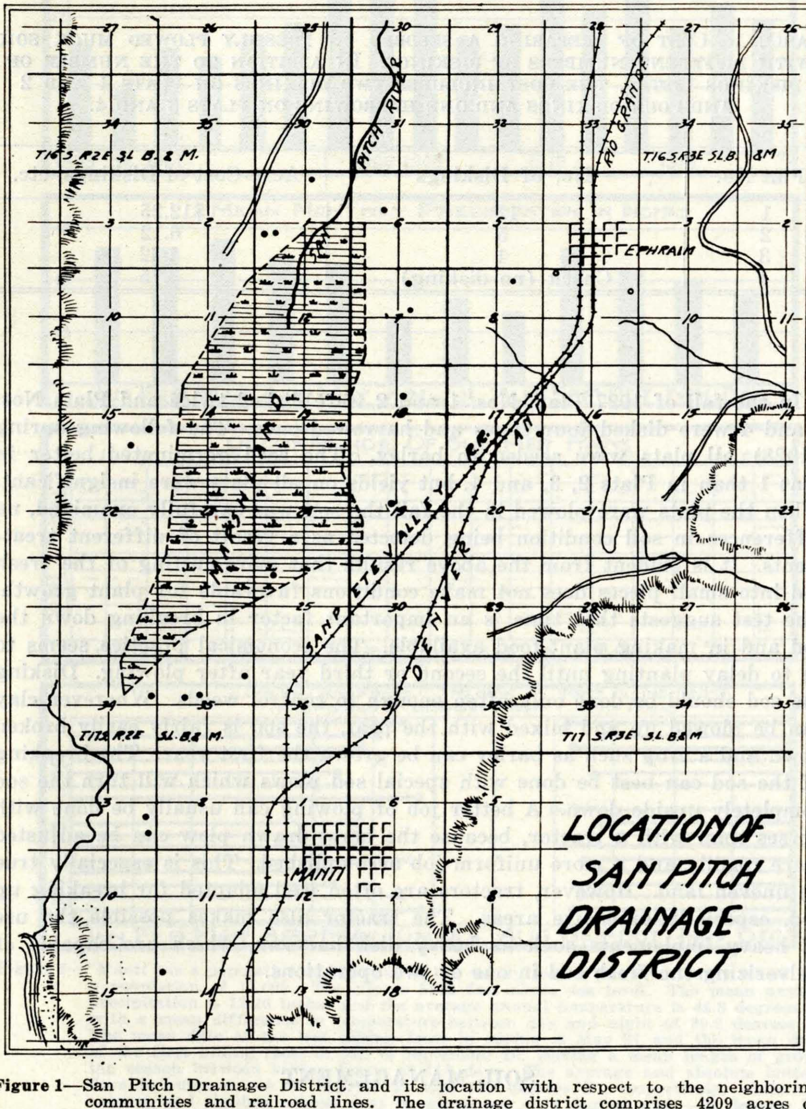

Figure 1—San Pitch Drainage District and its location with respect to the neighboring communities and railroad lines. The drainage district comprises 4209 acres of muck soil. A canal on the west side extends the entire length of the project and one on the east side about half its length. The canals join at the north end and divert water around the project. An open drain extends about three-quarters of a mile from the north end through the center of the project. It is intended that the east canal and center drain will be completed in the near future. The Experimental Farm is located near the north end, directly west of Ephraim.

SOD BREAKING

The first problem encountered was subduing the sod. Plats for treatment were staked off on freshly-plowed sod. The plats were disk-harrowed with a heavy double-tandem disk, as indicated in Table 1.

TABLE 1—COST OF PREPARING A SEEDBED ON FRESHLY PLOWED MUCK SOIL WITH DIFFERENT NUMBERS OF DISKINGS. IN ADDITION TO THE NUMBER OF DISKINGS LISTED, THE COST INCLUDES TWO DISKINGS ON PLATS 1 AND 2 AND FOUR DISKINGS AND ONE HARROWING ON PLATS 3 AND 4.

Plat No.	No. of Diskings	Acre-Cost of Diskings, etc.
1	12	$12.25
2	5	6.12
3	1	4.62
4	Check (no disking)	3.75

In the fall of 1927 Plats Nos. 1 and 2 were disked twice and Plats Nos. 3 and 4 were disked four times and harrowed once. The following spring (1928) all plats were seeded to barley. The seed germinated better in Plat 1 than in Plats 2, 3, and 4, but yields on all plats were insignificant. When the plats were plowed in the fall the soil was carefully examined, no differences in soil condition being detected as a result of different treatments. It is evident from the above results that mere cutting of the fresh sod into small pieces does not make conditions favorable for plant growth. The test suggests that time is an important factor in breaking down the sod and in making plant-food available. The economical practice seems to be to delay planting until the second or third year after plowing. Disking the sod should be done only often enough to control weeds. Wherever clay can be plowed up and mixed with the peat, the sod is fairly easily broken down and a crop such as barley can be grown the first year. The breaking of the sod can best be done with special sod plows which will turn the sod completely upside down. A better job of plowing can usually be done with horses than with a tractor, because the horse-drawn plow can be adjusted more readily and a more uniform job accomplished. This is especially true on uneven land. However, tractors are often well adapted for breaking up sod, especially extensive areas. The tractor also makes possible the use of heavy implements such as heavy disk harrows, which are capable of pulverizing the fresh sod in one or two operations.

SOIL MANAGEMENT

Rainfall. As shown in Figure 2, the mean annual precipitation at Manti from 1895 to 1917 was 12.26 inches (3). In Table 2 are given the precipitation data from 1918 to 1930, showing an average of 12.14 inches yearly.

