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REPORT

of

COMMITTEE ON THESIS

THE undersigned, acting as a committee of the Graduate School, have read the accompanying thesis submitted by James E. Chapman for the degree of Master of Science. They approve it as a thesis meeting the requirements of the Graduate School of the University of Minnesota, and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science.

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May 27 1915

A STUDY OF THE FERTILIZER REQUIREMENTS OF A HIGH MOOR.

A thesis submitted to the Faculty of the Graduate School of the University of Minnesota,

by

James E. Chapman,

in partial fulfillment of the requirements for the

Degree of Master of Science

June - 1915.

TABLE OF CONTENTS.

Table of Contents (Continued)

TABLES

PLATES

M A P S.

Photos.

A Study of the Fertilizer Requirements of a High Moor.

By

James E. Chapman.

INTRODUCTION.

Weber gives the following definition of **PEAT**:

"It is a mixed humus rock in which the humus is present in the form of Ulmin-bodies. The plant residues either retain their original form or they are more or less, and at times completely, disintegrated. On drying the peat forms a more or less coherent hard mass, which in being broken forms sharp-cornered fragments. By prolonged contact with water, the air-dry substance swells more or less according to the kind of plant residues it contains, and the degree, and perhaps the kind, of humification which it has undergone, but, even when completely softened never forms earthy, crumbly masses."

The same author defines **MOORS** as "deposits of peat in which, after drainage, there is a peat layer of at least 8 inches in thickness., HIGH MOORS are those which have convex surfaces, being highest in the middle. While many in Europe show such a convexity that it may be recognized by the naked eye, such have not as yet been reported in northern Minnesota, altho according to Davis (2) railroad profiles show a distinct convexity in the case of the larger bogs. The term HIGH MOOR refers to this convexity and not to the elevation above sea level, many high moors having an elevation of only a few feet above the sea, as is the case with the very large areas of moorland adjacent to the city of Bremen in Germany. LOW MOORS are low in the center, or, in other words, have a concave surface, they having resulted from the filling up of a former lake with the remains of aquatic vegetation, largely sedges, rushes, reeds and other plants that require a liberal supply of nutrient salts. High moors, on the other hand, are derived largely from sphagnum moss, together with various members of the heath family and also Eriophorum. Stunted coniferous trees, especially tamaracks, frequently occur. These plants, characteristic of high moors, grow only when the surface of the bog is above the average water-level, and are chiefly dependent upon the rainfall for their moisture. As a result the nutrient salts are steadily washed away from them and the chief supply is secured from capillary moisture, or from the decay of the preceding year's growth. Chemically high moors are distinguished by their low lime content.

The great success which had been attained by the application of the Rimpau method (3) of sand-cover in the case of low moors caused the Prussian Government, on the acquirement of Hanover, to plan an extensive reclamation project on the large peatland areas belonging to the government near the coast of the North Sea. The drainage operations were begun with and completed by the use of French prisoners during the Franco-Prussian war. The attempted farming operations which then followed showed that the Rimpau method was a complete failure on these lands. Accordingly, a Peat Experiment Station was established at Bremen in 1877. A few years before the Stassfurt Potash Salts had come into extensive use for agricultural purposes, while phosphorous fertilizers had been employed more or less extensively for the preceding thirty years. The Bremen Station (4) soon devised a satisfactory system for the reclamation of the high moors tributary to it. This consisted in first properly draining the moor, without unduly depressing the water-level, then using a heavy application of lime, (one to two tons per acre) which was followed by a heavy initial dressing of phosphates and potash salts. Nitrates were necessary unless legumes were employed. Following the first year of fertilization annual dressings of potash and phosphorous were given all crops and nitrates were used except with legumes. It was at first supposed that the Bremen method would be found satisfactory in the case of all high moors, but experiments at the various European Peat Experiment Stations, especially those at Flahult in Sweden (5), Bernau (6) in Bavaria, and Admont (7) in Austria, have shown that when the climate differs the Bremen method applies only in part. The precipitation and the temperature of the district affect not only the crops which may be grown, but also the amount and kind of fertilizer which should be employed, and especially the influence of the relative level of the ground-water. Thus, on some of the Alpine moors, where there is a heavy precipitation, it has been found impossbile to over-drain the bogs, the maximum crop being obtained on the banks of ditches 12 feet deep, while at Bremen maximum crops of hay require a water-level of not more than 20 inches from the surface. In the U.S. no peat land fertilizer experiments in any way comparable with European investigations have as yet been undertaken.

The bog on the Grand Rapids Experiment Station Farm is a typical high moor as shown both by the following analysis of a sample taken from the wild bog in 1914, and in the typical high moor vegetation occupying the virgin parts of its surface.

Vegetable matter	93.01 per cent
Ash	6.99 " "
Insoluble matter	5.49 " "
Nitrogen	2.00 " "
Calcium oxide	0.63 " "

A small part of this bog had been under experiment for a number of years with the results described below. These were so discouraging that they could lend little support to any scheme of development of such lands. In order to test out the possibilities insofar as was feasible in a single season and under the conditions prevailing, the experiments described in the following pages were carried out. Attention should be called at this point to the limitations under which the work was inaugurated. The acreage was limited to a little over one acre of land which had been under experiment with fertilizers for a considerable time, they having been applied to about 5/6 of the area in 1911 and again in 1912. There were distinct evidences of the wind having blown some of these beyond the limits of the plots for which they were intended. Other such disturbing factors may have existed without their presence having been revealed. On account of the repeated crop failures weeds had developed luxuriantly on most of the bog with the result that some of the crop failures reported below in the case of uncultivated crops may be due almost entirely to the action of the weeds. Further the water level is not uniform under the bog, thus causing a more liberal supply of moisture to certain parts than to others, especially during such a prolonged drought as characterized the past season. One extremely unfavorable condition was the absence of the protecting ditch which should be thrown around every experimental area on peat soil. As the result of the absence of this guard ditch a torrential rain late in June caused such a heavy run-off from the surrounding mineral soil that the bog was flooded. Potassium salts do not become well fixed in the peat soils, which differ in this respect from mineral soils. As a consequence large amounts of potash as well as of nitrates were probably moved from the fertilized to the unfertilized plots thru the action of the flood-water, which, however, would not affect the distribution of lime and phosphates. The frequent occurrence of summer frosts should not be regarded as due to any unusually unfavorable condition, but as an essential part of the climate of all peat lands in high latitudes.

Many of the measures taken were due to the desire to give the plants every opportunity to show whether peat soil on this high moor could, under favorable conditions, give satisfactory returns. The question of whether or not it would pay was entirely subordinated to that of what the soil, both when unfertilized and when fertilized, would produce.

The investigation was undertaken at the

suggestion of Professor F. J. Alway and carried out under his supervision, he making frequent visits to the bog. The writer spent the whole of the summer on the Grand Rapids Experimental Farm and remained there until the potato crop was harvested in October. Most of his time was spent either on the bog or close to the bog, it being necessary even to spend many nights watching the potato plots. Acknowledgment should be made at this point to the great assistance in the work rendered by Professor A. J. McGuire not only by advice, but also by the liberal supply of man and horse labor whenever this was needed. Without his hearty cooperation the work could not have been satisfactorily carried through. Acknowledgement should also be made of the assistance of Mr. O. I. Bergh after he assumed charge of the farm in August.

Previous History of Grand Rapids Muskeg.

The following account, which covers the period from the first attempt to reclaim the muskeg in 1898, up to the close of the crop season of 1913, is taken from the thesis of De F. Hungerford.

"In 1898 open ditches had been dug to remove the surface water from two of the areas of peat soil. These were found to be unsuccessful because the soil caved in, filling the ditches. In 1899 a cribbing was built of tamarack poles to support the sides of the ditches which gave the surface water a chance to run off. The layer of moss was then stripped off from a portion of the soil which the next year was seeded to oats and grass. No report of the results of this test was found but it was probably unsuccessful, since in 1903 Mr. H. H. Chapman, Superintendent of the farm stated: 'The experiment farm has worked for 7 years upon a

small muskeg 10 acres in extent. A portion of the swamp has been drained since 1896 and another piece since 1898. On both pieces the moss was stripped off after failing to get rid of it by burning. A horse and three-pronged hook was used to tear up the rough bunches of moss and shrubs and haul them off. The ground was left to rot but after rotting 3 and 5 years respectively the swamp has not been gotten into tame meadow! . . . . Apparently no further attempts were made to subdue the muskeg until 1910. . . . .
In 1910 a part of the farm including a portion of the peat soil was drained with tile. Professor John T. Stewart states regarding the peat as follows: 'Approximately 12 acres of peat land varying from 8 to 20 feet in depth of the peat deposit was underdrained, the object to determine the effects of tile on lands of this character, and later to

determine their value for agricultural purposes by planting them to various crops.'

"In the spring of 1911 a fertilizer experiment, planned by members of the Agricultural Division and Professor Ralph Hoagland, was started on the peat soil that had been drained the year before. The original plan of the experiment called for a 4-course rotation consisting of corn, oats, potatoes and barley, each crop to be represented each year on a series of six 1/10 acre plots. When the time came to lay out the plots, however, it was found that insufficient land had been prepared, so rather than reduce the number of plots which would interfere with the rotation the size of the plots was reduced."

Corn, oats, barley and potatoes were planted, and on June 20, 1911, the following report was made on the general appearance of the crop.

"

Plot	Fertilizer	Corn %	Oats %	Barley %	Potatoes
1	Nitrate of Soda	100	100	65	
2	Acid Phosphate	90	70	45	
3	Sulphate of potash	95	80	45	
4	Ground limestone	95	95	50	(Not reported)
5	Manure	97	90	75	
6	Check	85	60	30	

"The crops were not harvested because the wet condition of the soil made it impossible to get on the land with teams.

"The experiment which was continued in 1912 gave no results because the land was too wet for crops in the early part of the spring, and potatoes were substituted on all of the plots, which were killed by frost on July 19. The fertilizers were applied on May 18, by Superintendent McGuire, ground limestone being omitted.

"In 1913 no fertilizer was applied, but all of the plots were seeded to oats. August 20, the plots were examined and a very marked residual effect from the application of ground limestone could be seen. The lime plots and the manure plots were the only ones upon which the oats were doing well, and the manure plots were much better on the side next to those which had been treated with lime, suggesting the possibility that the wind had carried some of the powdered limestone over onto them while it was being applied. On the remaining plots smartweed was more abundant than the oats. . . . . The crop failed to ripen and was not harvested."

An examination of the plots early in May by Professor F. J. Alway indicated that ground limestone had been carried by a west wind at the time of its application over onto the plot to the east; thus Plots 3, 9, 15 and 21 had all been affected. The evidence of this lay in the rank growth of straw found on the plots treated with manure and limestone, and extending more or less to the eastward upon the potash plots. On all the other plots, as well as the unaffected portions of those treated with potash, there was practically no growth of straw,but a heavy residue of smartweed.

Climate at Grand Rapids.

Previous to June,1914, there is no meteorological record for either the experimental farm or the village of Grand Rapids, the nearest station of the U. S. Weather Bureau being Pokegama Falls, 2½ miles west of the village and 5 miles west of the farm. At this place observations have been made since May 1887. As the altitude and other conditions are similar to those at the experimental farm, it is probable that the data may serve to correctly indicate the climate at the latter and even to a considerable degree of accuracy the weather of any particular year. Accordingly in the following discussion of the climate at Grand Rapids it is assumed that it is the same as that at Pokegama Falls. The extreme importance of the different factors of climate in such a study as this is evident from the discussion of the experience of European Peat Experiment Stations referred to above and also from the effects of torrential rains and summer frosts which were experienced on the experimental tract in 1914, and which are discussed in detail in later portions of this thesis.

The annual precipitation for the past twenty-seven years is reported in Table I. It occurs chiefly as rain, over two-thirds falling during the growing season of grasses and clovers. Periods of summer drought such as occurred in 1914 have appeared at rather long intervals, viz: July 1894, May and June 1900, July 1906, May and June 1909, and lastly July and the early part of August 1914. Torrential rains are not infrequent, those in which the precipitation in 24 hours exceeds 2.00 inches occurring about once a year, thus showing

Table I

Precipitation at Pokegama Falls, Itasca Co.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec..	Annual
1887	---	---	---	---	3.79	5.36	5.29	2.37	1.58	2.81	0.73	2.65	
1888	1.13	0.45	1.93	2.17	2.75	9.39	3.97	0.76	1.56	1.68	1.16	0.18	27.13
1889	1.34	1.61	1.34	1.82	1.18	2.08	4.32	6.21	2.71	0.31	1.30	1.43	25.65
1890	0.65	0.95	1.21	1.27	1.76	7.42	2.64	3.16	3.91	2.81	0.59	0.26	26.63
1891	0.84	1.63	1.37	2.53	0.59	4.53	5.24	3.14	2.25	1.87	1.00	1.01	26.00
1892	1.00	0.57	1.21	2.69	5.12	1.35	4.00	3.55	1.20	0.28	1.38	0.24	22.59
1893	1.62	1.39	1.35	2.87	2.17	3.22	5.70	4.04	1.23	0.69	0.92	1.04	26.24
1894	1.11	0.21	3.80	4.35	4.21	5.79	0.36	1.89	3.57	4.52	0.92	1.28	32.01
1895	0.61	0.39	0.00	1.54	5.32	6.28	3.65	2.56	3.99	0.18	1.53	0.48	26.53
1896	0.88	0.20	1.40	5.66	7.26	3.13	2.39	2.42	1.72	3.79	2.69	1.04	32.58
1897	1.71	1.73	2.15	1.63	1.50	5.01	7.53	3.37	1.29	1.27	0.35	0.67	28.24
1898	0.27	0.57	1.14	0.62	3.19	5.57	5.40	4.01	2.10	2.58	1.46	0.64	27.55
1899	0.75	0.52	0.58	2.13	7.21	6.81	3.70	8.13	2.83	3.45	0.47	0.65	37.23
1900	0.55	0.31	0.39	0.44	1.10	0.58	3.65	9.85	6.79	4.20	0.78	0.71	29.35
1901	0.26	0.28	4.11	1.94	1.14	9.27	5.09	1.49	1.31	2.67	1.44	0.64	29.64
1902	0.55	0.62	1.20	1.20	5.03	2.44	3.04	5.45	1.76	1.97	2.55	1.32	27.13
1903	0.42	0.98	0.72	2.85	4.43	1.30	2.67	4.53	5.90	3.65	1.10	1.22	29.77
1904	0.13	1.26	1.96	1.03	1.06	2.46	4.76	1.39	4.49	2.75	0.36	1.01	22.66
1905	0.47	0.08	1.78	3.07	4.53	9.16	5.80	3.45	4.00	2.73	2.39	0.30	37.76
1906	1.30	0.15	1.10	1.32	4.63	4.09	0.67	4.53	3.15	2.13	2.73	0.87	26.67
1907	1.00	0.17	1.02	1.53	2.57	2.81	3.17	3.05	3.09	1.34	0.65	0.57	20.97
1908	0.32	1.03	1.48	1.48	6.03	4.66	3.95	0.90	2.19	1.31	1.21	0.38	24.94
1909	1.37	1.07	0.65	1.61	0.88	1.00	3.45	6.33	4.57	1.38	1.20	1.22	24.73
1910	0.32	0.61	0.29	1.49	2.20	1.68	5.76	2.36	3.93	0.51	0.89	1.21	21.25
1911	0.54	1.00	1.24	1.51	3.50	4.49	4.73	4.63	4.72	0.91	0.77	0.51	28.55
1912	0.15	0.04	0.16	1.19	3.60	1.78	2.94	2.30	3.52	0.18	0.33	0.78	16.97
1913	0.24	0.44	1.85	2.17	4.18	3.48	7.95	4.09	3.66	3.43	0.87	0.07	32.43
1914	0.54	0.47	0.95	2.42	1.92	5.13	1.01	3.07	3.92	1.32	0.65	0.12	21.52
Mean of 27 years	0.74	0.69	1.35	2.02	3.30	4.26	3.97	3.72	3.16	1.99	1.17	0.74	26.77

Table II. Torrential Rains (over 2.00 inches in 24 hrs.) at Pokegama Falls during the past 21 years.

Year	Month	Day	Amount in inches
1893	August	10	2.62
1895	May	25	2.60
"	September	23	2.15
1896	May	15	2.20
1898	July	1	2.14
"	August	22	2.10
1899	August	17	2.74
1900	August	6	2.03
"	August	20	3.20
1901	March	24	2.03
"	June	24	4.32
1902	August	31	2.35
1906	August	21	2.05
1908	May	25	2.39
1909	September	13	2.70
1910	July	23	3.18
1914	June	27	2.30

Table III

Mean monthly Temperatures at Pokegama Falls. (Elevation 1290 ft)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
1898	-9.5	8.9	25.4	39.6	50.6	61.7	65.5	61.8	55.8	39.1	25.0	4.4
1899	0.3	-1.6	8.2	39.2	49.7	60.7	66.0	64.0	51.7	44.2	35.4	12.8
1900	10.9	-2.4	18.0	47.4	55.0	62.2	63.4	70.4	55.7	51.8	22.7	11.6
1901	1.1	0.0	18.4	41.2	54.1	60.4	68.8	65.5	53.3	43.6	22.9	7.4
1902	9.1	5.6	30.7	40.0	56.0	59.9	69.0	61.4	50.3	40.9	28.2	7.6
1903	2.9	4.4	25.0	39.4	53.6	58.8	63.6	58.8	52.3	44.8	20.1	-0.6
1904	-4.2	-6.8	18.4	34.2	50.0	58.6	60.7	60.0	50.0	40.5	29.7	5.2
1905	-6.8	-.2	22.6	34.6	49.8	59.5	64.8	65.8	59.2	41.0	28.7	16.8
1906	14.2	8.8	16.2	45.0	49.5	62.0	66.2	64.8	61.2	44.1	29.2	10.9
1907	-1.2	10.4	22.8	30.8	41.8	61.1	65.0	63.5	53.4	42.4	29.0	17.6
1908	12.4	15.2	23.0	42.9	50.6	60.6	67.0	61.8	60.8	45.7	31.1	13.4
1909	5.8	8.4	21.9	30.9	50.1	63.4	66.4	66.6	55.6	42.0	30.8	8.6
1910	9.6	3.5	38.0	46.0	48.6	65.6	66.3	61.1	54.9	47.8	22.4	9.8
1911	0.6	12.5	28.8	40.8	56.2	65.8	64.8	61.0	53.0	41.2	18.6	17.3
1912	-11.8	5.5	16.0	42.3	52.8	58.2	65.9	59.4	55.3	45.0	30.5	16.5
1913	1.6	3.6	14.0	43.2	48.6	64.2	63.3	65.0	54.4	39.5	34.5	24.3
1914	12.5	-2.6	21.4	36.4	55.0	59.6	68.8	62.3	56.8	50.2	29.1	7.5
Mean from 1898 -- 1914	3.9	4.3	21.7	39.6	51.3	61.3	65.6	63.1	54.9	43.8	27.4	11.2

Table IV

Monthly Maximum Temperatures Pokegama Falls.

	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1888							85		78	69	54	--	
1889	47	50	65	72	75	92	90	88	85	74	50	--	92
1890	45	42	46	71	81	94	92	89	81	76	59	44	94
1891-	42	39	49	83	--	88	85	--	--	--	--	--	--
1892	--	--	56	65	75	--	--	91	83	74	--	32	--
1893	35	40	51	54	75	96	92	89	87	70	70	36	96
1894	54	45	60	76	76	92	98	90	87	69	39	47	98
1895	29	50	52	79	85	87	90	87	89	71	56	45	90
1896	34	50	48	74	88	91	91	91	79	75	35	46	91
1897	39	31	55	63	86	93	93	82	89	82	59	35	93
1898	40	44	56	71	81	90	89	86	90	74	56	40	90
1899	35	45	36	76	78	82	90	89	81	71	62	49	90
1900	50	37	53	82	90	95	88	95	87	78	61	40	95
1901	38	38	50	77	86	91	99	92	88	77	50	39	99
1902	49	50	69	79	95	90	95	87	80	72	54	42	95
1903	36	43	60	74	82	85	91	85	85	69	70	30	91
1904	36	37	46	75	83	87	91	89	79	68	71	44	91
1905	30	42	52	75	78	86	89	88	84	81	57	47	89
1906	48	49	52	78	81	86	91	92	92	85	55	35	92
1907	34	49	53	57	74	90	86	90	83	74	52	43	--
1908	53	42	57	82	80	84	92	88	89	79	58	42	--
1909	39	43	50	64	79	89	87	89	76	81	61	42	--
1910	40	38	76	76	74	96	93	87	85	84	42	38	--
1911	35	44	60	76	88	98	94	86	80	70	40	43	--
1912	25	36	49	78	80	94	89	84	89	79	57	43	--
1913	38	32	47	84	86	92	89	89	90	76	67	56	--
1914	41	46	50	67	85	83	94	91	83	79	59	42	--
For 27 Years	54	50	76	84	95	98	99	98	90	85	71	56	

Table V

Monthly Minimum Temperatures at Pokegama Falls.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1888								41	23	18	-9	-19	
1889	-33	--	-8	13	17	30	36	34	21	11	-25	--	
1890	-38	-36	-40	-17	16	43	38	34	24	12	-7	-24	40
1891	-26	-30	-40	15		20	34						
1892			-29	3	22			32	22	12		-37	--
1893	-40	-39	-30	10	19	31	45	34	20	6	-25	-40	-40
1894	-47	-42	-24	10	20	28	42	34	12	18	-24	-28	-47
1895	-42	-54	-24	15	18	33	39	32	26	8	-18	-23	-54
1896	-45	-35	-30	-16	29	39	38	30	18	5	-45	-51	-51
1897	-49	-50	-49	8	18	21	46	35	25	14	-13	-33	-50
1898	-32	-37	-17	7	24	33	40	36	28	14	-31	-57	-57
1899	-54	-50	-38	-17	21	36	37	38	17	18	10	-25	-54
1900	-38	-41	-26	14	19	28	37	41	28	22	-17	-45	-45
1901	-47	-38	-28	10	24	26	40	35	20	13	-8	-47	-47
1902	-50	-37	-17	6	22	31	41	40	24	15	-8	-45	-50
1903	-39	-59	-10	4	14	25	33	32	19	14	-37	-45	-59
1904	-57	-55	-41	4	19	32	34	27	15	11	-12	-37	-57
1905	--	--	-32	7	24	34	43	43	29	5	-25	-15	--
1906	-26	-39	-28	18	19	38	41	32	27	5	8	-31	-39
1907	-38	-47	-19	5	14	31	42	31	21	18	1	-19	-47
1908	-42	-27	-16	5	18	30	35	32	31	13	2	-19	-42
1909	-44	-37	-20	5	19	33	39	41	28	10	2	-32	-44
1910	-31	-43	2	15	18	32	37	33	26	21	-10	-39	-42
1911	-45	-34	-15	-1	19	35	38	33	28	10	-14	-18	-45
1912	-53	-36	-32	16	26	30	34	32	24	16	0	-16	-53
1913	-42	-37	-37	12	19	30	39	41	18	3	4	-3	-42
1914	-36	-46	-20	6	23	34	39	32	27	18	-5	-25	-46
For 27 Years	-57	-59	-49	-17	14	20	33	27	12	3	-45	-57	

Table VI. Frost data for Pokegama Falls during past 27 years. Unless indicated by # the datum is simply the last or first reading of 32.0° or lower. Otherwise the observer reported that tender vegetation had been killed.