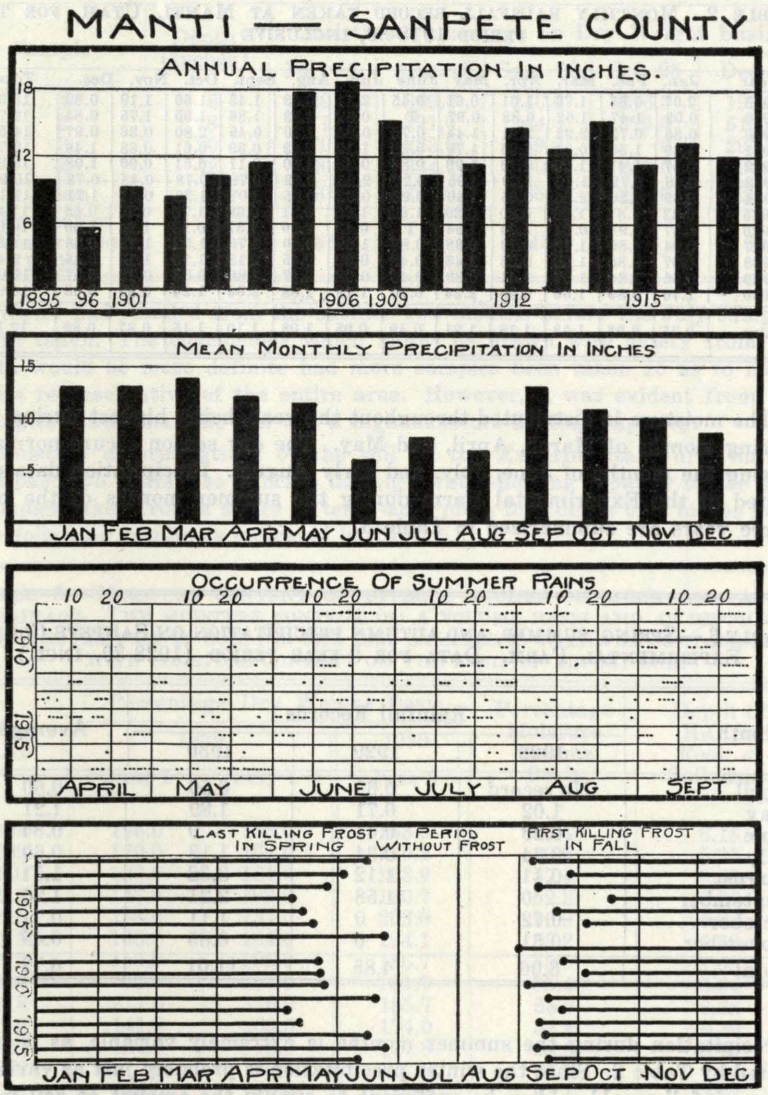

Figure 2—"Manti has a population of 2500 and is the county seat of Sanpete County which has a population of 17,000. The city is 5575 feet above sea level. The mean annual precipitation is 12.26 inches and the average annual temperature is 46.8 degrees F. with a mean difference in temperature between day and night of 30.2 degrees F. The mean date of the last killing frost in spring is May 27 and the mean date of the first killing frost in fall is September 20, leaving a mean length of growing season between killing frosts of 116 days. The average and absolute hottest days in summer are 93 degrees F. and 108 degrees F., respectively, while the average and absolute coldest days in winter are —14 degrees and —25 degrees F., respectively." (From Utah Agr. Exp. Sta. Bul. 166—"Climate of Utah," (1919), page 47.)

TABLE 2. MONTHLY RAINFALL RECORD TAKEN AT MANTI, UTAH, FOR THE PERIOD 1918-30, INCLUSIVE

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1918	2.07	0.35	1.73	1.01	0.61	0.45	2.11	0.43	1.43	1.69	1.19	0.32	13.39
1919	0.03	1.47	1.02	0.83	0.97	T	0.59	1.83	1.86	1.05	1.75	0.84	12.74
1920	0.35	0.72	2.22	2.91	1.44	0.76	0.24	1.30	0.46	2.80	0.36	0.97	14.58
1921	1.49	1.30	0.84	1.95	1.79	0.29	1.10	2.63	0.39	0.61	0.38	1.46	12.74
1922	0.57	1.41	1.80	1.16	1.99	0.84	0.48	1.50	0.11	0.51	0.90	1.98	13.25
1923	0.48	0.79	1.16	1.60	1.05	0.27	2.25	0.62	0.78	0.78	0.48	0.72	10.98
1924	0.39	0.20	2.54	0.65	1.40	0.00	0.92	0.65	1.07	1.28	0.81	1.21	11.12
1925	0.42	0.87	1.43	0.80	0.20	1.64	1.36	0.81	0.68	1.76	0.76	0.68	11.41
1926	0.27	0.94	0.91	1.44	1.34	T	0.43	0.90	1.37	0.18	1.28	1.00	10.06
1927	0.94	1.80	1.18	0.79	0.38	0.87	1.08	0.60	1.75	1.52	1.18	0.36	12.45
1928	0.37	0.80	1.59	0.25	1.43	0.49	0.05	0.45	0.18	1.19	1.16	0.46	8.42
1929	0.66	1.24	1.97	1.41	0.89	0.46	0.98	0.47	1.88	0.34	0.15	0.57	11.02
1930	1.76	0.89	1.50	0.58	2.24	0.30	1.18	1.88	2.34	1.24	0.85	0.03	14.97
Avg.	0.75	0.98	1.53	1.18	1.21	0.49	0.98	1.08	1.10	1.15	0.87	0.82	12.14

The moisture is distributed throughout the year, being highest during the spring months of March, April, and May. The dry season occurs normally during the months of June, July, and early August. Precipitation data collected at the Experimental Farm during the summer months of the past three years are summarized in Table 3.

TABLE 3.—SPRING, SUMMER, AND AUTUMN PRECIPITATION ON SANPETE COUNTY EXPERIMENTAL FARM. DATA FOR 3-YEAR PERIOD (1928-30, INCL.)

Month	Rainfall Records			Average
	1928	1929	1930	
April	No record	0.69	0.50	0.60
May	1.02	0.71	1.89	1.21
June	0.26	0.41	0	0.34
July	0.34	0.34	1.13	0.60
August	0.11	1.12	3.32	1.51
September .	0	1.58	2.21	1.26
October	0.72	0	1.11	0.71
November .	0.61	0	0.85	0.49
Total	3.06	4.85	11.01	6.72

Precipitation during the summer months is extremely variable, as is indicated by Table 2. Since the winter precipitation is probably just as variable, the rainfall would seldom be sufficient to supply the amount of soil moisture necessary for successful crop growth.

Soil Moisture. It was clear to the sponsors of the project that its feasibility depended in a great measure on the moisture-holding capacity of the soil because (1) there was little irrigation water available during the growing season and (2) the precipitation was light and variable. During the summer of 1924 the moisture content of the soil was determined under the direction of the district drainage engineer. The results of these determinations are recorded in Table 4.

TABLE 4.—MOISTURE CONTENT OF MUCK SOIL BEFORE DRAINAGE (1924)

Sample	Depth (Inches)	Moisture Percentage on Dry Weight Basis				
		July 11	Aug. 15	Sept. 26	Oct. 28	Dec. 16
1	6	229.2	369.0	340.0	276.0	199.4
2	18	571.0	291.0	344.0	379.0	513.0
3	30	370.0	223.0	259.0	0	293.5
4	42	230.0	234.0	199.0	207.0	190.0
Mean		350.0	280.0	285.6	287.0	300.0
Position of Watertable (Inches)		36	42	45	48	50

Water had receded from the surface two months before the July samples were taken. The conclusions which might be drawn with safety from the data would be more definite had more samples been taken so as to make them representative of the entire area. However, it was evident from the samples taken that the soil has a high moisture-holding capacity.

Moisture determinations of the soil on the Experimental Farm during the past two years also indicate the high water-holding capacity of the soil. Samples taken from a series of tenth-acre plats to a depth of 6 inches gave the following results as indicated in Table 5.

TABLE 5.—MOISTURE CONTENT OF UPPER 6 INCHES OF MUCK SOIL AFTER DRAINAGE. THE MOISTURE CONTENT ON A VOLUME BASIS AND AS DEPTH OF WATER PER FOOT OF SOIL FOR THE 1930 SAMPLES IS GIVEN FOR COMPARISON WITH MOISTURE CONTENT ON THE BASIS OF AIR-DRY SOIL

Plat No.	Percentage Dry Weight Basis			Percentage Moisture Volume Basis	Depth of H_2O per Foot of Soil (In.)
	1929		1930		
	June 1	July 1	June 1		
208	138.0	138.0	163.0	51.4	6.18
209	170.0	164.0	170.2	49.5	5.95
210	132.0	181.0	263.9	57.4	6.88
212	143.0	192.0	166.7	52.2	6.26
213	138.0	137.0	203.0	56.9	6.83
215	163.0	184.0	194.1	53.2	6.38
216	153.0	100.0	185.7	58.6	7.03
217	96.0	167.0	181.7	55.4	6.64
218	217.0	170.0	185.7	55.7	6.68
219	141.0	163.0	174.0	52.4	6.29
221	134.0	76.0	177.8	56.6	6.79
222	117.0	129.0	177.8	62.1	7.46
224	125.0	115.0	189.8	63.1	7.57
Average	143.6	147.4	187.1	55.7	6.68

In comparing these results with those obtained in 1924 (Table 4), it should be borne in mind that the results in Table 5 were obtained from the drained area, whereas the results in Table 4 were obtained from the undrained soil.

The soil if flooded in the winter contains enough moisture to mature most of the crops grown with satisfactory yields. However, it is necessary to irrigate the soil before setting out celery and cabbage plants. Subsequent irrigations on these crops have also proved valuable in most cases. If water were available, increased yields of potatoes and beets would probably result from irrigations during the later part of the growing season. It is doubtful whether grain and peas would benefit from irrigation.

Alkali. An important factor in connection with the reclamation of this area is the soil alkali. The alkali occurs mostly as sodium sulfate (Na_2SO_4)