Year	Last Frost of Spring	First Frost of Autumn
1887	June 5	August 25
1888	" 3	" 17
1889	" 22	September 8
1890	May 27	" 14
1891	June 6	———
1892	" 2#	August 31
1893	" 9	September 2
1894	" 4#	" 2
1895	May 21# (27)	August 21
1896	May 31	" 28
1897	June 7	September 17
1898	May 17	" 9#
1899	" 23	" 13
1900	June 30#	" 17
1901	" 8#	" 8
1902	" 23	" 12#
1903	" 11	August 30
1904	" 15#	" 29#
1905	May 8# (28)	September 13#
1906	" 28	" 29#
1907	June 14	August 20#
1908	" 14#	September 28#
1909	May 10# (26)	" 1#
1910	" 26# (June 5)	" 9#
1911	" 13#	" 3#
1912	June 8	August 2
1913	" 8	September 21#
1914	May 23#	October 13

that the flood on the 27th of last June is not to be regarded as at all exceptional. These rains are recorded in Table II.

Tables III, IV and V record the mean, maximum and minimum temperatures for the past 27 years insofar as these are available, except that the data for the minimum temperatures previous to 1898 were found so incomplete that they have not been included in Table III. No temperature of 100 degrees or more has so far been recorded altho temperatures from 90 to 99 degrees have frequently been recorded during June, July and August. Minimum temperatures of from 50 to 60 degrees below zero have occasionally been experienced in December, January and February. These however have little influence upon agricultural conditions. The extremely important late spring and early autumn frosts which determine the length of the growing season are recorded in Table VI. It will be seen that while frosts in June and August are by no means rare, none has so far been recorded for July. The data obtained on the bog in 1914 make it probable that if a weather station were maintained on an area of peat land July frost would be found of frequent occurrence.

Drainage.

In order to have an opportunity to study the capacity of the main tile line and the rate of flow of water thru this, two pits, No.1 and No.2 shown on Map III, were dug in June and a tile removed from the main line at each place. The pits were left open thruout the summer for observation. Various attempts to control the water-level of the bog by damming these tile lines proved unsuccessful on account of the ease with which the water made a channel thru the yielding peat surrounding the tiles.

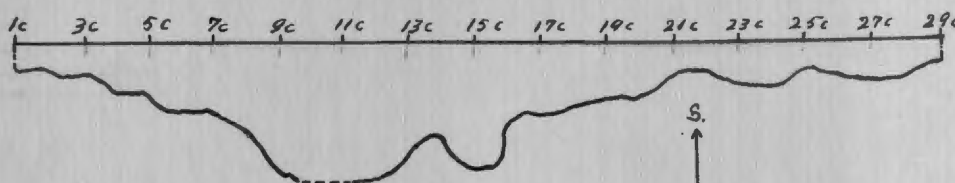
On June 11 the depth of water which was running slowly in the 16 inch tile was 2 inches. The flood of June 23, which covered the whole bog and raised the water-level on part of it above the surface presented an unusual opportunity to determine whether the main line would carry away the water as rapidly as it was delivered to it by the laterals shown on Map III. On June 28, less than 36 hours after the flood, measurements of the water in the main line showed that this was only 4.2 inches in depth at Pit 1 and 3.5 inches at Pit 2. Daily measurements were made from July 1 to July 12, during which time the water gradually fell to a depth of from 0.4 to 0.5 inches. This shows conclusively that the main line is able to handle far more water than the present laterals are able to deliver to it on account of the slowness with which water moves thru the peat. The temperature of this flowing water was determined daily from July 3 to July 11. The lowest temperature recorded was 48°F. and the highest 51°F. Soon after July 12 the main tile became quite dry and so remained during the growing season.

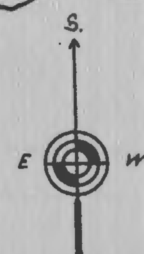
It will be seen from the maps that laterals passed under Plot 11-N, 12-S, 24-N, 24-S and 23-S. An attempt to evaluate the effect of these upon the crop yields was made in considering the effect of the varying water-levels and fertilizer treatments upon the crop yields, but I could find no effect which was distinctly due to the presence of these laterals.

The east lateral affords some protection from flood-water coming from the adjacent sloping mineral soil, while the main line, lying in a slight depression, partly protects the bog from the south. The west lateral serves as partial protection against storm-waters from the west. A shallow ditch at the north edge of the experimental plots may guard to some extent against a flood from the north, but at the same time may serve to lead any water from a heavy inflow from the east in such a way as to spread it over the whole of the north plots. The inflow from this may account for what appears to be a generally lower yield on this side

PLATE I - DRAINAGE

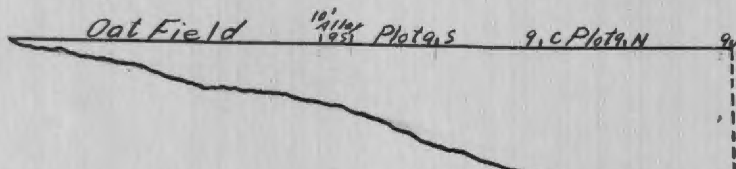
PROFILE I - Showing the depth of the bog along the center row of wells. (East to West)





Horizontal Scale 1" = 100'
Vertical Scale 1/8" = 1'
1c, etc. Wells.

PROFILE II - Showing the depth of the bog thru plots 9N, 9S and Oat Field. (North to South)



Horizontal Scale 1" = 50'
Vertical Scale 1/8" = 1'

than on the south, especially in the case of the oats, grasses and clovers.

Unfortunately the water resulting from the torrential rain of June 26-27 had escaped from the bog before daylight so that I was unable to observe the manner of its sudden appearance and speedy disappearance..

Weather of the Crop Season of 1914.

The precipitation on the bog from June 7, to September 23, is reported in Table VII. The readings were made daily at 5 P.M.

The rainfall on the bog for this period was nearly 2 inches below the normal due chiefly to the great deficiency in July, the rainfall of 1.01 inches being 2.67 below the normal for that month at Pokegama Falls. July of 1884 with a rainfall of 0.36 inches, and of 1906 with 0.67 inches are the only years during the past 27 with a lower recorded precipitation for this month. That for the months of June, August and September did not depart markedly from the normal for these months. On the whole the growing season was abnormally dry, the drought occurring at the most critical period of growth for many crops. The only torrential rain was that occurring during the

Table VII. Precipitation on Grand Rapids Bog during growing season of 1914.

	June	July	August	September
1	x	t	t	t
2	x			t
3	x	t		t
4	x	0.3		
5	x		t	t
6	x	t		
7	0.5		t	t
8	0.5	t		
9	0.3		t	
10		t	t	1.6
11	t			
12		0.5	t	
13			0.1	0.7
14				0.7
15			0.2	
16		0.1		t
17				
18			t	
19	0.5			
20	0.2			
21				0.4
22		0.1	1.8	
23	t		0.2	0.1
24	0.3		t	1 5
25		t	0.3	
26	t	0.1	t	
27	2.4			
28	0.1			
29			0.2	
30	0.3	0.2	0.3	
31	0.1		0.1	
Total	5.1	1.3	3.2	3.5

x- No measurement, but only traces.

night of June 26-27 when 2.4 inches fell. One rain gauge was kept on the mineral soil beside the thermometers mentioned below and one on the bog. The precipitation was, day by day, the same with each, and, for this reason, only that on the bog is mentioned in the table.

With the temperatures the situation was so different that extreme importance attaches to the differences between the minimum air temperatures over the bog and those over the adjacent mineral soil. The location of the maximum and minimum thermometers on the mineral soil was approximately 20 feet higher than that of those on the bog. The former were placed about 4 feet above the surface of the ground and the latter about 1 foot. All the temperature readings on these thermometers have been corrected by comparison with a standard instrument. All readings were made at 8 A.M. daily.

Table VIII. Maximum, minimum and mean temperatures on the Grand Rapids bog during June, July, August and September, 1914

	June			July			August			September		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
1	74	26	50	75	38	57	83	49	66	78	50	64
2	76	35	56	74	38	56	81	45	63	58	48	53
3	80	56	68	81	44	63	80	39	60	58	46	62
4	73	50	62	87	45	66	86	48	67	63	24	44
5	58	44	51	88	51	70	91	48	70	74	--	--
6	61	46	54	86	60	73	79	49	64	76	49	63
7	78	53	66	86	50	68	76	34	55	58	30	44
8	85	59	72	71	36	54	82	54	68	52	29	41
9	82	56	69	81	51	66	94	54	74	66	25	46
10	79	41	60	92	56	74	67	46	57	70	49	60
11	84	46	65	80	56	68	66	27	42	68	38	53
12	75	35	55	97	62	80	--	35	--	79	48	64
13	75	33	54	85	60	73	79	36	58	70	49	60
14	79	34	57	83	51	67	73	32	53	70	49	60
15	84	35	60	90	54	72	74	31	53	67	38	53
16	75	33	54	88	61	75	74	31	53	73	50	62
17	84	31	58	76	50	63	84	43	64	76	25	46
18	77	39	58	65	31	48	78	51	65	74	49	62
19	69	26	48	78	37	58	86	44	65	76	54	65
20	73	38	56	83	41	62	86	53	70	80	47	64
21	58	44	51	89	46	68	83	38	61	84	64	74
22	75	53	64	90	61	76	85	40	63	68	44	56
23	81	29	55	77	38	58	74	52	63	50	26	38
24	81	43	62	88	39	64	63	27	45	63	25	44
25	76	33	60	92	39	66	54	42	58	56	20	38
26	83	52	68	93	45	69	51	45	48			
27	80	48	64	92	60	76	56	27	42			
28	55	43	49	96	49	73	71	43	57			
29	73	40	57	82	34	58	67	51	59			
30	75	38	57	82	34	58	80	36	58			
31				78	56	67	71	43	57			
Means			58.0			66.0			58.7			
Absolute Maximum	85			97			94			84		
Absolute Minimum	26			31			27			20		

Table IX: Maximum daily temperatures over mineral soil and departures from these of that over peat soil, during June, July, August and September, 1914.

	June		July		August		September	
	Max. over m.s.	Departure over peat	Max. over m.s.	Departure over peat.	Max. over m.s.	Departure over peat.	Max. over ms.	Departure over peat.
1	72	2	74	1	84	-1	80	-2
2	76	-1	75	-1	82	-1	61	-3
3	82	-2	82	-1	82	-2	59	-1
4	69	4	85	2	87	-1	63	0
5	58	1	86	2	94	-3	74	0
6	60	1	87	1	80	-1	74	2
7	75	3	86	0	76	0	58	0
8	83	2	71	0	81	1	52	0
9	81	1	78	3	95	-1	68	-2
10	81	-2	89	3	68	-1	68	2
11	78	6	79	1	66	0	69	-1
12	74	1	91	6	--	-	78	1
13	79	-4	85	0	78	1	71	-1
14	71	8	84	-1	73	0	62	8
15	76	8	88	2	73	1	70	-3
16	77	-2	86	2	67	7	74	-1
17	76	8	75	2	86	-2	77	-1
18	70	7	66	-1	78	0	74	0
19	64	5	76	2	86	0	75	1
20	66	7	81	2	88	-2	81	-1
21	58	0	89	1	84	-1	84	0
22	71	4	89	2	87	-2	67	1
23	79	2	79	-2	75	-1	51	-1
24	78	3	86	2	67	-4	64	-1
25	74	2	89	3	55	-1	59	-3
26	81	2	87	6	51	0		
27	62	18	93	-1	56	0		
28	55	0	97	-1	71	0		
29	71	2	81	1	67	0		
30	76	-1	81	1	80	0		
31			77	1	81	0		

Table X. Minimum daily temperature over mineral soil and departure from this of that over peat soil, during June, July, August and September, 1914.

	June		July		August		September	
1	Min. over m.s.	Departure over peat	Min. over m.s.	Departure over peat	Min. over m.s.	Departure over peat	Min. over m.s.	Departure over peat
1	38	-12	44	-6.0	54	-5	51	-1
2	50	-15	43	-5	52	-7	48	0
3	57	-2	52	-8	49	-10	46	0
4	51	-1	48	-3	57	-9	29	-5
5	47	-4	58	-7	64	-16	44	-
6	48	-2	64	-4	51	-2	49	0
7	53	0	53	-3	42	-8	38	-8
8	61	-2	40	-4	59	-5	30	-1
9	58	-2	52	-1	59	-5	35	-10
10	51	-10	60	-5	48	-2	50	-1
11	54	-8	60	-5	32	-5	47	-9
12	47	-12	63	-1	44	-9	49	-1
13	43	-10	62	-2	44	-8	49	0
14	43	-9	53	-2	45	-13	49	0
15	46	-11	59	-5	39	-8	43	-5
16	43	-10	62	-1	50	-19	50	0
17	44	-13	50	-1	52	-9	34	-9
18	45	-6	37	-7	56	-5	49	
19	38	-12	48	-11	51	-7	55	-1
20	42	-4	57	-16	54	-1	58	-11
21	47	-3	57	-11	48	-10	65	-1
22	53	0	67	-6	57	-11	45	-1
23	38	-9	47	-9	53	-1	30	-4
24	49	-6	45	-6	33	-6	34	-9
25	40	-7	51	-12	44	-2	24	-4
26	53	-1	52	-7	46	-1		
27	49	-1	62	-2	30	-3		
28	45	-2	54	-5	43	-0		
29	44	-4	43	-9	52	-1		
30	44	-6	--	-	45	-9		
31	--	-	58	-2	51	-8		

Table XI: Mean daily temperature over mineral soils and departures from this of that over peat soil, during June, July, August and September, 1914

	June		July		August		September	
	Mean over m.s.	Departure over peat.	Mean over m.s.	Departure over peat.	Mean over m.s.	Departure over peat.	Mean over m.s.	Departure over peat.
1	54.8	-5.0	59.0	-2.5	69.0	-3.0	65.5	-1.5
2	62.8	-6.5	59.0	-3.0	67.0	-4.0	54.5	-1.5
3	69.5	-1.7	67.0	-4.5	65.5	-6.0	53.5	-1.5
4	60.0	1.5	66.5	-0.5	72.0	-5.0	46.0	2.5
5	52.3	-1.5	72.0	-2.5	78.8	-9.3	--	--
6	54.0	-0.5	75.5	-2.5	65.0	-1.0	61.5	1.0
7	64.0	1.5	69.3	-1.3	59.0	-4.0	48.0	-4.0
8	72.0	0	55.5	-2.0	70.0	-2.0	45.0	-4.5
9	69.5	-0.5	64.8	1.2	77.0	-3.0	51.5	-6.0
10	66.0	-6.0	74.5	-0.7	58.0	-1.5	59.0	0.5
11	66.0	-1.0	69.5	-1.7	49.0	-7.5	58.0	-5.0
12	60.5	-5.5	77.0	2.5	--	--	63.5	0
13	61.0	-7.0	73.5	-1.0	61.0	-3.5	60.0	-0.5
14	57.0	-1.5	68.5	-1.5	59.0	-6.5	55.5	4.0
15	61.0	-1.5	73.5	-1.5	56.0	-3.5	56.5	-4.0
16	60.0	-6.0	73.8	0.7	58.5	-6.0	62.0	-0.5
17	60.0	-2.5	62.0	1.0	69.0	-5.5	55.5	-10.0
18	57.5	0.5	51.5	-3.7	67.0	-2.5	61.5	0
19	51.0	-3.5	66.8	-9.3	68.5	-3.5	65.0	0
20	54.0	1.5	66.0	-4.0	71.0	-1.5	69.5	-6.0
21	52.5	-1.5	72.8	-5.3	66.0	-5.5	74.5	-0.5
22	62.0	2.0	77.8	-2.3	69.0	-6.5	56.0	0
23	58.5	-3.5	63.0	-5.5	64.0	-1.0	40.5	-2.5
24	63.5	-1.5	65.5	-2.0	50.0	-5.0	49.0	-5.0
25	56.0	3.5	70.0	-4.5	49.5	-1.5	41.5	-3.5
26	67.0	0.5	69.5	-0.5	48.5	-0.5		
27	55.5	8.5	77.5	-1.5	43.0	-1.5		
28	50.0	-1.0	75.5	-3.0	57.0	0.0		
29	57.5	-1.0	62.0	-4.0	59.5	-0.5		
30	60.0	-3.5	70.5	-12.5	62.5	-4.5		
31			67.5	-0.5	66.0	-9.0		

The temperature data are given in Tables VIII, IX, X and XI, the first being for the bog only. All are reported in degrees Fahrenheit. In Tables IX, X and XI the maximum, minimum and mean daily temperatures over the mineral soil and the departures from these over the bog are reported. The mean temperature for May was 3.7° higher, that for June 1.7° lower, that for July 3.2° higher, that for August 0.8° lower, and that for September 1.9° higher at Pokegama Falls than the normal for the past 17 years. Thus the average mean temperature for the 4 months was 1.3° above the normal. It is safe to assume that the same held true for the experimental farm.

The mean temperature over the bog averaged about 2° below the normal for Pokegama Falls. The range of the maximum and the minimum temperatures was greater by nearly 8°, due to the lower specific heat and the lower conductivity of the peat soil.

The maximum temperature was higher over the bog on sunshiny days, while on cloudy days it was the same or even a little lower than over the mineral soil. The minimum temperatures differed widely, being in no case lower over the mineral soil. The maximum difference was observed during clear calm nights, while when a strong breeze was blowing or a fog prevailed, the difference was small. During windy rainy nights the difference was very slight.

The length of the growing season on the mineral soil, as defined by the last killing frost in the spring and the first in the fall, was unusually long, while frosts occurred on the bog on 17 nights between June 1-- before which occurred the last killing frost of spring-- and September 25, when the first killing frost of autumn occurred over the mineral soil. The dates and minimum

Table XII. Summer Frosts on the Bog.

June	17-	31°
"	19-	26°
"	23-	29°
July	18-	31°
August	11-	27°
"	14-	32°
"	15-	31°
"	16-	31°
"	24-	27°
"	27-	27°
September	4-	24°
"	7-	30°
"	8-	29°
"	9-	25°
"	17-	25°
"	23-	26°
"	24-	25°
"	25-	20°

temperatures of the summer frosts on the bog are reported in Table XII.

The weather of the season of 1914 as a whole did not depart widely from the normal, it being slightly warmer with a longer growing season, much drier only in July and early August, and the normal single torrential rain occurring in mid-summer.

Arrangement of the Plots.

Owing to the large number of fertilizers to be used in 1914 the bog was resurveyed. The north line of the experimental plots is identical with that of the previous years. Where the old line was not clearly in evidence it was defined as 2 feet to the south of the bottom wire of a fence which has since been removed. As evidence that this north line is identical with the old one, the remains of many of the old stakes were found either still standing or broken off below the surface of the peat. The south line of the experimental plots was located 120 feet to the south and this was found to coincide with the old south line, many old stakes being found. The stakes set at the beginning of the work were removed during August, and permanent stakes set in their places.

The width of the old plots was 16½ feet while that of the new ones is only 15 feet, the change being made to permit of a 2½ foot alley instead of only 1 foot each as previously; therefore the east line of each new plot from 1 to 24 inclusive should coincide with the east line of the old plot of the same number. It was found that the majority of them coincided exactly and all within a very short distance.

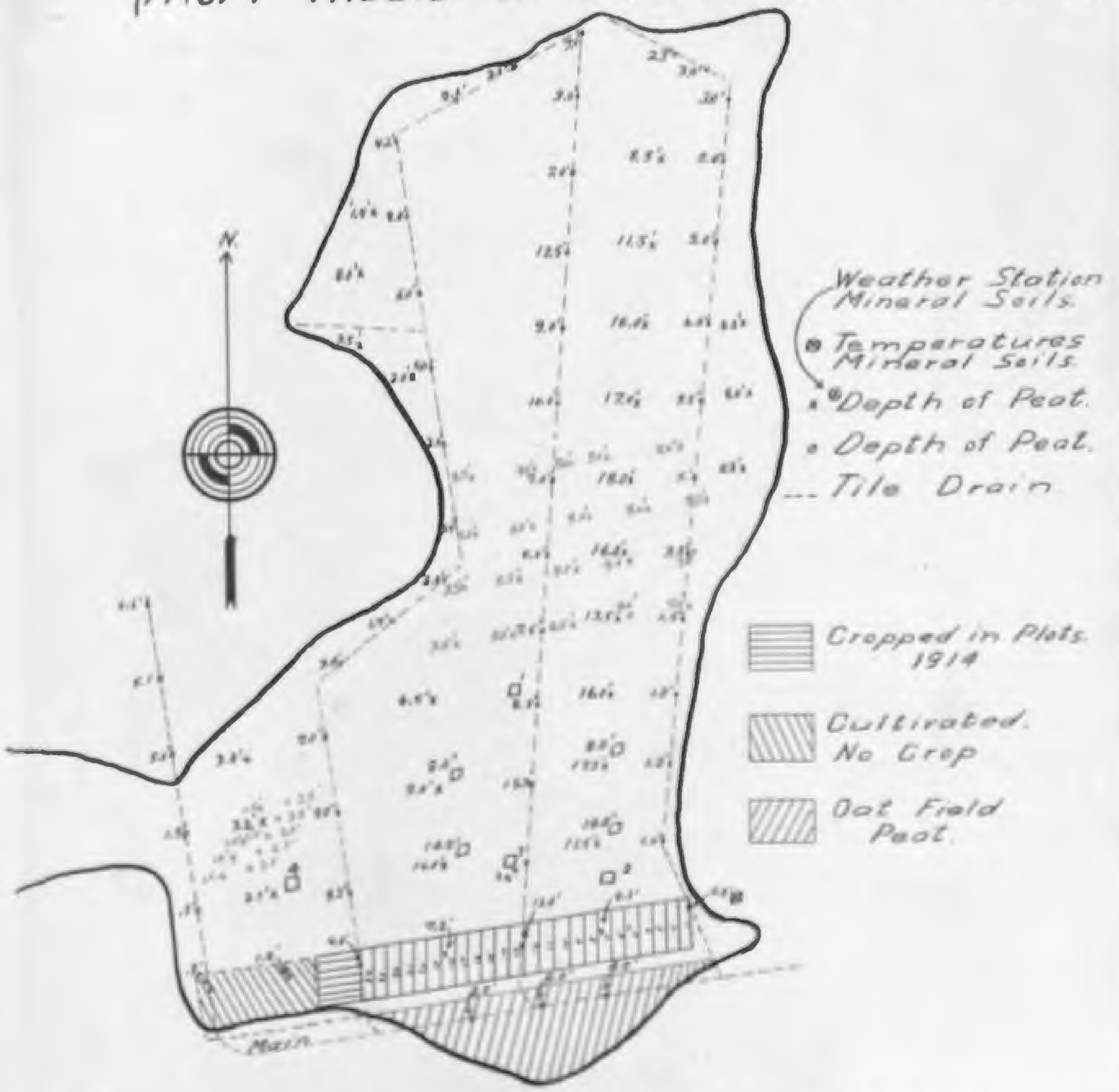
Each 6th alley under the old plan had a width of 2 feet, while in the new arrangement every 6th alley was given a width of 3½ feet. The increased width of the alleys helped to prevent any considerable mixing of the soil from plot to plot during tillage operations. To establish the north line of the series of plots known as 1 to 28 south, a stake set 58 feet northward from the south line of the old plots along the east line of the plots marked the position of the northeast corner of plot 1 south. Such an arrangement then left an alleyway 4 feet in width dividing the field in equal halves. This is known as the "wide alley". The result of this resurvey is shown clearly in Map III. (See photo.No.1.)