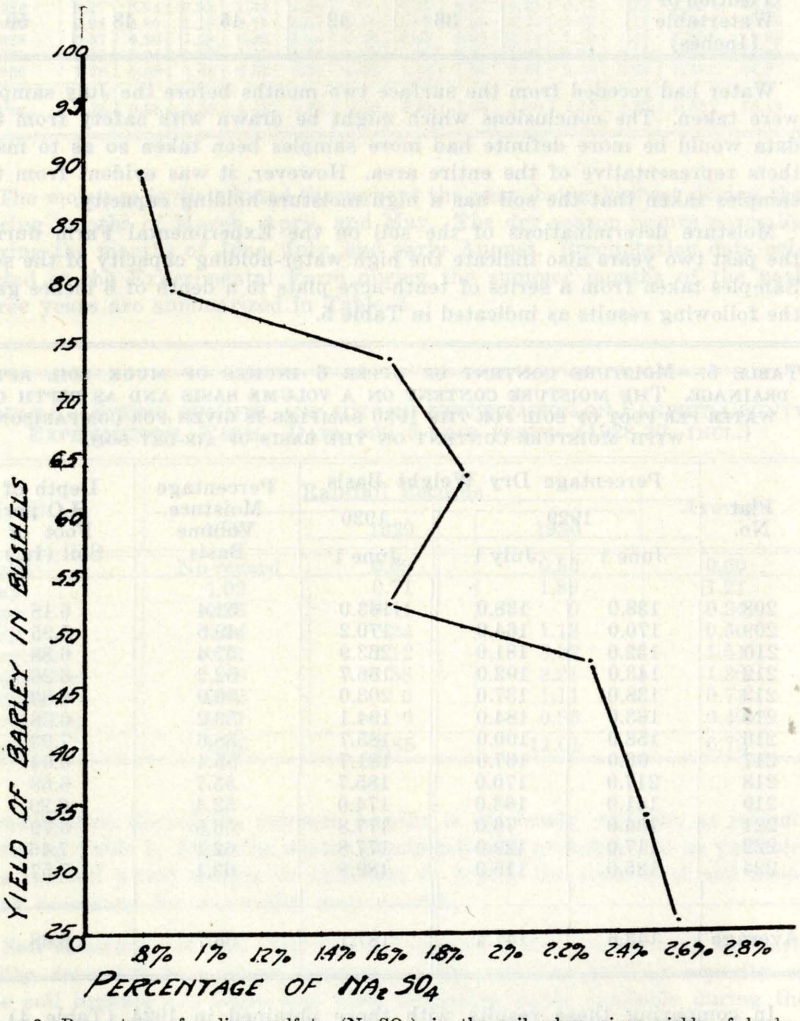

Figure 3—Percentage of sodium sulfate (Na_2SO_4) in the soil when given yields of barley were produced. In the main, the high yields of grain were obtained where the salt content was low and the low yields of grain where the salt content was high. This chart presents the yield data from 36 tenth-acre plats for 1929. The percentage of salt for each plat was determined from soil sample borings, composited for laboratory analysis.

and as sodium chloride (NaCl). Samples taken at different depths and analyzed for these salts indicate that they are concentrated near the surface. The parts per million of each salt for the first, second, and third feet are given in Table 5, the results representing an average of several samplings.

The salt content appears to be excessively high. It should be remembered, however, that the soil is light in weight and that a unit volume of muck weighs only about one-fourth as much as mineral soil. In comparing the salt content with that of mineral soils the figures here given should be divided by 4. Where the salt content is not materially higher than the proportions indicate, no serious damage to crops has resulted. A study of the effect of alkali on barley yields is being made. Figure 3 shows that the yield of barley increases as the sodium-sulfate content of the soil decreases and that the yields decrease with an increased amount of sodium sulfate.

TABLE 6.—ALKALI CONTENT OF MUCK SOIL ON THE SANPETE EXPERIMENTAL FARM AT DIFFERENT DEPTHS (PARTS PER MILLION)

Depth (Ft.)	Sodium Chloride (p. p. m.)	Sodium Sulfate (p. p. m.)
1	3757	16,440
2	2747	12,856
3	2036	9,469

Ground-Water. At frequent intervals throughout the season measurements of the position of the ground-water level have been made. Sys-

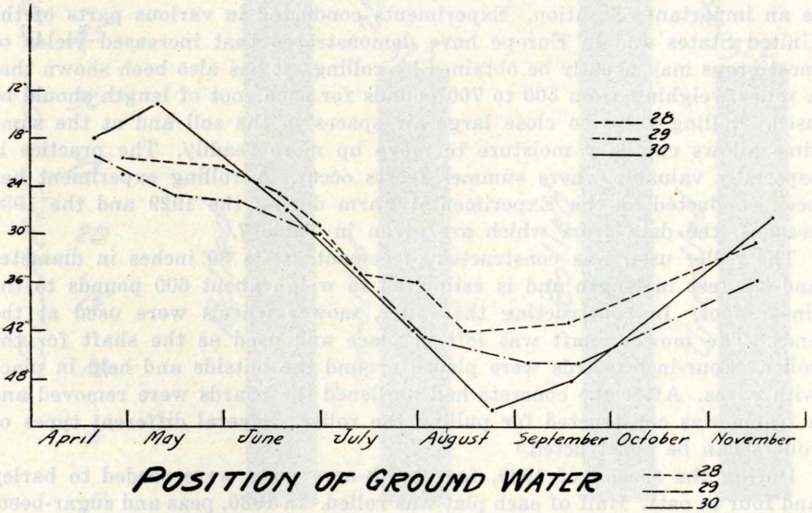

Figure 4—Average depth of ground water from 21 systematically distributed test wells by months, 1928-30, inclusive. In late April and early May the water-table was no deeper than 12 to 24 inches. As summer advanced the depth increased, until in August it was from 40 to 48 inches, after which in November it again rose to about 30 or 36 inches. Records were not kept during the winter months, December to March, inclusive.

tematically distributed test wells have been installed over the entire farm. Figure 4 shows the position of the ground-water level during the greater part of the year. The water-table is highest in the spring, gradually lowers during April and May, and recedes more rapidly during June, July, and August. In September the water-level begins rising, due somewhat to the fact that the crops have been harvested and to cooler weather. Little water is lost after harvest by transpiration or by evaporation.

The water-level in the early spring is probably too high for the best results. McCool and Harmer (6), working with muck soils in Michigan, have found that a high water-level in the spring produces a "cold" soil, resulting in delayed planting and frequently in poor germination and in slow growth.

With the exception of a high water-level in the spring the water-level maintained at the Farm is probably about right for best results. McCool and Harmer (6) further state that the majority of general farm and root crops produce their best yields on muck when the ground water-level during the summer months averages around 3 feet below the surface, although it may be somewhat higher during the early part of the season.

Winter Flooding. Flooding the soil during the winter months when water is available is the only present method of insuring a supply of moisture for the growing season. In the past, flooding has been delayed until February or early March. This practice is responsible for the high ground-water level in the spring. It would appear that a more desirable practice might be to flood in the fall whenever water is available. Fall flooding should be more effective in washing out soil alkali, since the water-table is normally lower at that time.

Effects of Rolling. In the management of peat and muck soils rolling is an important operation. Experiments conducted in various parts of the United States and in Europe have demonstrated that increased yields of most crops may usually be obtained by rolling. It has also been shown that a roller weighing from 500 to 700 pounds for each foot of length should be used. Rolling helps to close large air spaces in the soil and at the same time allows capillary moisture to move up more readily. The practice is especially valuable where summer frosts occur. A rolling experiment has been conducted on the Experimental Farm during the 1929 and the 1930 seasons, the data from which are given in Table 7.

The roller used was constructed of cement. It is 30 inches in diameter and 3.5 feet in length and is estimated to weigh about 600 pounds to the linear foot. In constructing the roller, mower wheels were used at the ends. The mower shaft was left in place and used as the shaft for the roller. Four-inch boards were placed around the outside and held in place with wires. After the concrete had hardened the boards were removed and a frame was constructed for pulling the roller. Several different types of rollers can be constructed.[3]

During the season of 1929, four tenth-acre plats were seeded to barley and four to oats. Half of each plat was rolled. In 1930, peas and sugar-beets were included in the test.

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[3]For detailed information on the construction of muck roller, reference is made to: "The Construction of a Muck Roller," by P. M. Harmer, and H. H. Musselman. In Mich. Agr. Exp. Sta. Quar. Bul., Vol. 6 (May, 1924) pp. 170-174.

TABLE 7.—SUMMARY OF ACRE-YIELDS, OBTAINED ON ROLLED AS COMPARED WITH UNROLLED PLATS, FOR 1929 AND 1930

Year	Acre-Yields			
	Crop	Rolled	Unrolled	Increase Due to Rolling
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.
	Peas			
	Acre-yield	1560 lbs.	850 lbs.	7151 lbs.
	Acre-value	$42.80	$24.70	$18.10

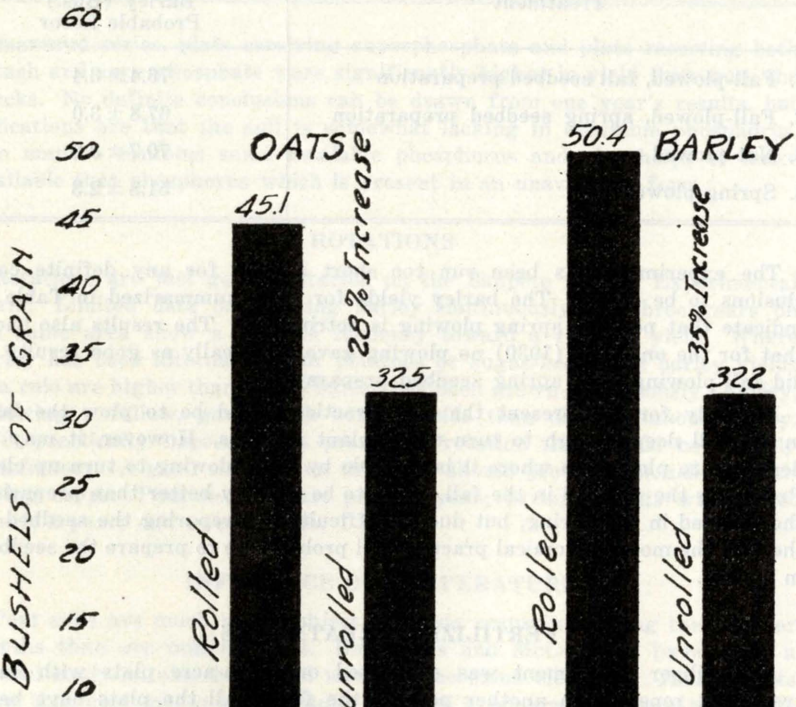

Figure 5—Effect of rolling the soil after seeding oats and barley, as compared with not rolling. The data presented represent the average of several tenth-acre plats for the 2-year period, 1929 and 1930. The yield of oats on the rolled plats averaged 28 per cent higher than on the unrolled plats; barley yields on rolled plats on the average were 35 per cent higher than yields obtained on the unrolled plats.

Figure 5 indicates the results obtained with barley and oats and are averages for the two years, 1929 and 1930. Peas show a proportionate increase but sugar-beets were a failure.

Plowing and Seedbed Preparation. An experiment was begun in 1929 for the purpose of obtaining information as to time of plowing and time of preparing the seedbed. The experiment included the following treatments: (1) Fall-plowed with fall seedbed preparation; (2) fall-plowed with spring seedbed preparation; (3) not plowed; and (4) spring-plowed in 1930. Each treatment is repeated three times; the following crops are being grown: Barley, canning peas, sugar-beets, sweet clover, and carrots.

TABLE 8.—ACRE-YIELDS OF BARLEY FROM PLATS PLOWED IN FALL OR PLOWED IN SPRING AND FROM SEEDBEDS PREPARED IN SPRING OR IN FALL AFTER FALL PLOWING

Treatment	Average Acre-Yield Barley (Bus.) Probable Error
1. Fall-plowed, fall seedbed preparation	76.4 ± 3.4
2. Fall-plowed, spring seedbed preparation ..	67.8 ± 3.0
3. Not plowed	70.7 ± 3.2
4. Spring-plowed	51.8 ± 2.3

The experiment has been run too short a time for any definite conclusions to be drawn. The barley yields for 1930, summarized in Table 8, indicate that perhaps spring plowing is detrimental. The results also show that for the one year (1930) no plowing gave practically as good results as did fall-plowing with spring seedbed preparation.