When the old plots were laid out and the plans drawn, it had been assumed that the plots were rectangular, but they were oblique parallelograms, as is shown on Map I. For plots 25 to 28 north and south the lines were extended into cultivated bog to the westward.

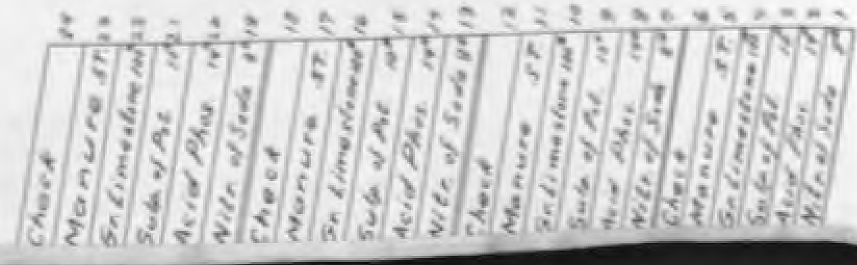
The area of each plot is given as 1/50 of an acre. This value is used in all the calculations in this paper.

MAP I - SHOWING BOG UNDER EXPERIMENT IN 1911-191

(FROM THESIS OF D. F. HUNGERFOFD - 1914.)



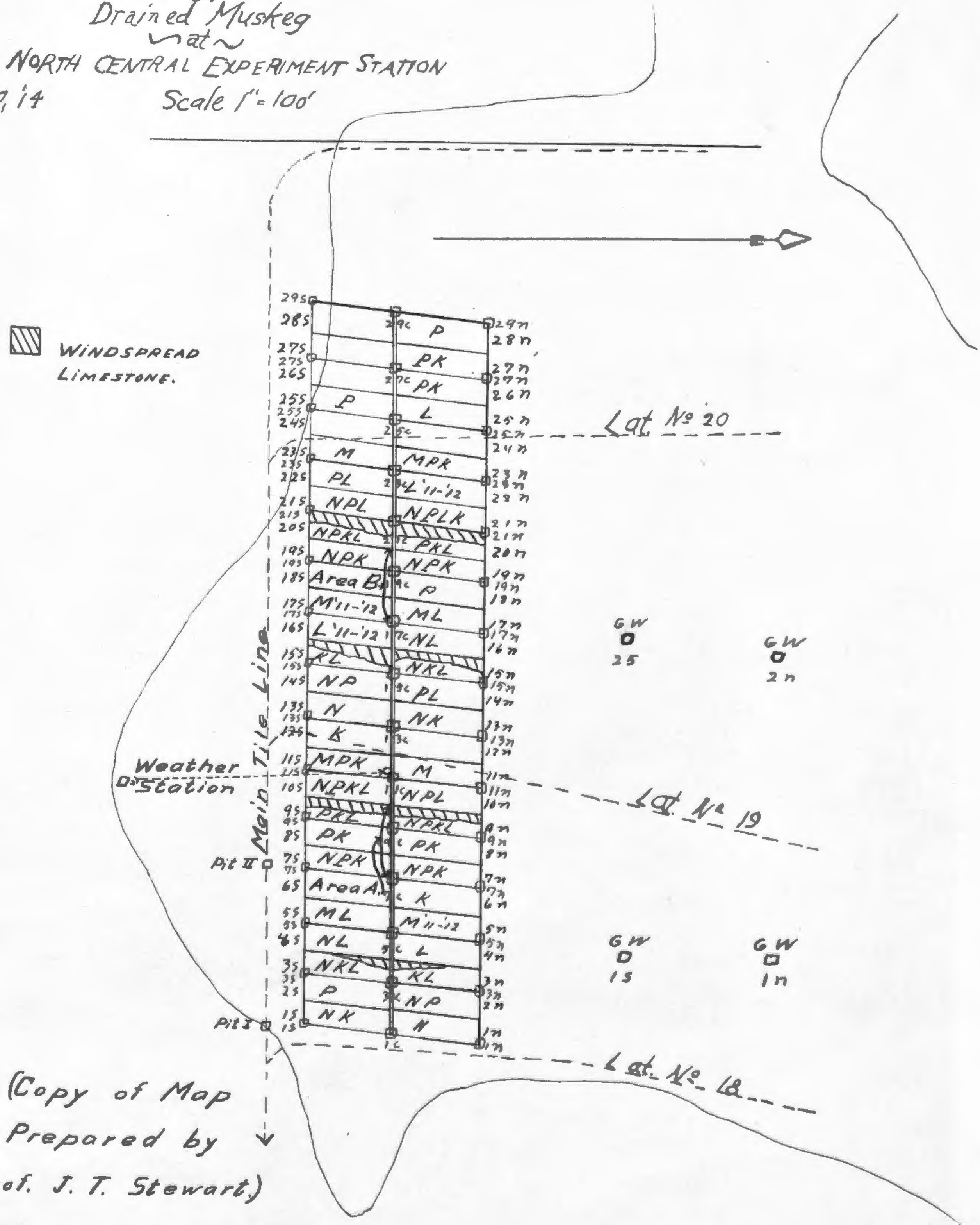
MAP II - SHOWING ACTUAL ARRANGEMENT AND FERTILIZATION OF PLOTS.



MAP III

EXPERIMENTAL PLATS
— AND —
OBSERVATION WELLS
— ON —
Drained Muskeg
— at —
NORTH CENTRAL EXPERIMENT STATION

Nov 10, '14 Scale 1" = 100'



(Copy of Map Prepared by Prof. J. T. Stewart)

Variation in Level of Ground Water.

- - - oOo - - -

Up to June 30th the well readings were made in temporary wells bored with a 2-inch soil auger, after that date they were taken in permanent wells consisting of a long narrow square box of pine boards with a square opening 4 x 4 inches inside measurement. These were placed in the bog vertically in such a manner that 48 inches of the box was below the surface of the ground and 16 inches above. These wells were painted white and marked with their respective numbers. A general view is shown in Photo I, B and C

Daily readings were made in the case of

Photo I

To face page 48.

A.

B.

C.

PHOTO. I.

A. View of the Grand Rapids muskeg on May 30,. 1914, showing the cultivated portion before the preparation of the seed-bed. Roots and remains of weeds and the previous oat crop are to be seen.

B. View of the same bog on August 12, 1914, showing Well No.1-C in foreground, with corner-post to different plots, and potatoes to right anf left. Oat plots appear in the background.

C. View of the bog after all crops had been harvested.

each well in the center row from June 2 to July 18, and in each of those inthe North and South rows from June 28 to July 18. After the latter date, daily readings were continued on only 11 C, 13 C, 17 C, and 19 C. All other well readings were made on each Monday and Thursday until September 14. The data are reported in Tables XIII, XIV, XV and XVI.

From July 19 to September 14, bi-weekly readings were made in the four wells in unreclaimed portions of the bog indicated on Map III as 1 S, 2 S, 1 N and 2 N. The data are reported in Table XVII.

In order to determine the experimental error of the readings on one day, July 30, I made readings of each of the 37 and then four times repeated the operation without looking at the previous data. The data are reported in Table XVIII. The greatest difference in the case of any one well was 0.4 inches, while the average difference for all was 0.3 inches.

The location of the wells is shown on Map III. When the water fell more than four feet below the surface, it was below the bottom of the well and in the Tables is reported as simply (+). The surface of the portion of the bog devoted to experimental plots is not horizontal and accordingly the relative heights above the sea level of the water surface in the different wells do necessarily not vary in-

Table XIII

Distance of Water Level Below Surface in Wells of Center Row, in Inches. The Numbers at the Head of the Columns are the Different Wells.

	Rain-fall	1	3	5	7	9	11
June 2		+	+	+	41	29.0	35
" 3	1.0	+	+	+	42	16.0	18
" 4	t	+	+	+	36	15.0	23
" 6	t	+	+	+	30	18	22
" 7	.50	+	+	+	29	13	15
" 8	.50	+	+	+	21	9	10
" 9	.25	30	+	33	16	10	11
" 10		27	+	35	22	14	17
" 11	t	28	+	37	24	16	24
" 12		26	+	40	27	18	21
" 13		27	+	45	21	19	23
" 14		29	+	+	30	20	23
" 15		+	+	+	30	21	23
" 16		+	+	+	31	22	24
" 17		+	+	+	31	22	24
" 18		+	+	+	31	22	24
" 19	.50	+	+	+	32	21	23
" 20	.20	+	+	+	32	21	23
" 21		+	+	+	32	21	23
" 22		+	+	+	31	21	24
" 23	.30	+	+	+	32	22	24
" 24		+	+	+	32	22	24
" 25		+	+	+	32	22	24
" 26		+	+	+	32	23	24
" 27	2.40	6	5	0	2	2	2
" 28	0.10	9	6	2	3	4	4
" 29		12	10	4	8	6	8
" 30	.30	40	12	7	12	9	11
July 1	t	33	10	5	10	7	9
" 2	t	32	14	8	13	10	12
" 3		32	17	11	16	11.5	14.5
" 4	0.3	36.8	13.8	9	13.4	10.	12
" 5		38.6	19	13.2	18.0	12.8	16.2
" 6		40.	22.6	18.2	21	15	18.4
" 7		42.2	25.2	21.4	22.4	16	19.2
" 8	t	44	27.6	24.8	24	17	20
" 9		45	29.6	27.8	24.4	17.4	20.6
" 10	t	46	31	30.2	25	18	21
" 11		46.4	32	32	25.4	18.4	21.6
" 12	.50	46.2	32	33	25	16.8	20
" 13		47	31.4	34	25.4	18	21
" 14		47.4	32.0	36.0	26.2	18.8	21.6
" 15		47.6	33.0	38.0	27.0	19.8	22.0
" 16	0.1	47.8	33.2	39.6	27.0	20.0	22.6
" 17	t	+	34.0	41.4	27.6	20.8	23.0
" 18	t	+	35.0	43.4	28.2	21.0	23.88
" 23	--	+	39.2	+	30.4	24.2	26.2
" 27		+	41.4	+	31.8	26.2	28.0
" 30		+	43.2	+	33.0	28.0	29.8

13	15	17	19	21	23	25	27	29
46.0	—	+	+	+	+	+	+	+
26.0	47	+	+	+	+	+	+	+
31.0	46	+	+	+	+	+	+	24
30.0	46	+	+	+	+	+	+	18
26.0	46	+	+	+	+	+	+	20
19.0	47	+	+	+	+	+	26	11
15.0	41	+	43	+	+	+	12	11
21	43	+	42	+	+	+	18	16
24	44	+	+	+	+	+	20	18
26	44	+	+	+	+	+	22	18
27	45	+	+	+	+	+	26	30
27	43	+	+	+	+	+	30	21
28	44	+	+	+	+	+	30	21
29	44	+	+	+	+	+	32	23
29	44	+	+	+	+	+	+	33
29	44	+	+	+	+	+	+	31
28	44	+	+	+	+	+	+	23
28	44	+	+	+	+	+	+	23
28	44	+	+	+	+	+	+	23
29	44	+	+	+	+	+	+	23
29	44	+	+	+	+	+	+	26
29	44	+	+	+	+	+	+	27
30	44	+	+	+	+	+	+	+
30	44	+	+	+	+	+	+	+
5	6	3	5	5	5	6	5	4
7	2	5	6	6	7	8	8	6
10	11	9	9	9	11	12	10	--
13	16	18	11	11	15	15	15	11
11	14	13	9	8	12	12	12	8
15	17	23½	12	12	18	17	16½	12
17.3	21	31.5	15.6	13.8	24.3	20	18	13.3
15	19.6	33	11.6	11.6	27.4	20.8	15.2	11.4
19.0	33.4	40	16	15.6	34	23.6	19.6	16.0
21.8	26	48	20	19	41.5	26.8	22.6	17.8
22.8	27.8	48	21.6	21	49	29.8	26.2	19.0
24	29.2	48	23.8	23.4	4[illegible]	32.6	28.6	20.0
24.8	30.2	47.5	25.4	25	49	35	39.5	21.
25.2	31	+	27	26	+	37	47	22
25.8	31.6	+	28	27	+	39	+	22.6
24.6	31.6	+	28	26	+	40.6	+	23
25.2	31.8	+	28.4	26	+	42	+	23.6
26.0	32.6	+	29.4	24.2	+	43.8	+	24.4
27.0	33.0	+	30.4	28.0	+	45.6	+	25.0
27.2	33.2	+	31.0	29.0	+	+	+	25.0
27.8	33.6	+	31.6	29.6	+	+	+	25.4
28.2	34.2	+	32.8	30.8	+	+	+	26.0
31.0	37.0	+	36.0	34.8	+	+	+	29.0
32.8	38.2	+	39.0	37.6	+	+	+	31.8
34.0	39.4	+	41.2	39.3	+	+	+	33.0

Table XIII Continued.

	Rain-fall	1	3	5	7	9	11
Aug. 3	t	+	45.4	+	33.8	29.0	31.2
" 6		+	46.6	+	34.6	30.0	32.8
" 10	t	+	+	+	36.0	31.0	33.2
" 13	.10	+	+	+	37.0	31.4	34.0
" 17		+	+	+	37.8	32.0	34.2
" 19		+	+	+	38.4	33.0	35.0
" 26	t	47.8	40.4	+	33.4	27.8	30.4
" 30	.30	48.0	38.6	+	33.0	26.2	28.6
Sep 2	t	+	38.0	+	33.0	26.0	28.0
" 8		+	39.0	+	35.2	28.2	29.8
" 10	1.60	40.8	25.0	36.2	21.6	21.2	27.2
" 11		38.6	17.2	32.8	25.2	22.2	23.0
" 12		37.2	19.2	35.0	27.6	23.0	24.0
" 14	.70	29.8	7.8	21.0	15.4	14.6	11.6

* For daily readings of wells 11, 13, 17, 19 see separate table.

13	15	17	19	21	23	25	27	29
35.4	40.6	+	43.2	41.8	+	+	+	34.8
36.0	41.4	+	44.8	43.2	+	+	+	35.4
37.0	42.	+	47.6	45.0	+	+	+	36.0
34.4	43.4	+	+	44.6	+	+	+	36.4
38.2	44.2	+	+	+	+	+	+	37.0
38.4	45.0	+	+	+	+	+	+	+
33.4	44.8	+	45.4	+	+	44.8	+	+
32.6	45.0	+	+	+	+	+	+	+
32.2	45.2	+	+	+	+	+	+	+
34.0	46.2	+	+	+	+	+	+	+
27.2	43.8	34.0	36.0	40.0	39.6	37.8	37.0	35.0
25.2	44.0	33.0	34.0	37.8	38.0	29.2	+	33.0
27.0	43.2	39.0	33.8	37.6	41.0	28.6	+	33.0
18.6	37.6	27.0	23.0	30.0	28.0	16.0	29.0	16.4

Table XIV

Distance of Water Level below Surface in Wells of North Row in Inches. The Numbers at the head of the column are those of the different wells.

		Rain-fall	1	3	5	7	9	11
June	28	0.10	4	5	5	3	3	6
"	29		10	9	7	5	5	10
"	30	0.30	38	21	9	9	8	14
July	1	t	32	12	9	6	6	13
"	2		31	14	12	9.2	9.5	15
"	3	t	32.6	17	14	12.3	10.8	16.8
"	4	0.3	32	17.2	12.4	10.6	9	15
"	5		33.2	19.6	15.2	13.6	12	17
"	6	t	33.8	21.2	18.0	15.6	14	18.2
"	7		34.2	23.2	19.4	17	15	19
"	8	t	34.6	25	21	18.2	16	19.2
"	9		35	25.8	22.6	19	16.8	20
"	10	t	35.6	27	24	20.4	17.4	21
"	11		35.8	27.6	24.8	21	18	21
"	12	0.5	35.8	28.0	25.4	21	17.8	20.4
"	13		36	28.4	26.	21.2	18	21
"	14		36.4	29.4	29.6	22.0	18.8	21.4
"	15		37.0	30.0	28.0	23.0	19.6	22.0
"	16	0.1	37.0	30.4	29.0	23.4	20.0	21.2
"	17	t	37.8	30.6	29.8	24.2	21.6	23.0
"	18	t.	38,8	314	308	25.0	21.6.	23.8
"	23		40.0	33.4	33.0	28.0	26.4	26.2
"	27		41.0	35.0	43.0	30.0	27.8	27.2
"	30		41.0	37.0	43.6	31.4	29.2	28.2
Aug	3		41.0	38.0	45.0	32.4	30.2	28.8
"	6		41.8	39.2	+	32.2	32.0	30.0
"	10	t	41.8	40.0	+	34.00	320	30.6
"	13	0.10	41.8	41.0	+	34.4	32.4	31.0
"	17		42.2	42.2	+	34.4	32.2	31.2
"	19		42.2	42.8	+	34.6	328	31.6
"	26	t	40.8	43.4	41.2	29.6	26.8	24.8
"	30	0.30	40.6	44.0	40.0	28.8	24.1	22.8
Sept	2	t	40.4	44.6	39.8	28.6	24.2	23.0
"	8		41.2	45.8	41.0	31.0	35.8	24.6
"	10	1.60	2.8	6.2	28.4	22.2	12.4	15.2
"	11		15.2	15.2	15.8	15.4	12.6	16.6
"	12		25.0	18.4	18.8	19.0	15.0	18.2
"	14	0.70	2.2	8.8	10.0	10.0	6.4	11.8

13	15	17	19	21	23	25	27	29
3	3	3	5	7	9	19	6	6
5	5	6	7	9	11	18	10	7
7	9	10	9	13	15	30	12	11
6	9	8	9	11	13	25	9	8
8	10.2	10	12.5	15	16	23	13	12
9.5	11	11.8	12.6	15.4	17.8	23.6	14.8	14.2
7.8	9.4	11.2	11.6	13.6	16.2	24	13.2	12.4
10.4	11.6	13	13.6	16.2	19	24.6	16	15.4
12.2	13.5	15	15.8	19	21	25.6	18.8	17.4
13	14.8	16.8	17	20.2	22	26.4	21.0	19
14	15.8	18	18.2	21.6	23.2	27.2	23	22
14.2	16.6	18.8	19.2	22.8	24	28	29	32.2
15	17.8	20	20.4	24	24.6	28.6	28.4	31.6
115.2	18	20.6	21.0	24.2	25.2	29.2	28.6	31
14.8	16.2	19	19.2	22.4	25.2	29.6	29.2	30.8
15	17.6	19.8	20.2	23.6	25.2	30.0	29.	30.8
16.0	18.8	21.0	21.8	25.0	26.0	30.4	28.8	30.2
16.8	19.8	22.2	22.6	26.0	27.0	31.0	29.0	30.2
17.0	20.2	23.0	23.4	27.0	28.2	31.2	29.2	30.2
18.0	22.0	24.[illegible]	24.2	28.0	29.2	31.4	29.8	30.0
18.6	22.2	25.8	25.0	28.2	29.6	32.0	30.2	30.0
22.2	26.4	26.8	29.8	32.2	31.0	33.8	33.8	31.0
23.8	27.8	30.2	30.4	33.6	32.8	35.0	40.0	31.6
25.0	28.4	31.6	32.0	34.6	34.0	36.0	40.4	33.0
26.0	29.0	32.6	33.0	35.8	35.0	37.0	41.2	33.8
27.0	30.0	33.2	34.0	36.8	36.0	37.6	42.2	34.8
37.2	30.0	33.8	34.6	37.4	37.0	39.0	43.2	36.0
27.2	30.6	34.0	34.6	37.6	37.8	40.8	44.0	41.2
27.6	30.6	34.0	35.0	38.0	38.4	40.4	45.4	41.8
27.8	31.0	34.4	35.2	38.4	39.0	42.0	46.2	42.2
20.0	21.6	25.0	25.6	29.0	34.6	38.6	39.2	34.4
18.2	20.2	23.8	25.0	28.0	33.6	37.8	42.2	35.4
18.6	20.6	24.0	23.6	28.8	33.4	37.2	44.0	36.0
20.6	23.2	27.0	28.2	31.8	34.8	37.6	+	38.0
7.4	12.0	17.0	16.6	19.0	31.0	34.8	39.+	34.4
10.0	13.0	15.4	15.6	18.2	26.2	31.4	40.2	34.0
12.4	14.8	18.0	18.4	21.0	26.4	31.2	41.6	33.8
5.2	8.0	11.2	11.4	12.4	20.0	27.8	40.8	32.2

Table XV.

Distance of Water Level Below Surface in Wells of South Row in inches. The numbers at the head of column are those of the different wells.