Probably for the present the best practice would be to plow the land in the fall deep enough to turn under plant residues. However, it may be desirable to plow deep where it is possible by deep plowing to turn up clay. Preparing the seedbed in the fall seems to be slightly better than preparing the seedbed in the spring, but due to difficulty in preparing the seedbed in the fall, the most economical practice will probably be to prepare the seedbed in spring.

FERTILIZER TREATMENTS

A fertilizer experiment was conducted on tenth-acre plats with each treatment repeated in another part of the field. All the plats have been seeded continuously to barley. Fertilizers have been applied each spring for the past three years. The 1930 season was the first time that yields were obtained from any fertilizer treatment which were significantly higher than those from no fertilizer. Fertilizer treatments and plat yields are given in Table 9.

In the series of plats receiving manure, no treatment shows a yield significantly higher than those of the manure checks. The yields on this series were much more uniform than were the unmanured series. On the

TABLE 9.—ACRE-YIELDS OF DUPLICATE 1/10-ACRE PLATS OF BARLEY WITH VARIOUS COMMERCIAL FERTILIZER TREATMENTS WITH AND WITHOUT FARM MANURE

Treatment	Acre-Yield (Bus.) Probable Error	Treatment	Acre-Yield (Bus.) Probable Error
Manure and lime	64.1 ± 5.9	Manure and potash	71.4 ± 6.6
Manure and gypsum	68.7 ± 6.4	Checks (No fertilizer)	31.4 ± 2.9
Manure and superphosphate	75.7 ± 7.0	Lime	56.5 ± 5.2
Manure and rock phosphate	77.3 ± 7.2	Gypsum	59.2 ± 5.5
Manure checks	66.0 ± 4.8	Superphosphate	67.9 ± 6.3
Manure, potash and superphosphate	72.7 ± 6.7	Rock phosphate	60.5 ± 5.6
Manure, potash and rock phosphate	64.1 ± 5.9	Checks	48.2 ± 4.5
		Potash and superphosphate	72.4 ± 6.7
		Ammonium sulfate	53.2 ± 4.9
		Potash	52.4 ± 4.9

unmanured series, plats receiving superphosphate and plats receiving both potash and superphosphate were significantly higher in yield than were the checks. No definite conclusions can be drawn from one year's results, but indications are that the soil is somewhat lacking in available phosphorus. The manure contains some available phosphorus and also helps to make available that phosphorus which is present in an unavailable form.

ROTATIONS

Rotations are just getting started on the Sanpete County Experimental Farm. Limited data on growing barley continuously for three years on the same area show a definite tendency toward a reduced yield. Where barley has been alternated with potatoes or sugar-beets, the barley yields as a rule are higher than where barley has been grown continuously. Barley, following a fallow, gave much better yields than did continuous barley. It is practically impossible to present a rotation that would be entirely satisfactory. A good rotation on this area should probably include the following crops: Potatoes, 1 year; peas, 1 year; barley or oats with sweet clover, 1 year; and sweet clover, 1 year.

INFLUENCE OF TEMPERATURE

Peat soils are much more subject to frosts occurring during the summer months than are mineral soils. Bouyoucos and McCool (4) have made a careful study on clay loam and muck at the same elevation. Their results show that heat moves more readily through a mineral soil than through a muck soil. An interesting illustration of this effect is described by Bouyoucos (5) 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 to prevent a frost. The clay, therefore, which manages to keep the surface warm will prevent a frost, while the muck which allows its surface to become cold will permit a frost. Plants, therefore, freeze more easily on mucks and peats than on mineral soils."

Frost injury during the summer months has been common on the Sanpete County Experimental Farm. Instances similar to the one described by Bouyoucos have occurred a number of times. Wherever it has been possible to plow up clay and mix with the muck, the injury has been slight as compared with straight muck. Rolling the muck has also decreased the amount of frost injury. Summer frost occurred, as shown in Table 10.

TABLE 10.—DATES ON WHICH FROSTS OCCURRED ON SANPETE EXPERIMENTAL FARM DURING 1927, 1928, 1929 AND 1930

1927	1928	1929	1930
May 29 June 20 August 14 September 1	June 2 June 19 July 7 August 24 August 29 September 10	June 3 September 9	May 23 June 14 September 12

Summer frosts were more frequent and did more damage during the first two years than during the last two years. This may be due to some extent to the fact that the soil is gradually becoming more compact.

CROP TESTS

Crops Adapted to Muck Soils

Barley. Trebi barley does well on soddy soil and is the best crop to raise for the first two years after the sod is broken, where the alkali is not too concentrated. Barley is not seriously injured by spring frosts and it matures early, thus escaping fall frosts. Good yields are obtained on soil fertilized with manure or acid phosphate. In maintaining high yields, rotations are also beneficial. A variety test including 25 selections and varieties was started during the 1930 season. No yields were obtained that were significantly higher than Trebi. The average acre-yield of Trebi was 72.2 bushels.

Oats. Swedish Select oats is the common variety grown. Where alkali is concentrated oats do better than barley. In fact, oats did well where barley was completely killed out by alkali. However, where barley grows well it yields more than do oats. A variety test of oats was started at the same time as the barley variety test; 64 strains and varieties of oats were included. The average acre-yield of Swedish Select check plats was 62.2 bushels. No significantly higher yields were obtained.