		Rain-fall	1	3	5	7	9	11
June	28	.10	2	4	4	5	4	16
"	29		34	8	7	9	9	20
"	30	.30	45	12	10	14	15	23
July	1	t	38	9	8	10	13	20
"	2		44	12.5	10	13.5	17	21
"	3	t	48	14.5	12.8	16.2	17.5	23.5
"	4	.3	49	15.2	10.4	15.3	18	24
"	5		51+	17.6	14.2	17.4	19.2	25
"	6	t	51+	20	17.5	19.4	20.2	25.6
"	7		51+	23	18.4	21.2	21.2	26.2
"	8	t	51	25.2	20.0	23.0	22.0	26.8
"	9		51 +	27	21	24	22	27.2
"	10	t	51†	28.2	21.4	25.8	22.4	27.6
"	11		+	29.6	22	27.2	23	28
"	12	.5	50.6	30.0	22.4	28.0	23	28
"	13		+	30.8	22.8	29	23.2	28
"	14		+	31.2	23.0	30.0	24.0	28.6
"	15		+	31.8	24.0	29.8	24.4	29.0
"	16	0.1	+	32.4	24.4	30.8	24.6	29.0
"	17	t	+	32.2	24.5	31.4	25.0	29.2
"	18	t	+	32.8	25.0	32.2	25.4	29.8
"	23		+	33.8	27.2	36.2	27.6	31.8
"	27		+	34.0	28.6	38.6	29.0	33.0
"	30	0.2	+	34.0	29.6	40.0	30.0	34.0
Aug	3		+	34.6	31.0	41.8	31.0	35.0
"	6		+	35.0	32.0	43.0	32.0	35.6
"	10	t	+	35.0	33.0	44.2	33.0	37.0
"	13		+	35.6	34.0	45.2	33.8	37.6
"	17		+	35.8	35.0	46.4	34.4	38.2
"	19		+	36.2	35.2	47.4	35.0	39.0
"	26	t	+	34.4	35.6	43.6	32.6	37.2
"	30	.30	+	34.6	36.8	44.4	32.4	37.0
Sept	2	t	+	34.8	37.0	44.8	32.2	37.0
"	8		+	35.6	38.2	46.2	33.4	38.0
"	10	1.60	11.4	32.6	31.2	38.2	29.2	33.2
"	11		31.6	25.0	20.6	26.4	26.2	31.0
"	12		46.0	22.4	17.6	24.0	26.2	30.8
"	14	.70	56	5.0	4.4	8.6	19.8	25.4

13	15	17	19	21	23	25	27	29
7	5	6	16	5	5	6	8	12
1 2	7	10	15	9	9	22	--	--
15	12	13	22	12	11	14	18	23
13	9	10	18	10	9	11	15	18
16	13	15	22	13.5	12	15	22	26
17.5	14.3	16.5	25.5	15 5	13	18	25	29
17	14	17	28.6	12.8	13.2	17.5	23	28.4
18.6	16	18.2	31.4	16.4	14.4	20.	27	31.8
20.2	18.2	20.2	34.4	18	16	22.2	29.2	34.6
21.6	19.8	22	36.4	19	17.4	23.4	31	35.8
23.0	21.4	23.6	39	20	18.6	24.2	32.5	37
23.6	22.8	24.8	41	20.4	19	25	33.8	38.6
24.4	24	26	42.0	21.2	19.6	26	33.6	39.6
25	25	27.4	43	22	20	26.6	35	40
25.2	25.8	282	43.4	22.2	20	26.8	35	41.2
26.	26.8	29.4	44.2	23.0	20	27.2	35.8	46.5
26.4	27.4	30.2	46.0	24.0	21.0	27.8	36.0	41.5
27.0	28.2	31.8	48.0	24.8	21.0	28.2	36.4	+
27.6	29.0	32.4	+	25.2	21.4	28.6	36.8	41.8
28.0	29.8	33.2	+	26.2	21.8	29.0	37.4	+
28.6	30.2	34.2	+	27.0	22.4	30.0	38.0	+
31.0	33.0	38.0	+	32.2	25.0	33.0	40.	42.0
32.8	36.0	41.0	+	35.0	27.0	35.0	+	+
34.0	37.8	42.6	+	37.4	28.8	37.0	+	+
35.0	39.6	44.8	+	39.0	30.2	40.	+	+
36.0	41.0	46.6	+	40.6	31.0	42.2	+	+
37.2	42.2	+	+	42.2	32.8	44.8	+	+
37.8	43.6	+	+	43.6	34.0	+	+	+
38.8	45.0	+	+	45.4	36.2	+	+	+
39 .2	46.4	+	+	46.6	37.8	+	+	+
30.2	40.4	+	+	38.8	28.6	37.2	+	+
32.4	41.4	+	+	38.0	29.2	39.4	+	+
32.6	42.0	+	+	38.4	30.0	31.0	+	+
34.6	43.4	+	+	40.6	32.0	+	+	+
18.2	34.8	36.6	44.2	16.0	13.0	28.4	+	+
16.4	26.8	20.4	43.0	16.4	12.8	19.2	+	+
18.8	24.2	19.2	42.2	17.6	14.2	20 6	+	+
8.2	5.2	4.8	30.6	9.4	8.4	8.0	39.2	+

Table XVI
Readings of Center Wells in Inches.

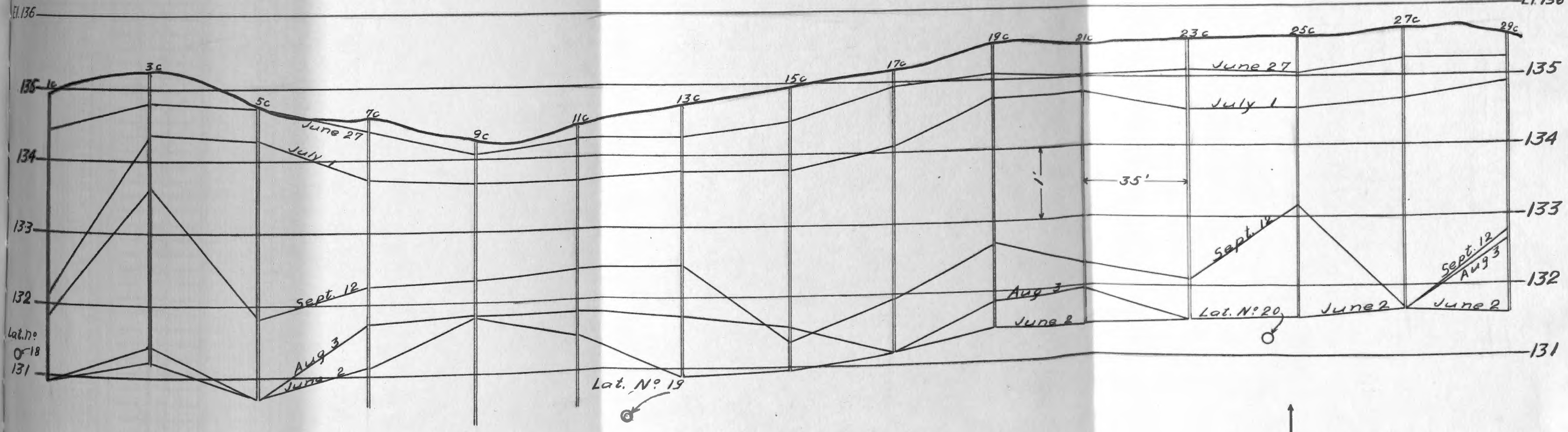
	11C	13C	17C	19C
July 19	24.0	28.8	+	33.6
" 20	24.4	29.0	+	34.0
" 21	25.0	29.6	+	34.8
" 22	25.2	30.0	+	35.4
" 23	26.2	31.0	+	36.0
" 24	--	--	--	--
" 25	27.2	31.8	+	37.8
" 26	27.6	32.0	+	38.2
" 27	28.0	32.8	+	39.0
" 28	29.0	33.2	+	38.0
" 29	29.4	33.8	+	40.6
" 30	29.8	34.0	+	41.2
" 31	30.0	34.0	+	41.4
Aug. 1	30.4	34.6	+	42.2
" 2	31.0	35.0	+	42.6
" 3	31.2	35.4	+	43.2
" 4	31.8	35.6	+	44.0
" 5	32.0	35.8	+	44.4
" 6	32.8	36.0	+	44.8
" 7	32.8	36.4	+	45.4
" 8	33.0	36.4	+	46.0
" 9	33.2	36.8	+	46.6
" 10	33.2	37.0	+	47.6
" 11	34.0	37.2	+	48.0
" 12	--	--	--	--
" 13	34.0	37.4	+	+
" 14	--	--	--	--
" 15	34.4	38.0	+	+
" 16	34.4	38.0	+	+
" 17	34.2	38.2	+	+
" 18	34.4	38.2	+	+
" 19	35.0	38.4	+	+
" 20	35.2	38.6	+	+
" 21	35.2	38.6	+	+
" 22	35.4	39.0	+	+
" 23	33.4	34.2	39.4	42.2
" 24	32.2	34.0	43.2	43.4
" 26	30.4	23.4	+	45.4
" 30	28.6	32.6	+	+
Sept. 2	28.0	32.2	+	+
" 8	29.8	34.0	+	+
" 10	27.2	27.2	34.0	36.0
" 11	23.0	25.2	33.0	34.0
" 12	24.0	27.0	39.0	33.8
" 14	11.6	18.6	27.0	23.0

Table XVII

Water Levels in Unreclaimed Bog.

	1S	2S	1N	2N
July 19	49.5	19.4	47.2	44.4
July 23	47.8	21.4	35.2	39.8
July 27	44.2	20.6	27.6	34.6
July 30	44.4	22.4	29.6	36.0
Aug. 3	48.4	23.6	31.0	37.2
Aug. 6	47.0	26.0	31.4	42.6
Aug. 10	46.6	25.2	32.4	40.4
Aug. 13	46.8	25.8	33.0	40.8
Aug. 17	48.0	26.4	34.0	41.2
Aug. 19	47.0	27.0	34.0	41.8
Aug. 26	43.0	21.4	33.0	41.0
Aug. 30	45.8	19.8	32.4	41.0
Sept. 2	+	19.2	32.0	41.0
Sept. 8	48.0	26.0	32.0	41.6
Sept.10	18.2	10.8	22.6	36.6
Sept.11	23.2	14.6	23.2	37.0
Sept.12	29.4	15.6	26.0	38.0
Sept.14	9.2	5.8	9.8	17.0

PLATE II



PLOT SHOWING

GROUND WATER

IN THE

PEAT EXPERIMENTAL PLOTS

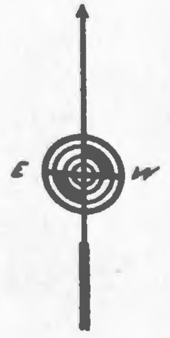
ON

NORTH CENTRAL EXPT. FARM

GRAND RAPIDS

MINN.

= 1914 =



Scale { Horizontal 1¼" = 35'
Vertical 1" = 1.2'

Prepared from a blue print by Prof. J. T. Stewart.

Traced by G.F.K.

Table XVIII. Five readings from each of 35 Wells on July 30th.

Well Nos.	Readings 1	2	3	4	5	Max. Error
3S	34.0	34.4	34.4	34.4	34.2	0.4
5S	29.6	29.8	29.8	29.8	29.4	0.4
7S	40.0	40.2	40.4	40.2	40.2	0.4
9S	30.0	30.0	30.0	30.0	30.0	0.0
11S	34.0	33.8	34.0	34.0	34.0	0.2
13S	34.0	34.0	33.8	34.0	33.8	0.2
15S	37.8	37.8	37.8	38.0	37.8	0.2
17S	42.6	42.6	42.6	42.8	42.8	0.2
21S	37.4	37.2	37.4	37.4	37.4	0.2
23S	28.8	28.8	29.0	28.8	28.8	0.2
25S	37.0	37.0	37.2	37.2	37.2	0.2
3C	43.2	43.4	43.2	43.2	43.4	0.2
7C	33.0	33.0	33.0	32.8	33.0	0.2
9C	28.0	27.8	27.8	27.8	27.6	0.4
11C	29.8	30.0	29.8	30.0	30.0	0.2
13C	34.0	34.0	34.2	34.2	34.0	0.2
15C	39.4	39.4	39.6	39.6	39.6	0.2
19C	41.2	41.0	41.0	41.0	41.2	0.2
21C	39.3	39.4	39.4	39.4	39.2	0.2
29C	33.0	33.4	33.0	33.0	33.2	0.4
1N	41.0	41.0	41.0	41.0	41.0	0.0
3N	---	36.8	36.4	36.6	36.6	0.4
5N	43.6	43.6	43.8	43.8	43.6	0.2
7N	31.4	31.0	31.2	31.0	31.0	0.4
9N	29.2	29.0	29.2	29.0	29.0	0.2
11N	28.2	28.2	28.2	28.4	28.2	0.2
13N	25.0	25.2	25.2	25.0	25.2	0.2
15N	28.4	28.2	28.4	28.2	28.2	0.2
17N	31.6	31.6	31.6	31.6	31.6	0.0
19N	32.0	32.0	32.0	32.0	32.0	0.0
21N	34.6	35.0	34.8	34.8	34.6	0.4
23N	34.0	34.0	34.0	---	34.0	0.0
25N	36.0	36.0	35.8	36.0	35.8	0.2
27N	40.4	40.4	40.4	40.2	40.4	0.2
29N	33.0	33.0	32.6	33.0	33.0	0.4

versely as the distances of these below the bog surface at the respective wells.

Prof. J.T. Stewart made, late in the Autumn of 1914, a survey of the experimental area determining the height of the different wells, etc. The accompanying diagram is copied from the Blue Print prepared by him. On this he has indicated the water levels on different days constructing the lines from my data.

The range of water level is great, it being at the surface in all of the wells during the flood during the night of June 26-27. If it had not covered the surface of all of the Plots the water would not have remained to the next forenoon so high in the wells where the ground surface is highest.

It will be seen from the latter that after this flood the water level fell steadily until August 22nd, when heavy rains caused a rise which continued irregularly until the end of the record on September 14.

Soil Temperatures.

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These temperatures in the case of the bog were determined during the growing season in alley-ways between plots, viz; Alleys 2, 3, 4, 9, 10, 11, 17, 18 and 19, within four feet of the East and West wide alley from East to West. A few readings were made on Plot 8 South. On the mineral soil about 30 feet due East of Well No.1 North similar determinations were made. These readings were made between 8 and 10 A.M. with the exception of the readings for September 1 which were made between 4 and 5:30 P.M.

Table: XIX Soil Temperatures on Bog and adjacent Mineral soil.

Date	Depth	Bog Soil	Mineral Soil	Difference	Atmosphere	Time
1914		°F	°F	°F	°F	
July 6	3 inches	69	77	8	85	A.M.
	6 "	63	70	7	85	"
	9 "	61	66	5	85	"
July 14	3 "	68	72	4	--	"
	6 "	66	67	1	--	"
	9 "	64	66	2	--	"
July 22	3 "	68	71	3	--	"
	6 "	66	69	3	--	"
	9 "	64	68	4	--	"
Aug. 3	3 "	62	67	5	72-78	"
	6 "	64	66	2	72-78	"
	9 "	63	63	3	72-78	"
Aug. 10	3 "	60	62	2	--	--
	6 "	62	63	1	--	--
	9 "	62	64	2	--	--
Aug. 17	3 "	61	64	3	73	A.M.
	6 "	61	64	3	73	"
	9 "	59	63	4	73	"
Sept. 1	3 "	60	62	2	56	P.M.
	6 "	59	61	2	56	"
	9 "	59	61	2	56	"

The data are reported in Table XIX, all being corrected by comparison of the thermometers with a standard instrument.

The peat soil showed the lower temperatures throughout the season, the difference being most marked at the beginning and the least nearthe close. These were sufficient to materially affect the rate of growth of any crops doing best on warm soils, which makes it evident that crops most suitable to the peat land of any district may be those which do best on mineral soils in decidedly cooler localities.

Moisture Content of the Soil.

Method of Sampling: The samples of peat soil used for moisture determinations were taken either with a narrow spade or a 4-inch plasterer's knife, a rectangular block of soil being cut out in such a way that it had a surface 4 inches by 4 inches and a depth of either 4 or 8 inches according to the depth to which the samples in question were being taken. Three cubes or blocks were thoroly mixed to form a composite sample in each case.

Previous to June 21 the samples were taken in triplicate from the wide alley running east and west and between the north and south portions of Plots 10, 11 and 12. After this they were taken only in duplicate until July 18. After this date only a single composite sample was taken from each group of plots on any one day except in certain special cases mentioned below.

The significance of differences in the moisture content are discussed in detail below. In order to make the data more significant the water content has been expressed on the dry basis except in Table XX where it is reported also on the wet basis. The former has the advantage of showing directly the relative changes of moisture content; the latter has one advantage, viz: that it minimizes the effect of slight changes in the water content.

From June 10 to July 21 samples were taken in the wide alley adjacent to Plots 7, 8 and 9, and also adjacent to Plots 17, 18 and 19, in such a manner that each sample was a composite of three cubes, one from adjacent to each of the three plots in the area.

From July 27 to August 17 samples were taken in the same manner from between the rows of potatoes on the different areas, the one referred to as that of "high water level" including Plots 7N, 8N and 9N, and the other as that of "low water level" including Plots 17N, 18N and 19N.

Table XX shows the moisture content in clean uncropped soil between June 10 and June 23, a period of very dry weather. During the first week that in the first 4-inch section fell 41 per cent, on the dry basis, with a corresponding fall of 7 inches in the water level. In the second 4-inch section no consistent change of moisture content is to be observed. The light rains during the second week, amounting to approximately 0.8 inches, prevented a marked change in the moisture content or water-level. It will be seen from the table that the average moisture content during the first week for the first 4-inch section was

Table XX Moisture in clean uncropped soil durimg two weeks of dry weather in June.

Date	Rain since previous samplimg. Inches	Water level below surface Inches	Water Content on wet basis: 1 to 4 in. P.ct.	5 to 8 in. P.ct.	9 to 16 in. P.ct.	Water Content on dry basis: 1 to 4 in. P.ct.	5 to 8 in. P.ct.	9 to 16 in. P.ct.
June								
10		19	78.3	81.1		362	365	
11	t	24	78.6	80.9		365	431	
12	0	24	78.1	81.3		350	418	
13	0	25	78.8	81.7	83.3	371	446	500
14	0	--	--	--	--	--	--	--
15	0	25	78.0	81.9		354	453	
16	0	26	77.0	79.1		334	382	
17	0	26	76.5	81.4*		321	432 *	
18	t	26	77.1	80.3		337	407	
19	0.5	26	79.7	80.9		344	423	
20	0.2	26	77.7	81.7	84.2	349	428	535
21	0							
22	0	26	76.8	80.0		331	400	
23	t	26	77.5	81.8		334	448	
Maximum		26	79.7	81.9	84.2	365	453	535
Minimum		19	76.5	79.1	83.3	321	382	500
Mean for 1st week		24	77.9	81.1	83.3	351	418	500
Mean for 2d week		26	77.8	80.9	84.2	341	421	535
Difference			0.1	0.2	-0.9	10	3	35

* Indicates thatonly one composite was made.

practically the same as for the second week altho there was a difference of 2 inches in the average water level. The second 4-inch section also remained practically constant in moisture thruout the two weeks. As is to be expected the same holds true with the second 8-inch section. Thus the moisture content and the water level in the uncropped soil remained almost constant thruout this period.

Table XXI shows the variation in the moisture content in clean uncropped soil from June 23 to August 12, thus including a flood on June 26 and a period of prolonged drought.The relation of the moisture content to the changing water level may be seen, the one area sampled having a distinctly higher water level than the other both before and after the flood referred to. Before the torrential rain on June 26-27 the first 4 inches in

Table XXI

Moisture Content on Clean Uncropped Peat Soil, Showing the Influence of the Water Level.

Date		Rain since previous Sampling Inches	Water level below surface A	B	Diff.	Moisture Content. Area A with higher water level 1 to 4 inches P.ct.	5 to 8 inches P. ct.	9 to 16 inches P. ct.
June	23	0	27	48+	21+	352	402	--
"	25	0.3	27	48+	21+	349	394	--
"	26	0	27	48+	21+	331	399	--
"	30	2.8	10	14	4	450	478	534
July	1	0	9	11	2	387	--	--
"	2	t	12	18	6	399	436	--
"	3	0	14	24	10	382	435	--
"	4	t	12	22	10	398	424	--
"	6	0.3	18	34	16	388	432	443
"	7	t	19	35	16	384	399	--
"	8	0	21	36	15	381	409	--
"	9	t	21	36	15	373	395	--
"	10	0	22	37	15	343	385	--
"	11	t	22	38	16	360	411	--
"	13	0.5	22	39*	17	376	428	512
"	14	0	23	40*	17	374	395	--
"	15	0	23	41*	18	335	395	--
"	16	0	23	41*	18	379	439	--
"	17	0.1	24	42*	18	354	423	--
"	18	t	25	44*	19	351	390	--
Maximum			27	48+	21+	450	478	534
Minimum			9	11	2	331	385	437
Mean June		23-26	27	48+	21+	344	398	
" July		1-7	14	24	10	389	425	
" "		8-14	22	38	16	368	404	
" "		15-18	24	42	18	373	412	

* Average includes one depth of 48

<u>Area B</u> with lower water level			Excess of water in area with higher water level		
1 to 4 inches P. ct.	5 to 9 inches P. ct.	9 to 16 inches P. ct.	1 to 4 inches P. ct.	5 to 8 inches P. ct.	9 to 16 inches P. ct.
--	--	--	--	--	--
336	420	--	+13	-26	--
341	411	--	-10	-12	--
459	487	499	- 9	- 9	+35
416	420	--	-29	--	--
415	433	--	-16	+ 3	--
399	428	--	-17	+7	--
402	432	--	- 4	+8	--
379	441	463	+9	-9	-20
399	426	--	-15	-27	--
403	418	--	-22	- 9	--
374	408	--	- 1	-13	--
362	419	--	-19	-34	--
352	419	--	+8	- 8	--
384	433	489	- 8	- 5	+23
385	400	--	-11	- 9	--
349	418	--	-14	-23	--
358	403	--	+21	+36	--
351	395	--	+ 3	+28	--
353	410	--	- 2	-20	--
459	487	499	+21	+36	+35
336	395	461	-29	-34	-20
339	416		+5	-18	
402	430		-13	- 5	
377	416		- 9	-12	
370	407		+3	+5	

Area A showed practically the same moisture content as that in Area B. In case of the area of high water level the changes from July 1 to July 23 were insignificant, and similar to those in the area of low water level.

Table XXII shows the water content between the rows of potatoes in both an area of high water level and one with low water level. An average difference of 19 inches in water level from July 27 to August 24 was accompanied by a difference of 100 per cent in the moisture content of the first 4-inch section on July 27 and of 119 per cent on August 10, two weeks of very hot dry weather having intervened.

In the sections below the surface 4 inches the changes in moisture content in the case of Area A were less than those in Area B, especially in the second foot. The most marked difference

Table XXII. Moisture between rows of potatoes showing the influence of the water-level.

Date	July 27	Aug.3	Aug.10	Aug.17	Aug.24
Rain since previous sampling.	0.1	t	t	0.2	2.0
Water level (A	29	31+	33	35	
below surface, in (B	48+	48+	48	48+	48+
" difference	19+	17+	15	13+	
Water Content					
	P.ct.	P.ct.	P.ct.	P.ct	P.ct.
In Area A with higher water level.					
1-4 in.	370	275	264	230	279
5-8 "	404	348	342	328	353
9-16 "	489	434	447	426	424
17-24 "	629	604	675	562	609
25-36 "	858	862	824	---	---
In Area B with lower water level.					
1-4 in.	270	210	145	165	184
5-8 "	353	264	182	219	223
9-16 "	426	387	341	328	351
17-24 "	590	524	558	521	541
25-36 "	743	644	714	---	---
Excess in Area A.					
1-4 in.	100	65	119	65	85
5-8 "	51	84	162	109	130
9-16 "	63	47	106	98	71
17-24 "	39	80	117	41	68
25-36 "	115	218	110	---	--

Table XXIII Moisture content of soil on potato plots after prolonged dry weather, showing relative effects of position in the plot and of level of ground-water.

	Water level ins.	Water-Content 1-4 ins. P.ct.	5-8 ins. P.ct.	9-16 ins. P.ct.
Aug.10, Plots 7, 8, 9, Between rows	34	264	342	447
" " " 17,18,19, " "	48	145	182	341
" 12-13 " " " " " "	48	149	211	350
" " " " " " " Under hills	48	182	228	348
" 12 " " " " In Alley	48	226	347	390
" 12 " 7, 8, 9 " "	34	300	328	437

in the moisture content is to be observed in the second 4-inch section.

Table XXIII gives the difference in moisture content found between different portions of the plots after a long period of dry weather. The samples on August 12-13 taken from the rows on Plots 17N, 18N and 19N were from 15 inches south of Row No.1, the most northerly on the plots. The moisture content of the first 4-inch section in the case of Plots 7N, 8N and 9N was 35 per cent lower between the potato rows than in the adjacent uncropped alley, while the lower sections differed to a less extent.

In the case of Plots 17N, 18N and 19N there was found in the first 4-inch section in the alley 81 per cent more moisture than between the rows of potatoes. In the second 4-inch section the difference in moisture content between the high water level and the low water level areas was very small where the samples were taken in the alleys, but there was a marked difference in the case of those taken between the rows. It is interesting to observe that there was if anything slightly less moisture between the rows than under the hills of potatoes. This may be due to protection from evaporation and a lower soil temperature on account of the protection from the sun afforded by the vines. An examination of the root distribution showed that the roots were more numerous between the rows than under the hills. It is clear from the table that while in the case of the uncropped peat soil there appears to be no distinct dependence of the moisture content upon the relative water level, this is not true in the case of the cropped land. In the former capillarity tho weak may be sufficient to counterbalance evaporation, while in the latter the enormous loss of water thru transpiration far exceeds that supplied from below.

Table XXIV shows the difference between the moisture content under the hills and that between the rows where Plots 17, 18 and 19 were sampled separately, the averages of the date being recorded in Table XXIII. In the case of the surface 4 inches there was slightly more moisture under the hills, but in the case of the second 4 inches and the second 8 inches there was no distinct difference found.

Table XXV shows the water content in a field of oats on thoroly drained peat soil from July 23 until the crop was harvested on August 19. A distinct decrease in water content is to be observed at all depths where the data of the last 4 weeks are compared with those for the first 4 weeks.

Table XXIV. Differences in moisture of soil under the hills and between the rows of potatoes. Six weeks of dry weather preceded the date of sampling

Date	Plot No.	Under Hills 1-4 ins. P.ct.	Under Hills 5-8 ins. P.ct.	Under Hills 9-16 ins. P.ct.	Between Rows 1-4 ins. P.ct.	Between Rows 5-8 ins. P.ct.	Between Rows 9-16 ins. P.ct.	Excess under hills 1-4 ins. P.ct	Excess under hills 5-8 ins. P.ct.	Excess under hills 9-16 ins. P.ct.
Aug. 12	17	172	258	363	137	207	333	35	51	30
" 13	18	199	250	383	184	273	388	15	-23	-5
" "	19	176	177	298	126	153	328	50	24	-30
Averages		182	228	348	149	211	350	33	17	-2

Table XXV. Changes in water-content of soil in an oat field on thoroly drained shallow peat during the month preceding maturity.

Date	Rain	Water-content 1-4 ins. P.ct	5-8 ins. P.ct	9-16 ins. P.ct	17-24 ins. P.ct.	25-36 ins. P.ct.	Decrease in water since previous sampling 1-4 ins. P.ct	5-8 ins. P.ct	9-16 ins. P.ct	17-24 ins. P.ct.	25-36 ins. P.ct.
July 23		187	256	340	--	--	--	--	--	--	--
" 27	0.1	168	201	318	484	--	19	55	22	--	--
" 30	0.2	176	185	305	479	--	-8	16	13	5	--
Aug. 3	t	123	148	306	419	425	53	37	-1	60	--
" 5	t	141	171	303	438	460	-18	-23	3	-19	-35
" 10	t	105	138	225	412	342	36	33	78	26	118
" 13	0.1	121	129	252	404	--	-16	9	-27	8	--
" 17	0.2	118	125	265	370	--	3	4	-13	34	--
" 19	0	133	139	253	404		-15	-14	12	-34	--
Average first 5 wks.		159	192	314	455	443	--	--	--	--	--
Average last 4 wks.		177	133	249	397	342	--	--	--	--	--
Total for first 4 wks.	--	--	--	--	--	--	46	85	37	46	--
Total for last 4 wks.	--	--	--	--	--	--	8	32	50	34	
Total for the 8 weeks	--	--	--	--	--	--	54	117	87	80	

Free Water in Mineral Soil
Adjacent to Bog Soil.

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The mineral soil sampled was within 40 rods of the bog plots including 9 of the so-called Fertilizer Plots.

The first samples were taken on June 25th from the corn plots, the plants being very small at the time. It may accordingly be concluded that at the time the soil was carrying its maximum load of water. The second set of samples was taken from the clover plots on July 20, the day the hay was cut. There had been three weeks of dry weather and accordingly the soil was probably as dry as it will often be found at Grand Rapids. The third set of samples was taken on August 14 from the oat plots the day the crop was harvested.

The moisture content ranged from 3.8 to 18.2 per cent in these plots as compared with a range from 118 to 404 per cent in the peat soil.

We could scarcely secure a better illustration of the lack of significance of a mere statement of the total water content in the soil. Thus, there was six times as much total water in the peat soil of the oat field when the crop ripened during a drouth as there was in the corn land when it was wettest.

The lower limit of available water in the peat soil is at present in process of determination but the data are not yet available.

TABLE XXVI.

Moisture Conditions in Mineral Soil.

Foot Section	Total Water P. Ct.	Hygro-scopic Coeffi-cient.	Free Water P. Ct.	Field Notes	Ratio Water Total / Hy. Coeff.
Series I. June 25, 1914, - Corn Field.					
Plot I					
First	14.7	4.3	10.4	Moist	3.4
Second	13.4	4.0	9.4	"	3.4
Third	13.9	4.4	9.5	""	3.2
Fourth	14.0	3.9	10.1	Very Moist	3.6
Plot VII					
First	15.8	3.9	11.9	Moist	4.1
Second	11.5	2.2	9.3	"	5.2
Third	18.2	6.0	12.2	"	3.0
Fourth	15.7	3.2	12.5	Very Moist	4.9
Plot XIII					
First	14.6	3.4	11.2	Moist	4.3
Second	10.3	1.9	8.4	"	5.4
Third	8.1	1.3	6.8	"	6.2
Fourth	13.2	3.3	9.9	Very Moist	4.0
Average for Three Plots:					
First	15.0	3.9	11.2		3.9
Second	11.7	2.7	9.0		4.7
Third	13.4	3.9	9.5		4.1
Fourth	14.3	3.5	10.8		4.2

TABLE XXVI continued.

Foot Section	Total Water P. Ct.	Hygroscopic Coefficient.	Free Water P. Ct.	Field Notes	Ratio Water Total / Hy. Coeff.
		Series III.			
		July 20, 1914, - Clover Field.			
Plot 5					
First	13.0	4.3	8.7		3.0
Second	11.8	3.9	7.9		3.0
Third	11.6	4.4	7.2		2.6
Fourth	13.3	4.4	8.9		3.0
Plot 11					
First	6.3	4.1	2.2		1.5
Second	6.1	2.6	3.5		2.3
Third	7.8	3.0	4.8		2.6
Fourth	9.7	3.4	6.3		2.9
Plot 17					
First	6.2	3.8	2.4		1.6
Second	6.8	2.9	3.9		2.3
Third	7.0	2.5	4.5		2.8
Fourth	6.6	2.4	4.2		2.8
Average for Three Plots:					
First	8.5	4.1	4.4		2.0
Second	8.2	3.1	5.1		2.5
Third	8.8	3.3	5.5		2.7
Fourth	9.9	3.1	6.5		2.9

TABLE XXVI. (continued)

Foot Section	Total Water P. Ct.	Hygro-Scopic Coeffi-cient.	Free Water P. Ct.	Field Notes	Ratio Water Total / Hy. Coeff.
Series II.					
August 14, 1914, - Oat Field.					
Plot 17					
First	4.1	4.9	-0.8	Dry	0.8
Second	5.5	2.7	2.8	Very slightly Mst.	2.0
Third	7.2	2.9	4.3	Moist	2.5
Fourth	8.8	3.1	5.7	"	2.8
Plot 11					
First	6.3	5.5	0.8	Dry	1.1
Second	8.2	4.1	4.1	Moist	2.0
Third	9.3	3.9	5.4	"	2.4
Fourth	6.5	2.2	4.3	"	3.0
Plot 5					
First	4.2	4.0	0.2	Dry	1.0
Second	3.9	2.4	1.5	Dry	1.6
Third	3.8	1.4	2.4	Moist	2.7
Fourth	6.1	1.9	4.2	"	3.2
Average for three plots:					
First	4.9	4.8	0.1		1.0
Second	5.9	3.1	2.8		1.9
Third	6.8	2.7	4.0		2.5
Fourth	7.1	2.4	4.7		3.0

TABLE XXVII.

Hygroscopic Coefficients of Soil on Fertilizer Plots.

Plot	1st.ft.	2nd.ft.	3rd.ft.	4th.ft.
		Series I.		
1	4.3	4.0	4.4	3.9
7	3.9	2.2	6.0	3.2
13	3.4	1.9	1.3	3.3
Av.	3.9	2.7	3.9	3.5
		Series II.		
5	4.0	2.4	1.4	1.9
11	5.5	4.1	3.9	2.2
17	4.9	2.7	2.9	3.1
Av.	4.8	3.1	2.7	2.4
		Series III.		
5	4.3	3.9	4.4	4.4
11	4.1	2.6	3.0	3.4
17	3.8	2.9	2.5	2.4
Av.	4.1	3.1	3.3	3.4

Preparation of the Seed Bed and Planting of the Crops.

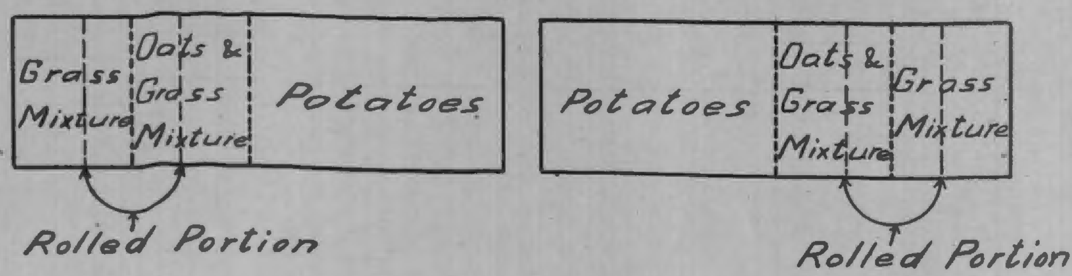
An attempt was made to plow the experimental area but it had to be abandoned on account of the lack of bog shoes. On May 30 and June 1 and 2 the following operations were performed on the whole area:

1. Four double diskings.
2. Two cultivations with a spring-tooth harrow.
3. Two cultivations with a smoothing harrow.
4. Two rollings.

One-fourth of each plot was seeded to Ligowo Oats and a mixture of Medium Red Clover, Alsike Clover, Timothy and Red Top (with 4, 2, 6 and 4 pounds respectively). Another fourth of each plot was seeded to the same mixture of grass and clovers but without the oats. In the case of both portions of the plot the grass seed was scattered by hand. Where it was followed by the oat drill no harrowing

PLATE III

LOCATION OF THE CROPS ON THE PLOT



Scale 1" = 20'

was necessary but on the portions seeded without oats a single stroke of the smoothing harrow was given the grass seed. After seeding the grass mixture a portion of both the oats and the grass plots were rolled once as shown on the accompanying diagram. The other half of each plot was planted to potatoes during the following ten days, it requiring this time to complete the work. The tubers were placed at intervals of 12 inches in rows 30 inches apart. A wooden stake sharpened at the lower end with a step attached served to facilitate the planting, the seed pieces being placed from 2 to 3 inches below the surface. To render cultivation convenient the rows ran crosswise of the plot, from east to west. The seed used was partly "Early Ohio" and partly "Early Six Weeks" there not being sufficient of the former obtainable. Neither was a pure bred stock.

The size of the seed pieces, the date of planting and the variety are indicated in Table XXVIII.

Table XXVIII. Size and variety of Potato Seed Pieces, with date of planting.

Row	Variety	Date of Planting.	Size of Tuber.
1	Early Ohio	June 5	1 medium.
2	" "	" 6	½ of "
3	" "	" 9	1 large.
4	" "	" 9	½ of "
5	" "	" 9	1 small.
6	" "	" 10	½ of medium.
7	" "	" 11	(1 large, north plots (1 small, south "
8	" "	" 11	¼ of medium.
9	Early Six Weeks	" 11	1 "
10	" " "	" 11	½ of large.
11	" " "	" 12	½ of small.

Wt. of small potatos 1-3 oz.
" " medium " 3-5 "
" " large " 4-7 "

Fertilization.

The fertilizers used, the rate of application per acre, and the composition insofar as this was determined by analysis, are reported in Table XXIX.

Table XXIX. Fertilizers used.

Reference abbreviations.	Fertilizer	Composition	Rate per acre of application.
N.	Sodium nitrate	15% N	400 lbs.
K.	Potassium sulphate	50% K_2O	400 "
P.	Steamed bone meal	20% P_2O_5	800 "
P.	Ground rock phosphate	25% P_2O_5	2,000 "
L.	Quick lime	-------	2,000 "
M.	Barnyard manure	-------	20,000 "

The treatment of the different plots is shown in Table XXX every treatment appearing in duplicate while there were six check plots. On account of the previous fertilization the distribution of the different fertilizers was sharply limited, it

Table XXX.
Fertilization of the Different Plots.

Plot No.	North Plots: In 1914	North Plots: Previous to 1914	South Plots: In 1914	South Plots: Previous to 1914
1	N	N1911&1912	NK	N1911&1912
2	NP	P " "	P	P
3	KL	K " "	NKL	K
4	L	L " "	NL	L " "
5	None	M " "	ML	M " "
6	K	None	None	None
7	NPK	N " "	NPK	N
8	PK	P " "	PK	P " "
9	NPKL	K " "	PKL	K " "
10	NPL	L " "	NPKL	L " "
11	M	M " "	MPK	M " "
12	Nome	None	K	None
13	NK	N " "	N	N " "
14	PL	P " "	NP	P " "
15	NKL	K " "	KL	K " "
16	NL	L " "	None	L " "
17	ML	M " "	None	M " "
18	P	None	None	None
19	NPK	N " "	NPK	N " "
20	PKL	P " "	NPKL	P " "
21	NPKL	K " "	NPL	K " "
22	None	L " "	PL	L " "
23	MPK	M " "	M	M " "
24	None	None	None	None
25	L	None	P	None
26	PK	None	None	None
27	PK	None	None	None
28	P	None	None	None

being necessary, for instance, to use on a plot previously treated with potash either potassium sulphate alone or some mixture including this. As arranged there were many pairs of duplicates of which one was on shallow peat and the other on deep peat.

On account of the flood of June 26-27 a second application of sodium nitrate and of potassium sulphate was made on July 24 to the east half of each potato plot which had previously received this, but at only half the original rate of application. The two halves of each row on each plot were harvested separately so that it might be seen whether the yield had been seriously affected for want of either nitrogen or potash due to the leaching of these fertilizers by the flood.

The applications of lime and rock phosphate were made previous to the first double disking and that of the other commercial fertilizers after this operation, thus permitting all to become thoroly mixed with the soil before seed was introduced into the ground. Where barnyard manure was used this was scattered on the surface immediately after the seeding of the oats and grass.

The Potato Crop.

These were kept free of weeds, it being necessary to go over the ground with a wheeled rake twice during the latter half of June, with a wheeled hoe twice during the first half of July, while all were hoed by hand on the 13th and 24th of the same month, thus making 6 cultivations in all. The plants were sprayed with Bordeaux Mixture on July 17 and 28, and with Paris Green about once a week from July 17 on.

As there had been a second application of fertilizers to the east half of each of 30 of the plots it was necessary to harvest the potatoes on these by half plots. In most cases there were 14 hills in a row. Where, however, this was not the case the tubers in the hill on the line were placed with that half of the row to which the greater part of the hill belonged according to the exact location. The tools used for harvesting were potato hooks, after pitchforks, spading forks and hoes had been tried but found unsatisfactory. The bog was far too soft to have permitted of the use of a potato digger had one been available.

The tubers were separated into "marketable" and "unmarketable" according to the size, those less than 1 7/8 inches in diameter being placed in the latter class. All weights were recorded in the field and confirmed before the pails were removed from the spring balance used for the purpose. The weights were recorded by plot number, row number and half row whenever the last division was necessary. From the potatoes from each plot half a bushel of average size were selected and sent to the Experiment Station to later be tested for quality.

In Table XXXI there are recorded the yields

Table XXXI.

Yields of Potatoes in Pounds and Ounces Given for Each Row on the Different Plots.

North Plot

Plot	Fertilizer	Total per Plot	Row 1	Row 2	Row 3	Row 4
1	N	149-14	12-0	15-12	12-14	14-8
2	NP	168-2	16-2	17-0	17-6	14-14
3	KL	202-7	16-13	21-0	21-8	21-10
4	L	178-14	15-10	16-14	16-14	16-10
5	M'11 &'12	136-8	11-12	14-14	13-8	13-8
6	K	105-7	6 -17	14-10	11-12	11-10
7	NPK	214-14	19-14	16-4	26-4	22-8
8	PK	191-15	18-7	16-4	16-8	20-6
9	NPKL	226-10	21-8	27-6	20-10	24-10
10	NPL	194-12	18-3	14-14	19-8	23-14
11	M	196-8	19-5	20-0	21-8	17-5
12	None	160-0	14-4	15-8	13-12	13-8
13	NK	199-10	17-8	18-2	16-10	20-4
14	PL	207-8	17-14	19-12	18-10	14-4
15	NKL	211-12	17-12	24-0	15-6	20-6
16	NL	179-8	18-8	17-8	15-12	22-8
17	ML	173-5	17-7	18-14	14-12	18-2
18	P	123-14	13-6	13-6	11-12	9-6
19	NPK	196-3	20-7	19-2	18-8	18-0
20	PKL	194-12	20-12	20-2	19-8	14-14
21	NPKL	221-8	20-10	21-14	21-0	16-14
22	L'11 &'12	133-4	13-2	8-14	13-2	9-12
23	MPK	205-8	22-6	18-2	17-14	16-4
24	None	128-10	13-0	10-10	11-12	10-0
25	L	144-11	14-13	14-6	15-4	11-10
26	PK	213-13	22-5	18-4	20-10	18-8
27	PK	174-8	17-8	17-2	17-2	16-8
28	P	122-0	10-8	10-2	13-4	9-12
Total for 28 plots		4956-5	468-13	480-10	473-12	461-15

Row 5	Row 6	Row 7	Row 8	Row 9	Row 10	Row 11
11-14	12-0	14-8	12-14	13-14	13-12	15-14
13-12	12-6	18-8	13-4	16-2	12-14	15-14
17-8	17-2	21-4	12-12	16-12	17-0	19-2
16-6	14-6	21-14	12-8	17-4	14-10	15-14
11-0	7-14	16-0	7-0	14-2	17-0	9-14
12-10	2-6	6-6	6-12	10-2	12-6	9-12
19-6	15-2	21-0	13-14	22-14	20-6	17-6
16-2	10-10	22-4	13-6	20-0	16-8	21-8
17-14	15-4	18-0	16-0	24-2	22-8	18-12
22-0	20-2	15-13	14-6	16-2	12-2	17-12
19-14	20-8	8-6	17-0	18-2	16-12	17-12
13-2	13-8	17-14	12-2	13-12	15-2	17-8
21-0	13-12	25-2	12-0	18-4	16-12	20-4
19-8	15-0	25-8	13-10	24-8	21-4	17-10
22-2	9-10	27-4	12-8	20-8	17-8	24-12
15-12	13-12	20-8	15-2	15-2	15-14	8-2
14-8	13-2	21-8	9-14	16-0	14-8	14-10
9-14	7-4	12-4	9-6	14-4	12-4	10-12
18-14	16-12	24-8	6-12	17-4	18-8	17-8
19-4	15-14	14-10	12-2	20-6	18-2	19-2
22-14	15-6	22-4	17-6	17-6	24-10	21-4
11-0	10-10	16-12	10-6	11-10	15-8	12-8
19-0	16-12	22-14	14-2	19-2	19-12	19-4
12-2	11-12	14-2	7-2	12-14	13-2	12-2
13-6	10-8	18-0	7-4	13-8	15-0	11-6
21-10	17-2	23-10	13-14	18-0	21-4	18-10
15-10	16-10	20-8	9-4	15-12	16-14	11-10
12-12	9-14	15-4	8-0	8-4	11-6	12-14
460-6	375-0	526-7	330-10	466-0	463-4	449-6

Table XXXI Continued.

South Plots.

Plot	Fertilizer	Total per plot	Row 1	Row 2	Row 3	Row 4
1	NK	196-5	18-13	25-6	18-14	19-10
2	P	193-1	18-3	20-14	20-12	18-0
3	NKL	208-6	20-8	21-6	19-14	18-2
4	NL	186-1	21-9	19-14	16-12	13-10
5	ML	159-10	16-6	18-8	15-6	13-10
6	None	119-13	9-15	13-6	13-4	11-8
7	NPK	223-5	18-3	22-8	22-0	20-12
8	PK	139-3	7-9	13-0	9-2	11-14
9	PKL	209-2	19-0	21-14	17-10	19-8
10	NPKL	240-0	17-14	24-12	25-12	17-14
11	MPK	205-6	16-4	24-14	19-2	16-10
12	K	198-10	19-2	22-12	17-2	18-14
13	N	188-6	17-2	16-12	17-0	17-4
14	NP	210-10	15-0	21-4	21-2	19-8
15	KL	185-6	15-12	18-12	16-0	16-14
16	L'11&'12,	156-8	14-6	15-2	16-14	14-4
17	M'L1&'12	146-6	14-8	15-6	14-4	13-6
18	None	114-14	10-10	11-8	12-6	10-6
19	NPK	188-14	16-12	18-4	21-6	21-8
20	NPKL	200-12	14-4	21-0	19-6	20-6
21	NPL	181-15	16-1	17-2	18-8	19-2
22	PL	196-0	17-4	22-4	18-4	18-4
23	M	196-2	18-10	17-2	19-4	20-2
24	None	148-7	15-2	15-8	14-8	13-14
25	P	142-2	14-2	14-4	13-10	16-8
26	None	135-14	9-14	15-12	13-8	14-12
27	None	143-14	11-6	12-6	11-12	13-12
28	None	141-11	9-13	12-14	12-4	15-8
		4956-11	432-1	514-6	475-10	465-6
Total 28 plots		4956-5	468-13	480-10	473-12	461-15
Total 56 plots		9913-0	900-14	995-0	949-6	927-5

Row 5	Row 6	Row 7	Row 8	Row 9	Row 10	Row 11
26-10	14-14	19-10	11-2	14-0	16-2	13-4
15-12	14-2	18-8	10-10	17-4	17-0	22-0
22-14	14-10	20-2	10-6	18-14	20-8	21-2
21-8	11-8	12-2	12-0	16-8	21-8	19-2
14-10	8-6	12-0	7-8	20-6	14-10	18-4
14-14	8-10	13-6	9-4	7-8	10-0	8-2
24-4	18-8	16-4	17-12	18-14	21-0	23-4
10-0	9-10	14-12	11-2	16-2	16-8	19-8
23-4	14-4	19-6	16-0	17-2	18-0	23-2
28-8	19-6	27-8	14-6	19-8	24-0	20-8
24-4	15-14	22-2	12-2	19-14	15-14	18-6
18-10	16-10	22-8	11-8	16-4	15-12	19-8
19-0	17-0	22-10	12-6	12-8	18-2	18-10
23-6	18-6	20-4	15-12	13-8	20-4	22-4
20-2	14-12	20-14	11-8	16-4	16-0	18-8
15-0	12-6	15-4	12-0	12-12	13-0	15-8
15-2	10-8	16-12	10-10	13-10	10-6	11-14
6-12	9-12	8-12	9-4	11-4	12-0	12-4
16-2	18-12	13-6	10-2	16-4	23-4	13-2
19-12	11-0	19-12	8-4	22-12	22-0	22-4
17-2	11-8	19-4	8-8	18-8	20-10	15-10
22-2	14-6	18-12	12-14	15-10	19-0	17-4
17-4	16-0	18-4	14-14	17-6	19-14	17-6
14-4	10-2	14-12	9-10	12-2	14-6	14-2
15-2	10-0	12-2	11-14	13-0	12-0	9-8
14-12	10-8	10-14	10-2	10-8	11-14	13-6
15-8	12-2	14-2	11-8	14-6	13-8	13-8
16-4	11-2	13-4	12-10	12-14	11-14	13-4
512-12	374-10	477-4	325-10	435-8	469-0	474-8
460-6	375-0	526-7	330-10	466-0	463-4	449-6
973-2	749-10	1003-11	656-4	901-8	932-4	923-14

in pounds and ounces of each row on the different plots, as well as the yield per acre for the entire plot.