Wheat. Wheat has been tried each year. Near the edges of the swamp where the soil contains considerable clay, wheat has done well; however, in the muck soil for the first two years it was tried wheat was nearly a complete failure. During the past year a 45-bushel crop to the acre was obtained on the muck soil. Dicklow is not well adapted to muck soil. It lodges easily and is unusually susceptible to rust.

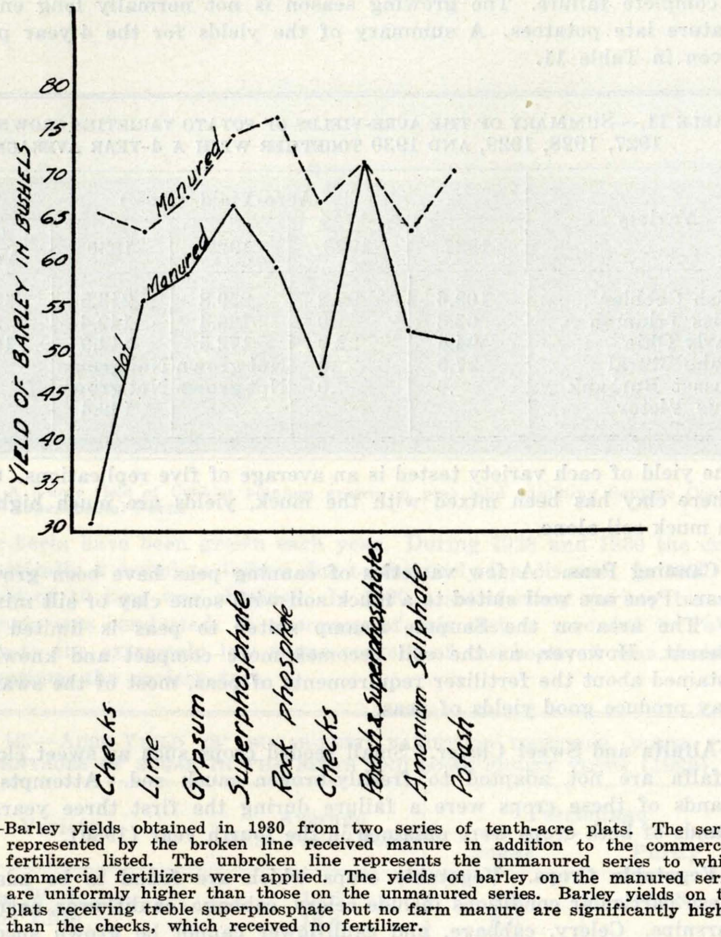

Figure 6—Barley yields obtained in 1930 from two series of tenth-acre plats. The series represented by the broken line received manure in addition to the commercial fertilizers listed. The unbroken line represents the unmanured series to which commercial fertilizers were applied. The yields of barley on the manured series are uniformly higher than those on the unmanured series. Barley yields on the plats receiving treble superphosphate but no farm manure are significantly higher than the checks, which received no fertilizer.

Near the edges of the area where clay has been plowed up and mixed with the muck, Dicklow, Federation, and two unnamed wheats, known as 14-85 and 01-24, products of the Agronomy Department of the Experiment Station, were grown in 1930. The yield data follow:

Variety	Acre-Yield (Bus.)
Federation	54.3
Dicklow	59.4
14-85	53.4
01-24	62.4

No special significance can be placed on one year's results, but they do indicate that satisfactory yields of wheat can be obtained.

Potatoes. Several varieties of potatoes have been grown, including both late and early varieties. The late varieties were grown during the first two years and were then eliminated from the test because they were a complete failure. The growing season is not normally long enough to mature late potatoes. A summary of the yields for the 4-year period is given in Table 11.

TABLE 11.—SUMMARY OF THE ACRE-YIELDS OF POTATO VARIETIES GROWN DURING 1927, 1928, 1929, AND 1930 TOGETHER WITH A 4-YEAR AVERAGE

Variety	Acre-Yield (Bus.)				
	1927	1928	1929	1930	4-year Average
Irish Cobbler	109.6	97.2	259.8	213.5	185.0
Bliss Triumph	63.3	.0	125.4	149.4	84.5
Early Ohio	94.5	22.0	172.5	114.9	100.9
Idaho Rural	27.0	.0	Not grown	Not grown	.0
Russet Burbank	.0	.0	Not grown	Not grown	.0
Blue Victor				149.4	

The yield of each variety tested is an average of five replications. On plats where clay has been mixed with the muck, yields are much higher than on muck soil alone.

Canning Peas. A few varieties of canning peas have been grown each year. Peas are well suited to a muck soil with some clay or silt mixed with it. The area on the Sanpete swamp suited to peas is limited for the present. However, as the soil becomes more compact and knowledge is obtained about the fertilizer requirements of peas, most of the swamp area may produce good yields of peas.

Alfalfa and Sweet Clover. Small seeded crops such as sweet clover and alfalfa are not adapted to freshly-broken muck sod. Attempts to get stands of these crops were a failure during the first three years. Good stands of both crops were obtained in the fourth year (1930).

Vegetable Crops. Vegetable crops which are found to be adapted to these particular conditions include celery, cabbage, cauliflower, carrots, and parsnips. Celery, cabbage, and cauliflower cannot be grown successfully unless irrigation water is available. Irrigation of the soil at the time the plants are set out has been found necessary. One or two subsequent irrigations have also proved valuable in most cases.

Crops Not Adapted to Muck Soils

Attempts have been made to grow most of the crops commonly grown in the state. It was soon found that the more tender crops, because of summer frosts, could not be grown successfully. These crops include cucumbers, cantaloupes, melons, squash, tomatoes, eggplants, peppers, corn, and beans.