The method which gave the highest yields was that in which whole large potatoes were employed, this being closely followed by that in which halves of large potatoes were used. The lowest yield was from a row in which quarters were employed. The ratio between the highest yield obtained from the whole large potatoes and the lowest from the quarters is approximately 5 to 3.

The data in table XXXII show the effect of the second application of sodium nitrate and sulphate of potash, the details being given in a previous table. The effect of the second application is negligible, an actual decrease being shown.

TABLE XXXII

Effect of Second Application of Nitrate and of Potash upon Potatoes. The data are the average for the number of plots indicated in the second line.

Fertilizer	K	N	NK	All
No. of Plots	12	8	12	32
One application				
Marketable lbs.	58.5	48.4	68.2	59.6
Unmarketable lbs.	31.8	38.2	35.4	34.8
Total	90.3	86,6	103.6	94.4
Two applications				
Marketable lbs.	57.5	47.8	67.1	58.7
Unmarketable lbs.	30.7	37.2	31.2	32.5
Total	88.2	85.0	98.3	91.2
In crease due to second application.				
Marketable lbs.	-1.0	-0.6	-1.1	-1.0
Unmarketable lbs.	-1.1	-1.0	-4.2	-2.3
Total	-2.1	-1.6	-5.3	-3.3

TABLE XXXIII.

Effect of the Different Fertilizers upon the yield of Potatoes reported as bushels per acre.

Effect of Lime.

Fertilizer	Without Lime	With Lime	Increase	Decrease
O	219	270	51	-
N	293	305	21	-
P	275	337	62	-
K	253	323	70	--
NP	255	336	81	-
NK	347	350	3	-
PK	338	337	--	1
NPK	337	357	20	-
NPK	350	385	35	-
M	327	278	--	49
Average	299	328	29	

Effect of Sodium Nitrate.

	Without	With	Increase	Decrease.
O	219	293	74	-
P	275	255	--	20
K	253	347	94	-
L	270	305	35	-
PK	338	337	--	1
PL	337	336	--	1
KL	323	350	27	-
PKL	337	357	20	-
PK	262	350	88	-
Average	290	326	38	

TABLE XXXIII (continued).

Effect of Bone Meal.

Fertilizer	Without	With	Increase	Decrease.
O	219	275	56	--
N	293	255	--	38
K	253	338	85	--
L	270	337	67	--
NK	347	337	--	10
NKL	350	357	7	--
Average	289	317	28	

Effect of Raw Rock Phosphate.

	Without	With	Increase	Decrease.
O	219	220	1	-
K	253	262	9	-
NK	347	350	3	-
NKL	350	385	35	-
Average	292	306	14	

Effect of Manure.

	Without	With	Increase	Decrease
O	219	327	108	-
L	270	278	8	-
PK	338	343	5	-
Average	276	316	40	

Effect of Manure applied in previous years.

	Without	With	Increase	Decrease
O	219	235	16	-

TABLE XXXIII (continued).

Effect of Sulphate of Potash.

Fertilizer	Without	With	Increase	Decrease.
O	219	253	34	-
P	275	338	63	-
N	293	347	54	-
L	270	323	50	-
NP	255	337	82	-
PL	337	337	0	-
NL	305	350	45	-
NPL	336	357	21	-
P	220	262	42	-
Average	279	323	44	

Effect of Lime in Previous Years.

	Without	With	Increase	Decrease.
O	219	242	23	-

SUMMARY

Fertilizer	No.of Plots	Without Treatment	With Treatment	Increase
L	10	299	328	29
N	9	290	326	38
P	6	289	317	28
P	4	292	306	14
M	3	276	316	40
M 11 & 12	1	219	235	16
K	9	279	323	44
L 11 & 12	1	219	242	23

We may safely conclude that notwithstanding the probable removal of a large amount of potash and nitrate by the water of the flood of June 26, there still remained so much potassium and nitrogen available to the potatoes that neither of these was a limiting factor in the yield in the case of those plots to which they had been added.

The effect of the different fertilizers may be seen from Table XXXIII in which are shown the average yields arranged in such a way that the effect of any fertilizer, either alone or in combination may be readily seen. Potash appears to cause an increase in 8 out of 9 cases, lime in 7 out of 10, nitrate in 6 out of 9, bone meal in 3 out of 6, rock phosphate in 1 out of 4, and manure in 1 out of 3. The potash, as was to be expected, showed the most marked benefit, and while the other fertilizers in general have a distinctly beneficial effect, this in any particular case cannot with any degree of certainty be predicted.

Potash with nitrogen and bone meal proved the combination that gave the highest yield. However even without nitrogen the yield was satisfactory. With bone meal and lime the potash failed to produce any improvement. It seems especially valuable in any of the combinations not containing lime or when it is used with lime alone.

With either potash or bone meal lime showed a distinctly beneficial effect, but in combination with the two it seemed to have a slightly depressing effect. It should be pointed out that the plot receiving manure alone was located over a tile drain, while that receiving both manure and lime was not so situated. The last mentioned combination seemed to have no beneficial effect over the lime. The combination of lime with nitrate and bone meal or with raw rock and potash showed a tendency to promote the development of rot. This tendency, however, was more marked on the south plots which were nearer the mineral soil.

Bone meal was most effective when combined with potash and less so in combination with lime, while with nitrogen it did not seem beneficial.

Nitrogen showed its most beneficial effects when combined with potash alone or with raw rock and potash. When used alone, while not producing consistent results, it caused on the whole a distinct increase in yield. In contrast with its beneficial effects with lime, with potash and lime together, or bone meal, potash and lime, it did not show a benefit when used with bone meal alone.

Manure when used alone gave the highest yield of any fertilizer or combination of fertilizers, but when used along with commercial fertilizers, this beneficial effect was not seen. It is of interest to observe that lime and manure used together failed to give a distinct increase in yield over either used alone.

Raw rock phosphate showed a decidedly beneficial effect when combined with nitrogen, potash and lime. Altho used at the ra te of 2,000 pounds per acre it failed to produce the effects caused by lime or limestone when it was used alone.

Ground limestone added in 1911 showed a beneficial effect. On all other plots where limestone had been added in 1911 the effects were favorable.

Manure added in 1911 and 1912 showed but little effect, the duplicate plots giving concordant yields.

Table XXXIV.
Effect of Previous Treatment upon Yield of Potatoes.

Treatment in 1914	Plot Nos. a	Plot Nos. b	Fertilizers previous to 1914 a	Fertilizers previous to 1914 b	Difference in water level Inches	
NPKL	9N	20S	K	P	12.5	
NPK	7N	19S	N	N	9.9	
NPKL	10S	21N	L	K	7.1	
NPK	7S	19N	N	N	9.9	
MPK	23N	11S	M	M	*	15.9*
NKL	15N	3S	K	K		2.5
NPL	10N	21S	L	K	7.1	
PKL	9S	20N	K	P	12.5	
NL	4S	16N	L	L	3.1	
PL	14N	22S	P	L	6.7	
ML	17N	5S	M	M		5.5
KL	3N	15S	K	K	1.5	
PK	27N	8S	O	P		3.7
PK	26N	8N	O	P		17.3
NP	2N	14S	P	P		3.7
NK	15S	13N	N	N		9.1
M	11N	23S	M	M	15.9*	*
L	4N	25N	L	O	3.3	*
N	13S	1N	N	N	9.1	*
K	12S	6N	O	O	4.3*	
P	2S	18N	O	P		0.6
P	25S	28N	O	O		6.1
M'11&'12	17S	5N	M	M		5.5
L'11&'12	16S	22N	L	L		0.3
Check	12N	6S	O	O	4.3	
Check	24N	18S	O	O	*	3.1

* A tile line under or very near the plot.

Yield a	Yield b	Percentage Marketable a	Percentage Marketable b
Bu. per acre			
378	335	69.4	64.7
358	315	68.8	63.4
400	369	64.6	70.0
374	327	63.0	68.8
343	342	66.0	65.6
353	347	73.6	60.2
325	303	64.4	59.6
349	325	61.7	71.2
310	299	59.2	64.2
346	327	67.3	64.7
289	266	73.1	57.9
337	309	58.3	58.8
291	232	65.6	59.9
356	320	72.2	68.5
260	251	41.1	58.2
361	333	62.1	66.2
328	327	63.5	62.3
298	241	56.8	53.0
333	249	54.8	32.9
331	176	58.2	62.8
342	207	57.4	57.4
237	203	48.9	51.9
244	226	56.0	64.9
261	222	52.1	61.5
267	200	58.5	55.4
214	191	48.0	47.6

Surprisingly good yields were obtained on even the completely unfertilized plots, these giving a yield of 219 bushels per acre against 385 bushels on those receiving nitrate ,phosphate and potash, the combination which gave the highest yield. This strongly suggests that during the flood of June 26 there was a distinct movement of both potash and nitrate from the fertilized to the unfertilized plots. The difference in yield between the two plots receiving the same fertilization is shown in Table XXXIV. It seems that we must look to other causes than differences in fertilization to account for many of the differences in yield. Thus there was a difference of 155 bushels between the duplicates receiving potash alone, of 135 bushels between those receiving bone meal alone, the various others showing differences of from 30 to 60 bushels. The character of the previous fertilization does not account for these differences in yield (Table XXXIV).

It has already been pointed out that the relative moisture content of the soil between the rows of the potato plots during the period when the potatoes were making their chief growth was influenced by the distance of the water level below the surface. The soil where this was near the surface was found to be distinctly more moist. This would suggest that in the case of duplicate plots where one had water at a much greater distance from the surface than the other, capillarity would not be able to supply water from the soil as rapidly as it was needed by the plant and accordingly that the yield on the former plot would be depressed by this deficiency of moisture in the soil. To show just what dependence upon the relative water levels the yields exhibit the data have been arranged as shown in Table XXXV. This shows in a case of each

Table XXXV

The relation of the yield of potatoes to the distance of the water level below the surface.

Treatment	Plot No.	Yield Bu. per Acre	July 1-7 in.	July 8-14 in.	July 15-21 in.	July 22-28 in.	J. & A. 29-4 in.	Aug. 5-11 in.	Aug. 12-18 in.
NPKL	9N	378	12.7	18.8	21.2	25.8	29.2	31.0	32.5
	20S	335	14.5	26.0	20.1	36.6	41.1	44.8	46.7
NPKL	10S	400	13.6	19.8	22.1	26.5	29.8	32.2	33.3
	21N	369	19.4	32.9	35.6	40.1	43.1	45.4	46.7
NPK	7N	358	12.9	22.7	25.1	29.1	31.8	33.7	35.5
	19S	315	14.9	26.5	30.8	37.1	42.0	45.5	47.3
NPK	7S	374	12.9	22.7	25.1	29.1	31.8	33.7	35.5
	19N	327	14.9	26.5	30.8	37.1	42.0	45.5	47.3
MPK	23N	343	26.8	44.9	48 +	48 +	48 +	48 +	48 +
	11S	342	16.6	22.2	24.5	28.7	31.9	34.2	34.8
NKL	15N	353	28.4	36.7	38.3	41.1	42.7	43.9	45.2
	3S	347	15.7	30.9	36.1	42.9	45.5	48.0	48 +
NPL	10N	325	13.6	19.8	22.1	26.5	29.8	32.2	33.3
	21S	303	19.4	32.9	35.6	40.1	43.1	45.4	46.7
PKL	9S	349	12.7	18.8	21.2	25.8	29.2	31.0	32.5
	20N	325	14.5	26.0	30.1	36.6	41.1	44.8	46.7
NL	4S	310	14.0	31.0	38.3	45.4	46.8	48 +	48 +
	16N	299	30.1	42.4	43.2	44.5	45.3	46.0	46.6
PL	14N	346	20.9	29.1	31.5	36.0	38.2	40.1	41.3
	22S	327	24.5	40.5	41.8	45.4	45.5	46.7	47.3
ML	17N	289	27.8	41.0	42.5	44.5	46.1	47.4	48 +
	5S	266	12.7	29.1	36.2	42.4	43.1	43.8	44.5
KL	3N	337	15.7	30.9	36.1	42.9	45.5	48.0	48 +
	15S	309	28.4	36.7	38.3	41.4	42.7	43.9	45.2
PK	27N	291	15.4	39.5	40.5	42.1	43.3	43.9	44.2
	8S	232	12.3	20.2	22.7	27.2	30.1	32.1	33.6
PK	26N	356	19.5	44.9	48 +	48 +	48 +	48 +	48 +
	8N	320	12.3	20.2	22.7	27.2	30.1	32.1	33.6

Aug. 19-25 in.	A.&S. 26-2 in.	Sept. 3-9 in.	Sept. 10-16 in.	4 weeks July 1-28 in.	3 weeks July.28 Aug.18 in.	4 weeks Aug.19 Sep.16 in.	Av.for 11 weeks in.	Differ ence in
33.7	27.5	28.7	20.7	19.6	30.9	27.7	26.1	12.5
48 +	48.0	48+	34.8	26.8	44.2	44.7	38.6	
35.0	28.2	29.3	21.1	40.5	31.8	28.4	33.6	7.1
48+	48 +	48 +	36.5	32.0	45.1	45.1	40.7	
36.6	31.0	32.9	22.0	22.5	33.7	30.6	28.9	9.9
48 +	48 +	48+	33.3	27.3	44.9	44.3	38.8	
36.6	31.0	32.9	22.0	27.3	33.7	30.6	28.9	9.9
48 +	48	48 +	33.3	22.5	44.9	44.3	38.8	
48+	47.8	48+	33.8	41.9	48 +	44.4	44.8	t
36.1	30.2	31.2	22.5	23.0	33.6	30.0	28.9	15.9t
46.0	46.0	46.8	39.2	36.1	43.9	44.5	41.5	
48 +	42.0	42.0	22.0	31.4	47.2	38.5	39.0	2.5
35.0	28.2	29.3	21.1	40.5	31.8	28.4	33.6	7.1
48 +	48 +	48 +	36.5	32.0	45.1	45.1	40.7	
33.7	27.5	28.7	20.7	19.6	30.9	27.7	26.1	12.5
48 +	48.0	48 +	34.8	26.8	44.2	44.7	38.6	
48 +	45.0	45.0	27.0	32.2	47.6	41.3	40.4	3.1
47.0	47.0	47.4	36.3	40.1	46.0	44.4	43.5	
42.8	40.9	42.1	36.3	29.4	39.9	40.5	36.6	6.7
48 +	48 +	48 +	36.6	38.1	46.5	45.2	43.3	
48 +	48.0	48 +	32.8	39.0	47.2	44.2	43.5	
44.8	43.0	43.7	28.5	30.1	43.8	40.0	38.0	5.5
48 +	42.0	42.0	22.0	31.4	47.2	38.5	39.0	1.5
46.0	46.0	46.8	39.2	36.1	43.9	44.5	41.5	
48 +	48 +	48 +	36.8	34.4	42.9	45.2	30.8	
34.8	28.8	30.5	21.2	20.6	31.9	28.8	27.1	3.7
48 +	47.5	48 +	36.3	40.1	48	45.0	44.4	
34.8	28.8	30.5	21.2	20.6	31.9	28.8	27.1	17.3

Table XV Continued.

Treat-ment	Plot No.	Yield bu. per acre	July 1-7 in.	July 8-14 in.	July 15-21 in.	July 22-28 in.	J.&A. 29-4 in.	Aug. 5-11 in.	Aug. 12-18 in.
NP	2N	260	23.7	35.9	38.5	42.9	45.5	48.0	48 +
	14S	251	20.9	29.1	31.5	36.0	38.2	40.1	41.3
NK	1S	361	30.1	40.9	43.3	46.4	46.8	48 +	48 +
	13N	333	19.2	27.1	29.6	33.8	36.5	38.3	38.8
M	1N	328	16.6	22.2	24.5	28.7	31.9	34.2	34.8
	23S*	327	26.8	44.9	48 +	48 +	48 +	48 +	48 +
N	13S	333	19.2	27.1	29.6	33.8	36.5	38.3	38.8
	1N	249	30.1	40.9	43.3	46.4	46.8	48 +	48 +
K	12S	331	16.4	23.7	26.0	30.3	33.3	35.3	35.6
	6N	176	13.0	27.1	31.8	36.7	38.3	39.5	40.9
P	2S	342	23.7	35.9	38.5	42.9	45.5	48.0	48 †
	18N	207	21.3	34.1	37.0	41.0	44.1	46.8	48 +
<u>P</u>	25S*	237	20.5	41.7	48 +	48 +	48 +	48 +	48 +
	28N*	203	15.5	30.9	32.9	36.3	38.6	39.8	40.5
M'11&'12									
	17S	244	27.8	41.0	42.5	44.5	46.1	47.4	48 +
	5N	226	12.7	29.1	36.2	42.4	43.1	43.8	44.5
L'11&'12									
	16S	261	30.1	42.4	43.2	44.5	45.3	46.0	46.6
	22N	222	24.5	40.5	41.8	45.4	45.5	46.7	47.3
Check	12N	267	16.4	23.7	26.0	30.3	33.3	35.3	35.6
	6S	200	13.0	27.1	31.8	36.7	38.3	39.5	40.9
Check	24N	214	24.1	41.7	48 +	48 +	48 +	48 +	48 +
	18S	191	21.3	34.1	37.0	41.0	44.1	46.8	48 +
Check	24S*	247	24.1	41.7	48 +	48 +	48 +	48 +	48 +
	26S*	227	19.5	44.9	48 +	48 +	48 +	48 +	48 +
Check	27S*	240	15.4	39.5	40.5	42.1	43.3	43.9	44.2
	28S*	236	15.5	30.9	32.9	36.3	38.6	39.8	40.5
L	4N	298	14.0	31.0	38.3	45.4	46.8	48 +	48 +
	25N	241	20.5	41.7	48 +	48 +	48 +	48 +	48 +

* Shallow peat.

† A tile line under or very near the plot.

Aug. 19-25 in.	A.&S. 26-2 in.	Sept. 3-9 in.	Sept. 10-16 in.	4 weeks July 1-28 in.	3 weeks July 28 Aug. 18 in	4 weeks Aug.19 Sept. 16 in.	Av. for 11 weeks in.	Difference in.
48 +	42.0	42.0	23.7	35.3	47.2	38.4	40.3	
42.8	40.9	42.1	36.3	29.4	39.9	40.5	36.6	3.7
48 +	45.0	45.0	26.8	40.2	47.6	41.2	43.0	t
40.6	36.8	38.1	30.4	27.4	37.9	36.5	33.9	9.1
36.1	30.2	31.2	22.5	23.0	33.6	30.0	28.9	15.9 t
48 +	47.8	48 +	33.8	41.9	48 +	44.4	44.8	t
40.6	36.8	38.1	30.4	27.4	37.9	36.5	33.9	9.1
48 +	45.0	45.0	26.8	40.2	47.6	41.2	43.0	t
37.3	31.5	32.6	23.5	24.1	34.7	31.2	30.0	4.3 t
41.6	38.1	39.5	25.7	27.2	39.6	36.2	34.3	
48 +	42.0	42.0	23.7	35.3	47.2	38.4	40.3	
48 +	47.3	48 +	32.1	33.3	46.3	43.9	40.9	0.6
48 +	47.0	48 +	32.1	37.0	48 +	43.8	43.7	
48 +	48 +	48 +	33.1	28.9	39.6	44.3	37.6	6.1
48 +	48.0	48 +	32.8	39.0	47.2	44.2	43.5	
44.8	43.0	43.7	28.5	30.1	43.8	40.0	38.0	5.5
47.0	47.0	47.4	36.3	40.1	46.0	44.4	43.5	
48 +	48 +	48 +	36.6	38.1	46.5	45.2	43.3	0.2
37.3	31.5	32.6	23.5	24.1	34.7	31.2	30.0	4.3
41.6	38.1	39.5	25.7	27.2	39.6	36.2	34.3	
48 +	47.0	48 +	30.8	40.5	48 +	43.5	44.0	t
48 +	47.3	48 +	32.1	33.4	46.3	43.9	40.9	3.1
48 +	47.0	48 +	30.8	40.5	48 +	43.5	44.0	0.4 t
48 +	47.5	48 +	36.3	40.1	48 +	45.0	44.0	
48 +	48 +	48 +	36.8	34.4	42.9	45.2	30.8	6.6
48 +	48 +	48 +	33.1	28.9	39.6	44.3	37.6	
48 +	45.0	45.0	27.0	32.2	47.6	41.3	40.4	3.3
48 +	47.0	48 +	32.1	39.6	48 +	43.5	43.7	t

Table XXXVI.

Relation of difference in yield of potatoes to differences in water level.

Treatment	Yield on plot with low water Bu. per acre	Excess on plot with high water Bu. per acre	Seasonal Water level on plot with low water inches	Excess on plot with high water inches
NPKL	335	43	38.6	12.5
NPKL	369	31	40.7	7.1
NPK	315	43	38.8	9.9
NPK	327	47	38.8	9.9
NKL	353	-6*	41.5	2.5
NPL	303	22	40.7	7.1
NK	361	-28	43.0	9.1
L	241	57	43.7	3.3
N	249	84	43.0	9.1
K	176	155	34.3	4.3
PKL	325	24	38.6	12.5
NL	299	11	43.5	3.1
ML	289	-23	43.5	5.5
KL	309	28*	41.5	1.5
PK	356	-36	44.4	17.3
M'II&'12	244	-18	43.5	5.5
L'11&'12	261	-39	43.5	0.2
Cheek(9ft)	200	67	34.3	4.3
Check(4ft)	214	-23	44.0	3.1
Av.	289	19		

* Influemced by known factors other than water level and depth of peat.

treatment the yields of each of the duplicate plots and the average water level from July 1 to September 16 both by weeks and by 3 or 4-week periods. The pairs of plots of which one was on shallow peat (less than 3 feet in depth) should not be brought into comparison because the yield may be much more influenced by the depth of the peat than by the relative water level.

To obtain the water level for any particular plot the weekly average for the nearest well was multiplied by 2, that for the well on the opposite side added and the sum of these divided by 3. While the data for the North wells were used for the oats and grasses on the North plots, and those for the South wells for the same crops on the South plots, only the center wells in the case of the data on potatoes have been used.

The data as summarized in Table XXXVI,

Table XXXVII

Relation of yield of potatoes to average water level where the 56 plots are grouped according to the depth to water surface.

No. of Plots	Av. Water Level	Yield in Bu. per acre.
10	25 in to 30 in	328
8	31 in to 35 in	287
12	36 in to 39 in	293
26	40 in to 45 in	284

omitting all those for the shallow peat plots, show clearly that the water level has affected the yield, the average for the plots with high water level being 308 bushels per acre against 289 for those with low water level. In the case of the most of the treatments the plot with high water yielded more than the other. In all cases where the reverse was true the average difference in level was less than 6 inches with the exception of the NK and PK treatment where the differences were 9.1 and 7.3 respectively.

To decide whether it may be the water level and not the fertilization that determined the relative yields of the plots, the data have been grouped according to the average water level thru the season and the yields averaged as shown in Table XXXVII. While the highest yield is obtained in a group of 10 plots with the highest water level the three other groups show no relation between yield and water level. This is not unexpected for it has already been pointed out that it so happened that in most cases one plot of each pair of duplicates was located over low water and the other over high water.

Protection from Summer Frosts.

The original plan for warding off summer frosts was to cover as many of the plots of potatoes as possible with muslin, sacks and newspapers. As this would not be feasible for the whole bog those that had received complete fertilization and two of the checks received first attention. This was done whenever a temperature below 50° at sundown was accompanied by either a calm or a slight breeze from the north. Careful watching thru different nights showed that the minimum temperature was reached between 2:30 and 3:30 A.M. just about dawn. Forecasts based upon this rule were found to seldom fail of verification. When the temperature fell below 28° the protective measures taken did not appreciably lessen the injury from frost. After making this discovery a spray of water was used. On the night of

August 10, 12 plots were covered (9N, 10S, 7N, 7S, 21N, 20S, 19N, 19S, 15N, 6S, 12N, 18S and 24N). At 4:00 A.M. as many of these as time permitted were sprayed with cold water. This treatment, while proving helpful, could not be fully relied upon to prevent injury. So after this date smudging was resorted to, the fires being built at sundown, using for the purpose tamarack roots, weeds and partly dried peat. These produced a heavy smoke that hung over the bog for hours. The fires, kept burning from sundown until 10 P. M., replenished at 2:30 A.M. and again at sunrise, proved quite satisfactory. When the plants were badly frozen, a smudge fire, which checked the direct rays of the sun until the plants could thaw out, was found beneficial. In some cases the frost came without warning but when the temperature did not fall below 25° the vines, altho injured, were not killed. After the frost of August 13 a dense fog which hung over the bog greatly lessened the injury.

The maximum difference between the minimum temperatures over the mineral soil and over the bog has been shown in a previous table. On the nights when smudge fires were employed the differences between the minimum temperatures frequently amounted to 10°, but on September 8 when the air was still and a heavy fog prevailed the difference was only 1°. My conclusion at the end of the season was that smudges may be used with benefit, but care should be taken not to build the fires upon the surface of the bog as the peat takes fire and is very difficult to extinguish.

There is a widespread view that potash salts serve to a considerable extent as protection from injury by summer frosts. Thus von Seelhorst states:

> "Maerker explains the protective action of the kainit on the assumption that a

Table XXXVIII

Injury to Potatoes Vines by Frost of Sept. 4, 1914.

Treatment	Plot No.	Injury Severe	Injury Light	Water level in.
Check	6S		+	34.3
"	12N	+		30.0
"	24N	+		44.0
"	18S	+		40.9
N	1N	+		43.0
N	13S	+		33.9
P	18N	+		40.9
P	23S		+	40.3
P	28N	+		37.6
P	25S	+		43.7
K	6N	+		34.3
K	12S	+		30.0
M11&12	5N		+	38.0
"	17S	+		43.5
M	11N	+		28.9
M	23S		+	44.8
NP	2N	+		40.3
NP	14S		+	36.6
NK	13N		+	33.9
NK	1S		+	43.0
PK	26N		+	44.4
PK	8N		+	27.1
PK	27N	+		30.8
PK	8S		+	27.1
NPK	7N		+	28.9
NPK	19S		+	38.8
NPK	19N		+	38.8
NPK	7S		+	28.9
L'11&'12	22N	+		43.5

Treatment	Plot No.	Injury Severe	Injury Light	Water Level in.
MPK	23N	+		44.8
MPK	11S	+		28.9
L11&12	16S	+		43.5
L	25N	+		43.7
L	4N	+		40.4
LN	16N	+		43.5
LN	4S		+	40.4
LP	14N		+	36.6
LP	22S		+	43.3
LK	3N		+	39.0
LK	15S	+		41.5
LM	17N	+		43.5
LM	5S		+	38.0
LNP	10N		+	33.6
LNP	21S	+		40.7
LNK	15N	+		41.5
LNK	3S		+	39.0
LPK	20N		+	38.6
LPK	9S		+	26.1
LNKP	9N		+	26.1
LNKP	20S		+	28.6
LNKP	21N		+	40.7
LNKP	10S		+	33.6
Without K	28	10	18	
" P	26	17	9	
" N	30	19	11	
" L	30	16	14	

> more vigorous vegetation which results under the influence of the potash fertilization, covers the ground better and accordingly lessens the radiation of heat from the soil and the consequent lowering of temperature. Also it is probable from the experiments of Troschke that the soil fertilized with kainit allows less water to evaporate and as the night frosts take place thru the coincidence of the loss of heat by radiation and by evaporation it is possible that the lessened evaporation decreases the extreme lowering of temperature. It is also possible that the plants fertilized with kainit transpire less water than those which have not received such a treatment."

In Table XXXVIII the injury of frost as shown on September 4 is tabulated so as to show its relation to both the character of the fertilizer used and the level of the water under the plot. Those receiving potash alone were as badly injured as any, while those that show the least injury had received the most complete fertilization and accordingly had made the best growth. Where in the case of the two plots receiving the same treatment one was much more severely injured than the other, it will be seen that usually the least injury was experienced on the plot with the higher water level. The higher water level as shown above was accompanied by a higher moisture content of the surface 16 inches of peat, which in turn would be accompanied by a higher specific heat of the soil. Accordingly we must conclude that the frost injury is lessened by an increased amount of water in the soil which may either result from a higher level of the ground water or from a surface application of water. Further, less injury was experienced on the plots receiving proper fertilization, due rather to the more vigorous growth than to any protective action of the different fertilizing constituents. As potash is the constituent which usually shows the most marked benefit with crops on peat soils, it is also the one whose use is accompanied by the most marked benefit in warding off frost injury. Hence it is the fertilizer which not only most frequently increases the yield, but also most frequently lessens injury from summer frost.

In order to determine the cooking qualities of the bog potatoes, samples were taken from four lots , one from plots receiving sodium nitrate only, another from plots with a complete fertilizer including bone meal and lime, a third from the check plots 6-S and 12-N, and the fourth from the mineral soil of 27-S and 28-S. These were subjected to a careful boiling test under the supervision of Professor Josephine A. Berry. The boiled potatoes were mashed and judged by eight or ten different members of the Experiment Station staff. All agreed that the potatoes from the complete fertilizer were much the best, and those from the nitrate soil the poorest, but they did not agree as to the relative quality of the other two samples.

Later, baking tests were made, by myself, of potatoes from the different treatments, 4 or more tubers being used for each trial. Samples from 28-S, which has a mineral soil, having been secured,

Table XXXIX.
Quality of Potatoes shown by Baking Tests.

Treatment	Quality	Color	Remarks
0 2½ft	Excellent	White	
0 9 ft.	Good	Slightly reddish	Tubers too small
0 4 ft.	Good	White	
N	Excellent	White	
P	Rather soggy	White	
P	Slightly soggy	Slightly reddish	
K	Good	Slightly reddish	
M'11&'12	Excellent(remarks)	White	A few hard cores
M	Good(remarks)	White	One hard core
NP	Rather soggy	White	
NK	Good (remarks)	Gray	One watery core
PK	Excellent, very mealy	Slightly red	Very good flavor
PK	Very Good	White	
NPK	Good	White	
MPK	Slightly soggy	White	
L'11&'12	Good	Some reddish	
L	Good	Some reddish	
LN	Slightly soggy	Slightly reddish	
LP	Good	A few red spots	
LK	Good	White	
LM	Good (remarks)	White	Some watery cores
LNP	Excellent	White	
LNK	Good	Very white	
LPK	Good	Some red, but some of the best	
LNKP	Excellent	White	Did not shrink in baking.
LNKP	Soggy	White	

there was a fair opportunity to compare the quality resulting, not only from the different treatments, but also from the character of the peat itself. Sodium nitrate appears to influence the size rather than the quality of the potatoes. Potash in every combination seemed to improve the quality and also to cause a lighter color, the whitest potatoes being obtained from the plots which had received this fertilization. Raw rock phosphate even in a complete fertilizer, caused sogginess, and bone meal when used alone produced a similar result. Manure appeared to cause a hard watery core unless supplemented by potash and bone meal. The potatoes from the mineral soil were among the poorest tested. In general we may conclude that the tests failed to show any inferiority of the potatoes from the peat soil when compared with those from the adjacent mineral soil.

In Germany it has come to be recognized that the potatoes from the peat lands are fully equal to those from the best mineral soils so that in those localities where large quantities of one variety are produced on the peat lands, these are able to command a slightly higher price than even the best of those from the mineral soils.

It is popularly supposed that the potatoes produced on peat are more watery than those obtained from mineral soil. Determinations were made in the case of samples from a considerable number of plots. Those from mineral soil contained 77.9 per cent water while those from the different peat plots contained from 80.0 to 82.2 per cent, the most watery being those obtained with the complete fertilizer including bone meal. In spite of the higher actual water content there was nothing in the appearance of the cooked potatoes to suggest such a difference.

The samples from the different plots were kept in a root cellar until late in the winter and showed excellent keeping qualities. Those from the plots which had received lime were affected to some extent by scab and rot, while those from the other plots were all free from these.

The Oat Crop.

A good stand was secured on all the plots and the plants started out uniformly, making little, if any, better growth on the rolled than on the unrolled land. Weeds, however, soon appeared in great numbers on all the plots except the portions of those in the southwest corner on which there was little or no peat. On some of the plots the weeds were much more numerous than on others. This was doubtless due in part to those plots which had previously received either lime or manure having produced fair yields of oat straw in 1913, thus preventing such an accumulation of weeds as were found on the plots on which the oats had been a complete failure. The weeds gained such an ascendancy on many of the plots that at harvest time there were no oat

Photo I (A) To face page 123

A

B

C

Photo I (A)

A. View of Plot 1S Grand Rapids Muskeg on August 18, 1914, showing clovers and grasses in the foreground, the oats, largely displaced by smart weed, in the front of the assistant: pota toes, on this plot in the background at the right.

B. View of plot 5S on the same bog and the same date, showing the clovers and grasses in the forebround, the oats, in front of the assista nt; the potatoes, are hidden from view except at the extreme right.

C. View of Plot 9S on the same bog and the same date, showing the clovers and grasses in the foreground; a heavy growth oats completely hiding the potatoes from view.

plants to gather, the plot being entirely occupied by weeds. The photographs shown on the opposite page illustrate the conditions at harvest time. Early in the summer it was seen that the weed distribution would seriously interfere with the fertilizer results, and for this reason the "weeded row" mentioned below was brought under observation. The plots were harvested by hand as they ripened and the weather permitted, the bundles being allowed to stand exposed to the air,On account of wet weather it was necessary to frequently move these indoors during the prolonged drying period. Where there were no oats to gather, as on the check and nitrogen-treated plots, the weeds were mowed with a scythe and removed in order to give the clovers and grasses an opportunity. Harvest was begun on August 26 and completed 14 days later. The bundles were weighed in the air-dried condition and threshed at the Grand Rapids Sub-station, using a small implement made by studding a piece of board with finishing nails. The greater part of the chaff was removed from the seed by winnowing in the wind, care being taken to lose no grain. This part of the cleaned grain was then sacked and shipped to the Experiment Station at St. Paul, where it was later freed of all weed seed under the direction of Professor W. L. Oswald, who was so kind as to supervise this work.

On plots where there was considerable straw, but also a great quantity of weeds, the two were harvested together and later threshed. Before the latter operation about 100 oat plants were removed and threshed separately in order to determine the ratio of grain to straw. Using this ratio the weight of oat straw was calculated from that of the whole yield of clean grain from the plot. No

Table XL
Data on Oat Plots.

Fertilization 1914	Plot No.	Previous Fertilization	Average Water level 1914
None	6S	None	34.6
None	12N	None	22.5
None	18S	None	43.1
None	24N	None	34.1
N	1N	N	36.2
N	13S	N	32.3
P	18N	P	26.9
P	2S	None	36.3
P Raw Rock	28N	None	35.2
P# " "	25S	None	38.4
K	10N	None	30.4
K	12S	None	32.6
M'11&'12	5N	M	33.6
M'11&'12	17S	M	40.7
M	11N	M	24.9
M	23S	M	29.8
NP	2N	P	35.3
NP	14S	P	32.9
NK	13N	N	22.4
NK	1S	N	40.3
PK	26N	None	37.1
PK	8N	P	25.6
PK	27N	None	36.3
PK	8S	P	31.8
NPK	7N	N	26.4
NPK	19S	N	41.3
NPK	19N	N	28.2
NPK	7S	N	34.7
MPK	23N	M	33.0
MPK	11S	M	32.6
L'11&'12	22N	L	31.3
L'11&'12	16S	L	37.7
L	25N	None	36.3
L	4N	L	35.9
LN	16N	L	25.6
LN	4S	L	29.7

E estimated * Calculated from ratio grain to straw. # shallow peat.

							Yield per Acre	
Height on Rolled Portion								Dry Matter
June 21 in.	June 30 in.	July 7 in.	July 15 in.	July 23 in.	July 28 in.	Aug. 4 in.	Bu.	Lbs.
4	6	7	6	F	F	F	F	F
5	7	7	10	16	F	20	F	F
3	5	8	10	F	F	F	F	F
4	7	8	12	F	F	F	F	F
5	8	10	12	F	F	F	F	F
5	9	10	13	F	F	F	F	F
4	7	9	11	14	20	27	F	F
	8	9	14	F	F	F	F	F
3	7	9	14	18	F	F	F	F
5	9	14	20	26	30	40	15.25	2700 #
3	7	8	10	13	F	F	F	F
5	8	9	10	F	F	F	F	F
4	7	10	14	18	28	32	2.87	244*
5	7	9	12	F	F	F	F	F
5	8	12	18	25	29	38	8.82	2918
5	8	14	22	29	34	40	5.50	2924
5	8	11	17	22	F	F	F	F
5	10	12	16	F	F	F	F	F
5	9	12	17	23	28	32	F	F
6	9	11	12	F	F	F	F	F
5	8	9	13	17	F	F	F	F
5	8	10	13	15	17	20	1.69	552
4	7	10	14	18	F	27	F	F
6	7	9	13	F	--	F	F	F
5	8	12	16	F	F	F	0.37	364
5	8	14	20	25	30	30	F	600 E
4	9	12	15	18	F	F	F	F
5	9	11	13	F	F	F	F	F
4	7	11	16	25	27	31	1.31	328*
5	8	12	19	23	F	F	F	500 E
4	8	9	15	20	24	34	5.73	654 *
4	9	12	18	21	29	36	F	F
5	8	9	16	23	25	32	2.82	320 *
5	9	12	16	22	23	32	4.38	1240 *
5	9	12	15	23	26	33	5.56	2142
5	8	12	18	23	26	28	F	F

Table XL Continued.

Fertilization 1914	Plot No.	Previous Fertilization	Average Water Level 1914
LP	14N	P	22.8
LP	22S	L	29.0
LK	3N	K	35.3
LK	15S	K	36.2
LM	17N	M	26.7
LM	5S	M	31.6
LNP	10N	L	24.9
LNP	21S	K	31.9
LNK	15N	K	24.6
LNK	3S	K	30.4
LPK	20N	P	29.2
LPK	9S	K	30.7
LNKP	9N	K	24.9
LNKP	20 S	P	37.3
LNKP	21N	K	30.8
LNKP	10S	L	32.1

* calculated from ratio grain to straw.

E estimated.

Height on Rolled Portion

June 21 in.	June 30 in.	July 7 in.	July 15 in.	July 23 in.	July 28 in.	Aug. 4 in.	Yield per acre dry matter Bu.	Lbs.
5	8	11	15	22	25	31	5.53	556*
5	9	17	23	28	33	39	1.44	485*
5	8	12	20	26	28	32	F	F
5	9	12	20	26	31	37	9.14	2608
5	8	11	11	25	30	36	13.18	2878
4	7	10	16	22	26	33	0.50	582
6	9	14	20	28	30	38	5.53	2222
6	9	16	23	29	32	40	1.56	734*
5	10	14	17	25	32	36	9.44	3498
5	8	12	17	21	22	F	F	F
5	9	12	18	23	25	35	4.13	462*
6	10	13	20	26	30	40	4.69	796*
6	11	14	21	27	29	39	2.63	394*
6	10	16	22	26	30	34	0.13	)600 E)97*
5	9	12	19	25	30	37	4.06	534*
6	9	13	20	27	29	35	F	600 E

attention was paid to the yield of dry matter from the weeds, every effort being made to secure data as to the yields of clean grain and of oat straw freed of residues of other plants.

On some of the plots on which a very good crop seemed to be promised until within a week of harvest the straw lodged and during the ensuing wet weather became so badly decomposed that it was scarcely possible to harvest it. In the case of these the yields have been calculated, but where reported in the tables are so indicated.

Table XL reports the data showing the height of the plants from time to time, the average water-level, the fertilization in 1914 and that in the previous years, as well as the final crop yields calculated to an acre basis. The letter "F" where used in the table signifies that there either was no crop left to measure, the weeds having taken entire possession, or that at harvest time no crop remained to be harvested.

A detailed analysis of the data on yields from the standpoint of the effect of fertilization has been made, but it seems unnecessary to here discuss this in detail.

The crop was a complete failure on all the unfertilized plots, except those where the peat soil was either missing or very shallow, as was also the case on those receiving nitrate alone, bone meal alone, raw rock phosphate alone, potash alone, nitrate and bone meal, nitrate and potash, bone meal and potash, nitrate together with bone meal and potash, and lastly, nitrate together with raw rock phosphate and potash. The comparatively good yield secured on Plot 25-S, which was treated with raw rock alone, was due to there being only a very thin coating of peat on this plot so that here we had to deal essentially with the mineral soil.

Manure alone gave a good yield of straw and a light yield of grain on the duplicate plots, while one of those which had received manure in 1911 and 1912, but none in 1914, gave a very light yield and the other none. One of the duplicates treated with manure and lime gave a light yield of straw, while the other gave a yield equal to that obtained with manure alone. Both plots on which manure was used in combination with potash and bone meal gave only light yields of straw and practically no grain. It is difficult to draw definite conclusions except that manure was beneficial on the oats, and that commercial fertilizers added to it proved of little or no benefit.

Lime produced the most marked benefit of any one constituent added, it evidently being necessary to have an application of lime in order to obtain a crop with any commercial fertilizers, but the lime alone produced a very poor yield this becoming at all satisfactory only when supplemented by either nitrate or potash alone, or together, or with bone meal also employed.

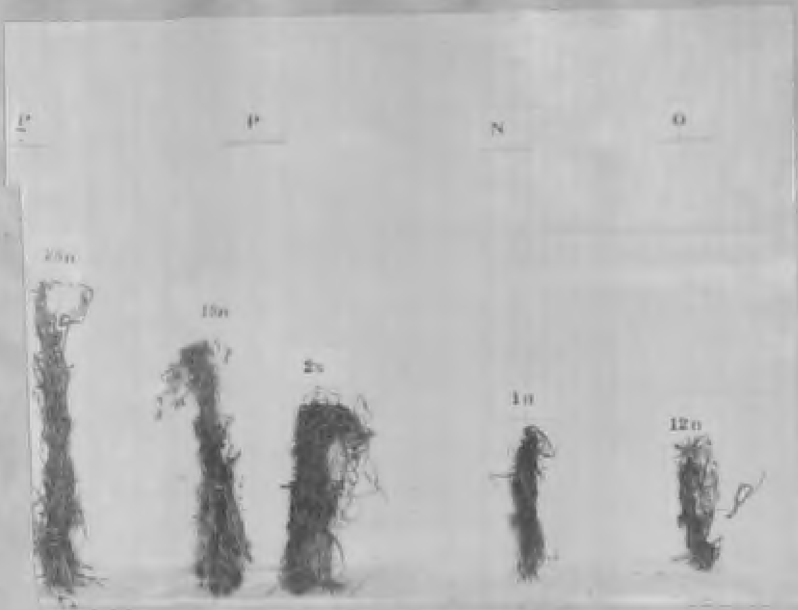
The data from these 56 plots on the whole afford an excellent illustration of the difficulty, or even impossibility, of safely drawing any reliable conclusions from the results of a single year's work with fertilizers where duplicate plots are not employed. Here where duplicates were employed in all cases and a most comprehensive scheme of treatments was laid out, and the whole work had been under continuous personal observation, we are forced to confine ourselves to the conclusion that manure alone will give a fair yield of straw at least, and that while lime alone gives no satisfactory yield it is indispensable in order to secure satisfactory returns from phosphates, potash or nitrates, either singly or in combinations of two or three. In 16 out of the 19 plots on which these commercial fertilizers were used without lime the crop was a complete failure, while on none of the other 3 did it exceed 600 pounds of dry matter per acre. (552 pounds of dry matter on 8-N with bone meal and potash, 364 pounds on 7-N with nitrate, bone meal and potash, and 600 pounds on 19-S with the same fertilizer as the preceding).

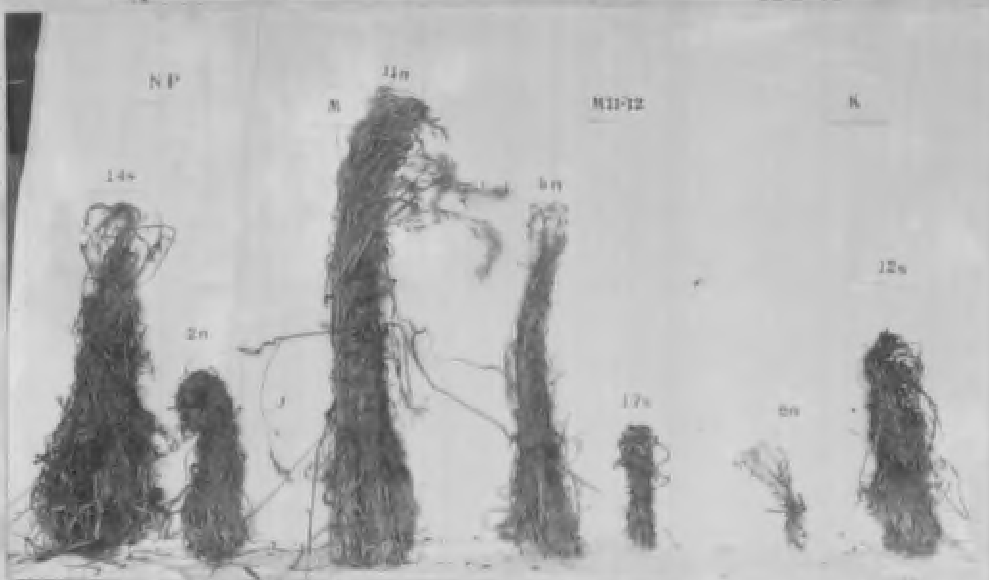
There is no distinct effect from the previous fertilization except in the case of manure and lime. Differences in the water-level were not found to have any such marked effect as in the case of potatoes, but the analysis of the data has not been as yet carried sufficiently far to justify the statement that the relative water-level had no effect upon the yield.