Other crops that have been partial failures due to other causes are onions, lettuce, asparagus, and sugar-beets. It is possible that when more is known about their requirements, some of this group of crops will do well on this area.

Figure 7—A 5-acre field of Cobbler potatoes grown on peat land adjoining Sanpete County Experimental Farm.

Sugar-beets have been grown each year. During 1928 and 1930 the crop was practically a complete failure due to the curly-top disease. In 1927 an acre-yield of 10 tons was obtained. In 1929 a satisfactory variety test of sugar-beets was conducted. A summary of this test is recorded in Table 12. Due to the extremely low sugar content of the beets, it was decided to discontinue the variety test.

TABLE 12.—ACRE-YIELD OF SUGAR-BEET VARIETIES TOGETHER WITH THE PERCENTAGES OF SUGAR IN THE BEETS AND SOME PURITY TESTS (1929)

Variety	Average Acre-Yield (Tons)	Percentage	
		Sugar	Purity
1 Dippe W. I.	11.6	8.0	62.3
2 Baune Elite	12.8	8.0	
3 Strube	13.2	7.8	
4 Dobrovice	15.6		
5 Hartman	14.8	6.1	56.2
6 R. & G. Pioneer	13.7		
7 Schreiber S. K. W.	15.0		
8 Fredericksen	14.1	7.6	66.5
9 Janascz	12.1	8.7	68.2
10 Ramon	13.7	9.1	69.0
11 Ivanovka	13.9	8.5	70.2
12 R. & G. Pioneer	12.9	9.7	
13 Uladovka	14.3	6.9	66.6
14 Bielotzerkov	13.7	7.1	
15 Vierchniatchka	15.1	8.7	
16 Kalnik	13.7	11.4	
17 Factory Seed (Strube)	12.6	9.0	

SUMMARY

Sod-breaking and Pulverizing. Sod-breaking is best accomplished when a special sod plow is used in order that the sod may be turned completely upside down. Where it is not possible to turn up clay, and where the sod is heavy, cropping should be delayed until the second or third year after breaking. Sod should be disked only enough for weed control.

Soil Moisture. The soil of the district has a high water-holding capacity. If the soil is flooded during the winter it retains enough moisture to mature most of the field crops with satisfactory yields. In setting out celery and cabbage plants, irrigation is necessary.

Alkali. Alkali is concentrated in the surface soil. Barley yields have increased with decreased salt content and have decreased with increased salt content of the soil.

Ground Water. The water-level in spring is probably too high for best results. A water-level that averages about 3 feet below the surface is about right for general field crops, although it may be somewhat higher during the early part of the season.

Rolling. Rolling the soil with a heavy cement roller has given increased yields of barley, oats, and peas, as compared with unrolled plats of the same crops.

Plowing and Seedbed Preparation. Poor yields resulted from spring plowing. No plowing has given practically as good results as has fall-plowing. Fall plowing is recommended to permit the turning under of plant residues and in some cases the turning up of clay. Preparing the seedbed in the fall seems to be slightly better than preparing it in the spring. However, it is more economical to prepare the seedbed in spring.

Fertilizers. On those plats receiving the following fertilizers, barley gave increased acre-yields: (1) Manure, (2) superphosphate, (3) potash and superphosphate, and (4) manure and superphosphate.

Frost. Muck soils are more subject to frost occurring during summer months than are mineral soils. Where clay is mixed with the muck there is less injury from summer freezes. Compacting of the soil is also somewhat beneficial in avoiding frost injury.

Crop Adaptability. The crops that have succeeded include barley, oats, wheat, canning peas, early potatoes, sweet clover, celery, cabbage, cauliflower, carrots, and parsnips. Cucumbers, tomatoes, peppers, beans, and corn so far have been failures.

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CONTENTS

DISCUSSION AND RECOMMENDATIONS

The problems involved in the reclamation of this area are strikingly different from those of other reclamation projects of the state. Little experimental work has been done with peat and muck soils in the United States. Most of the work that has been done is recent. Up to the present time the Michigan and Minnesota Stations have taken the lead in this field. While the muck soils formed in the more humid parts of the country as a whole are similar in many respects to the muck soils of Utah; nevertheless, there are many differences, due to climate as well as to the mineral soil material washed into the muck from the surrounding regions, all of which makes this problem unique. The more fundamental physical and chemical characteristics of soil which class it as a muck soil are necessarily similar to muck soils found in other parts of the country. In the study of this area experimental results from Michigan and Minnesota have in many instances proved valuable.

Due to the fact that experimental work has been conducted for a short time only, in many cases specific results obtained can only be suggested. However, experiments have been under way sufficiently long to enable the writers at this time to present some of the more important problems, as they see them.

A proper realization of the possibilities of the region should help to eliminate hazardous undertakings. It is thought that under the present physical and economic development of the project, the production of vegetable crops on a large scale is not warranted. While celery seems well adapted and is of excellent quality, before success can be assured there are many problems that need further study. Farmers would do well to consider the value of growing feed crops for their livestock. Since the major occupation of the valley is livestock raising, additional supplies of grain should prove of value in making it possible to fatten stock at home.

Peas and potatoes grown on selected areas should be successful as cash crops. The desirability of rotation and of fertilization should be borne in mind. Proper rotations and fertilizers will go far toward establishing and maintaining a permanent agriculture for the district.

The control of soil alkali is a problem of considerable importance. During the summer months water is being carried upward by capillarity and much of it evaporates, leaving the salts it carries to concentrate in the surface soil.

Flooding the soil should aid materially in keeping the salt out of the surface soil as well as in carrying it off the land into the drains. The construction of a center drain in the bottom of the swamp, running throughout its entire length, as well as dredging the river bed below the district are thought to be necessary for the success of the project.