The summer frosts while on various occasions injuring the oats to a greater or less extent, failed to prove serious. This is an important consideration as there is no hope of warding off, under practical field conditions, the summer frosts which must be expected in almost every year and which, from the results described above, render the cultivation of potatoes on the peat soils, to which they otherwise are especially adapted, very unpromising.

By the end of the third week in June it was evident that the weeds would be so numerous that they might entirely choke out the oat plants on nearly all the plots. On the 23nd of that month the three rows next the potatoes were hoed, but as a great share of the weeds were in the rows with the oats it was clear that this treatment would not prove satisfactory. Accordingly the outer row on all the plots was weeded by hand on July 10, and from that time on gone over carefully once a week to remove all weeds. These outer rows thus had favorable conditions for de-

Photo II. To face page 133.





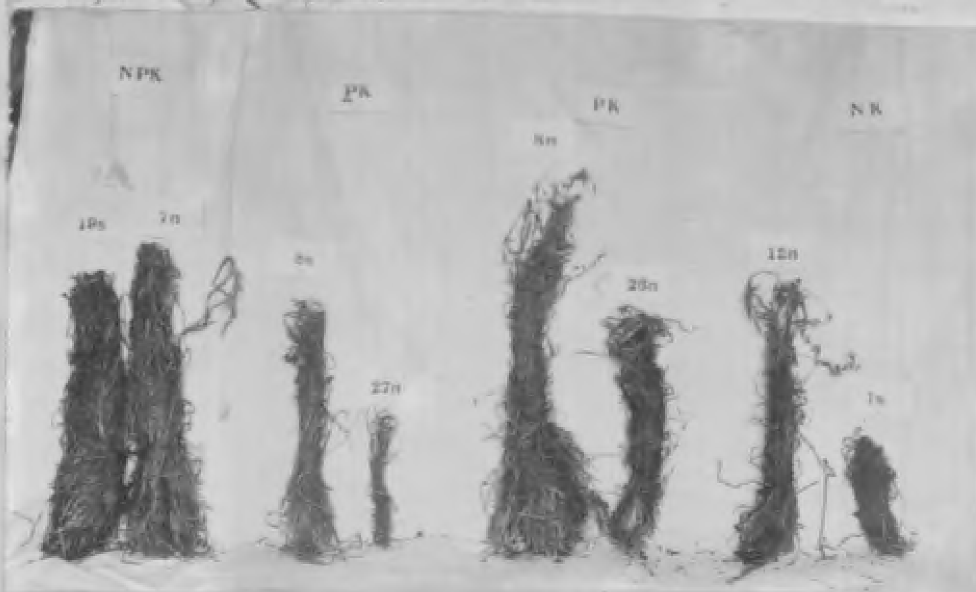


PHOTO II.

Oats from 15 foot weeded row on the different plots. All photographs were taken at the same distance from the camera. Both plot number and treatment are indicated above each of the bundles. Actual height of plants after cutting is given in Table XXXI.

Photo III. To face page 133.

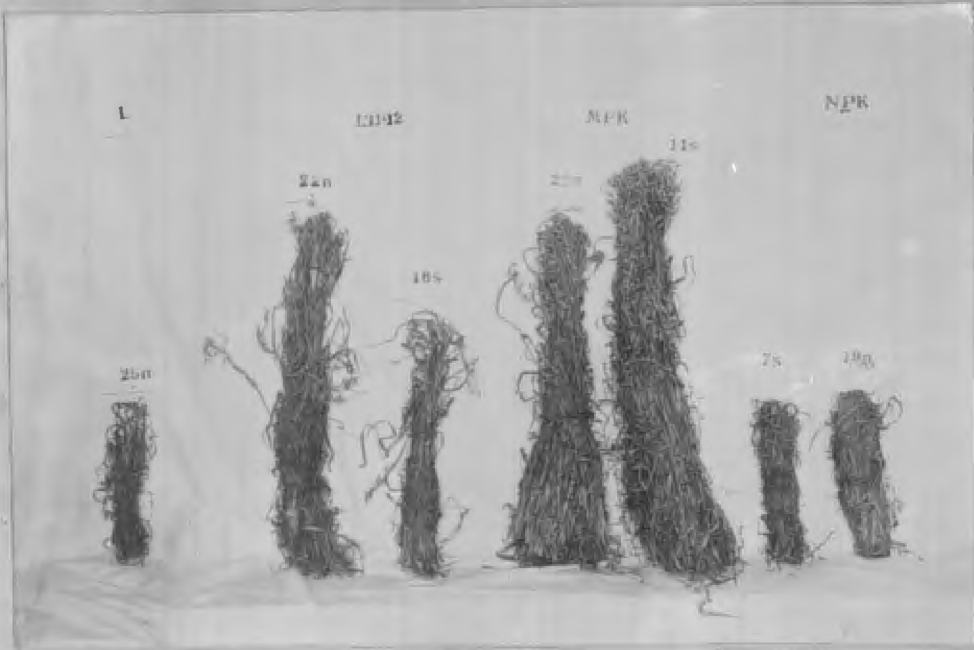
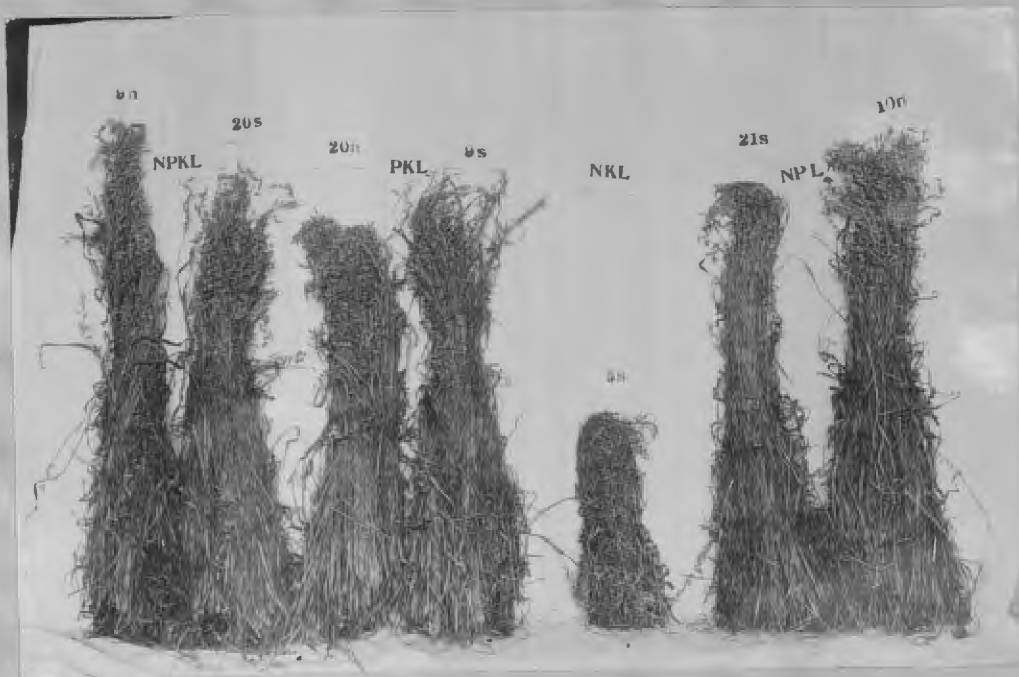


PHOTO. III.

Oats from 15 foot weeded row on the different plots. All photographs were taken at the same distance from the camera. Both plot number and treatment are indicated above each of the bundles. Actual height of plants after cutting is given in Table XXXI.

Photo IV

To face page 133.



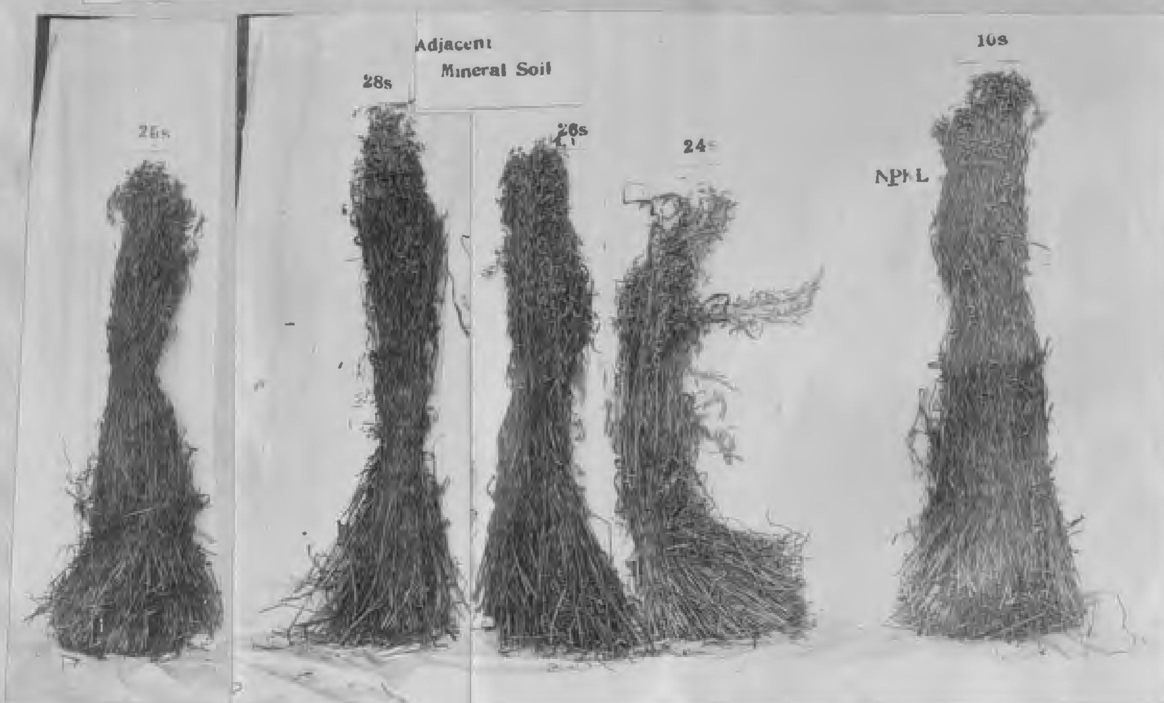


PHOTO. IV.

Oats from 15 foot weeded row on the different plots. All photographs were taken at the same distance from the camera. Both plot number and treatment are indicated above each of the bundles. Actual height of plants after cutting is given in Table XXXI.

velopment of the oat plants in so far as competition with weeds was concerned, there being a bare strip about 2 feet wide between this row on each plot and the nearest potato row, and the bare strip was kept free of weeds at all times, while the weeds were weekly removed from the row itself and the space between it and the second row of oats . Marked differences in the growth on the different plots were observed and these differences became greater as the season advanced. On August 26th the oats in this 15 foot row were harvested on each plot, the plants from each plot being tied up in a separate bundle. After drying these bundles were weighed and photographed. Several of the bundles were accidentally fed to the farm horses by one of the laborers. Table 41 reports the length of straw and the yield of dry matter calculated to an acre basis. In contrast with the results obtained on the unweeded portion of the plots the

Table XLI
Yield of Oats on Weeded Rows.

Treat-ment	Plot No.	Previous Fertil-ization	Dry Matter Lbs. per acre	Ht.	Remarks.
None	6S	None	Lost by accident		
None	12N	None	90	16	Hulls no kernels
None	24N	None			
None	18S	None			
N	1N	N	128	11	No heads
"	13S	N	Lost by accident		
P	18N	P	333	20	Hulls no kernels
"	2S	None	499	19	No heads
	Av.		416	20	
P	28N	None	346	24	Hulls no kernels
"	25S*	None	4122.	39	" " "
	Av.		2234	37	
K	6N	None	270	9	Heads existed
"	12S	None	704	19	" "
	Av.		365	14	
M11&12	5N	M	717	28	Hulls no kernels
"	17S	M	141	10	No heads
	Av.		429	19	
M	11N	M	2701.	40	Poorly filled
"	23S	M	Lost by accident		
NP	2N	P	576	16	Few heads
"	14S	P	1651	30	Hulls no kernels
	Av.		1113	23	
NK	13N	N	486	27	Hulls no kernels
"	1S	N	192	10	No heads
	Av.		339	19	
PK	26N	None	422	20	Few heads
"	8N	P	947	32	Poorly filled
	Av.		684	26	
PK	27N	O	38*	10	No heads
"	8S	P	269	21	Hulls no kernels
	Av.		154	16	
NKP	7N	N	1254	28	Hulls no kernels
"	19S	N	1639	22	Heads existed
	Av.		1447	25	
NPK	19N	N	474	13	Heads existed
"	7S	N	308	13	" "
	Av.		390	13	

Table XLI Continued.

Treat-ment	Plot No.	Previous Fertili-zation	Dry Matter Lbs. per acre	Ht.	Remarks.
MPK	23N	M	1869	30	Hulls no heads
"	11S	M	3329	33	" " "
	Av.		2599	32	
L'11&'12	22N	L	960	30	Fairly well filled
"	16S	L	371	22	Very poorly "
	Av.		666	26	
L	25N	O	140.[illegible]	13	Few heads
"	4N	L	Lost by accident		
LN	16N	L	1677	28	Poorly filled
"	4S	L	2150	30	Hulls no kernels
	Av.		1919	29	
LP	14N	P	3286	35	Poorly filled
"	22S*	L	5896	40	Hulls no kernels
	Av.		4591	38	
LK	3N	K	3456	30	Hulls no kernels
"	15S	K	2829	36	Fairly well filled
	Av.		3143	33	
LM	1 7N	M	3302	32	Fairly well filled
"	5S	M	2548	36	" " "
	Av.		2925	34	
LNP	10N	L	2765	40	Hulls no kernels
"	21S	K	3379	30	Very poorly filled
	Av.		3072	38	
LNK	15N	K	Lost by accident		
"	3S	K	1395	20	Few heads
LPK	2 0N	P	3329	28	Fairly well filled
"	9S	K	3340	34	Hulls no kernels
	Av.		3335	31	
LNKP	9N	K	3557	41	Hulls no kernels
"	20S	P	4403	38	" " "
	Av.		3980	40	
LNKP	21N	K	7411	41	Very poorly filled
"	10S	L	Lost by accident		

* On very shallow peat.

results from the duplicate rows with any one treatment are in general concordant. Here, as on the main portion of the plots, the crop proved to all intents and purposes a complete failure on those which received no fertilizer, or nitrate alone, bone meal alone, raw rock phosphate alone, potash alone, potash and bone meal, potash and raw rock phosphate, potash and nitrate, bone meal and nitrate or bone meal together with nitrate and potash, while the yield on even the plots receiving the complete fertilizer, including potash, bone meal and nitrate, but not lime, was very poor. All the plots that received manure, either alone or in combination with lime or with bone meal and potash, gave good yields. Lime, when used alone, either in 1914 or in [illegible] 1911 [illegible], gave a crop that was little better than a failure, but produced satisfactory yields when it was used in combination with either bone meal, potash, bone meal and potash, bone meal and nitrate, nitrate and potash with bone meal, or nitrate and potash with raw rock phosphate. Lime with nitrate only gave poor yields.

These data indicate that if the oats had been fertilized as above, but sown on plots reasonably free of weeds instead of on what was virtually a weed-bed, they would have proved a failure, except on the peat soil receiving either manure, or some combination of lime with either a phosphate, or potash, or nitrate together with one or both of these two. The results lend no support to any hope of obtaining satisfactory yields of oats on such peat soils without the use of lime and also of commercial fertilizers, unless manure is available. The latter, however, can be profitably applied to peat soils only when the owner has no mineral soil near-by on which he could make use of it.

Clovers and Grasses.

A good stand of both grasses and clovers was secured on all the plots. Differences in the rate of growth very soom became evident, and it was not long before the stand and growth on the rolled portion, both with oats and without a nurse crop, was found to be markedly better than on the unrolled. This difference in favor of the rolling was observed on each of the 56 plots, and continued thruout the season. The abundance of weeds on many of the plots made it necessary to cut them, they being mown with a scythe on July 9. Two weeks later all the south plots were cut with the same implement, but the weed growth on the north plotsdid not seem sufficient to justify mowing these, tho all large weeds were removed from them. An attempt to use a lawn mpwer to keep the weeds under control, without injuring the clover, was made on a narrow strip

Table XLII. Data on Clover and Grasses.

Fertilization	Plot No.	Previous Fertilization	Average Water Level in. below surface	Clover Stand-Growth	Timothy Stand-Growth
Check	6S	0	34.6	Failure	Failure
"	12N	0	22.5t	"	"
" "	18S	0	43.1	"	"
"	24N	0	34.1	"	"
Nitrate	1N	N	36.2t	"	"
"	13S	N	32.3	Poor--poor	Poor--poor
Bone meal	18N	P	26.9	Poor--poor	Fair--fair
"	2S	0	36.3	Fair--poor	Fair-fair
Rock phosphate	28N	0	35.2	Failure	Failure
"	25S*	0	38.4	Good--good	Good--vigorous
Potash	6N	P	30.4	Failure	Good--vigorous
"	12S	0	32.6t	"	Poor-fair
Manure	5N	M	33.6	Poor--poor	Good--poor
"	17S	M	40.7	Failure	Failure
Manure	11N	M	24.9t	Fair--fair	Good--good
"	23S	M	29.8t	Fair--good	V.good--good
Nitrate and Bone meal	2N	P	35.3	Failure	Poor--poor
	14S	P	32.9	"	Poor--poor
Nitrate and Potash	13N	N	22.4	Poor--poor	Poor--poor
	1S	N	40.3t	Fair--poor	Fair--vigorous
Potash and Bone meal	26N	P	37.1	Poor--poor	Fair--fair
	8N	P	25.6	Fair--poor	V.good--fair
Raw Rock and Potash	27N	0	36.3	Failure	Fair--poor
	8S	P	31.8	"	Good--good
Nitrate, potash and bone meal	7N	N	26.4	Good--good	V.good--vigorous
	19S	N	41.3	Fair--fair	Good--good
Nitrate potash and raw rock	19N	N	28.2	Failure	Good--fair
	7S	N	34.7	"	Fair--good
Manure, bone meal & potash	23N	M	33.0	Poor--poor	Good--vigorous
	11S	M	32.6t	Poor--vigorous	" "
Ground lime-stone 19&12	22N	L	31.3	V.good--fair	Fair--fair
	16S	L	37.7	Failure	" "
Lime	25N	0	36.3t	Good--fair	Poor--poor
"	4N	L	35.9	V.good-vigorous	Fair--fair

Table XLII Continued. Data on Clover and Grasses.

Fertilization	Plot No.	Previous Fertilization	Average Water Level in. Below Surface	Clover Stand-Growth	Timothy Stand-Growth
Nitrate and lime	16N	L	25.6	V.good-vigorous	V.good-Vig.
	4S	L	29.7	Good--fair	Good--good
Lime and Bone meal	14N	P	22.8	V.good-good	V.good-good
	22S*	L	29.0	Good-good	V.good-good
Lime and Potash	3N	K	35.3	V.good-vigorous	Good-good
	15S	K	36.2	Good-good	Fair-good
Lime and Manure	17N	M	26.7	V.good-vigorous	V.good-vigorous
	5S	M	31.6	Fair-poor	Fair-fair
Lime, Nitrate and Bone Meal	10N	L	24.9	V.good-vigorous	V.good-vigorous
	21S	K	31.9	" "	" "
Lime, Nitrate and Potash	15N	K	24.6	" "	" "
	3S	K	30.4	" "	" "
Lime, Bone Meal and Potash	20N	P	29.2	" "	Good-good
	9S	K	30.7	" "	V.good-vigorous
Lime, Nitrate, Potash & Bone Meal	9N	K	24.9	" "	" "
	20S	P	37.3	V.good-good	Good-good
Lime, Nitrate, Potash and Raw Rock	21N	K	30.8	V.good-vigorous	Good-good
	10S	L	32.1	Poor-vigorous	V.good-vigorous

* Very shallow peat.

† A tile line very near or under the plot.

thru the north plots, but it was found to be impossible to cut the plants sufficiently high to avoid seriously injuring the clovers. No attempt was made to harvest any grass or clover crop. Accordingly the only report to be made is in regard to the growth and final appearance of the plants on the different plots when winter set in. The conditions, according to the treatment, on both the portion sown to oats and that without a nurse crop, are reported in Table XLII. Observations were made at frequent intervals thruout the season. It is considered unnecessary to present these here as it has been found that the final condition indicates not only the state at the end of the season, but also, in a general way, the relative growth during the summer. Thus, on all of the check plots, according to the observations on August 12, the clover plants were present in large numbers but all very dwarfed, being not more than an inch or an inch and a half in height, while on the adjacent limed areas the plants were large, dark green and from six to ten inches in height. Later in the season the clover plants on the unlimed plots seemed to become much fewer in number. Early in the season those plots which received phosphates and potash in addition to lime showed a much more vigorous growth of clovers and grasses than those receiving lime only. The nitrate when used alone had a marked beneficial effect during the first few weeks, but after this the plants were no better than on the adjacent untreated plots.

In the case of the clover the effect of the fertilization was marked. At the end of the season it was found to be a complete failure on all the plots which had been left without fertilization or had received applications of bone meal alone, raw rock alone, potash alone, raw rock with potash, bone meal with nitrate, raw rock with both nitrate and potash, while on one plot each of the treatments with nitrate alone, lime in 1911, manure in 1911 and 1912, while not a complete failure, both stand and growth were only fair. In addition to these three the stand and growth were poor to fair where the applications had been bone meal alone, nitrate with potash, bone meal with potash, and manure with potash and bone meal, as well as on one of the two plots receiving nitrate together with bone meal and potash, Both growth and stand seemed entirely satisfactory on all the plots which received lime in 1914 either alone or with any other fertilizer, and also on one of the two plots which had received lime in 1911 and 1912. The only case in which a good stand and growth of clover were secured without the use of lime was on Plot 7-N which received an application of nitrate and potash together with bone meal.

The timothy was extremely similar in relative condition to the clover, but it should be pointed out that it was much harder to compare the conditions with the former than with the latter.

The water-level seemed to have a distinct influence upon the growth of clovers and timothy, those plots with the higher water-level doing the better providing that the fertilization was the same.

On account of the very limited growth made by both the clovers and grasses during their first season, the past season's work fails to indicate in any way what the relative yields of hay, resulting from the different forms of fertilization, will be.

The condition favorable to the securing of a stand of clover and grasses which takes first place after the liming is rolling. European experience in this respect is fully confirmed.

CONCLUSIONS.

I. The weather at Grand Rapids during the growing season of 1914 was more favorable than normal, the temperature being appreciably higher than normal, while the interval between the last killing frost of spring and the first of autumn was unusually long. No summer frost occurred on the mineral soil. The rainfall, especially during the middle of the summer was much below normal. A single torrential rain occurred, but the records at the Pokegama Falls Station show that such a rain is to be expected on the average of once every season.

II. The temperature of the peat soil was found to be lower throughout the season than that on the adjacent mineral soil, the difference being most marked during the early part of the summer.

III. The daily maximum and minimum temperatures of the air were determined both on the cultivated portion of the muskeg and on the adjacent mineral soil. The maximum was frequently the higher over the bog, while the daily minimum was always lower on the bog, on 17 nights the temperature on the bog falling to 32°F or lower, and frost occurring even in July. Tender vegetation was frequently injured on the bog, while no injury occurred with the same crop on the adjacent mineral soil. As the temperature on the mineral soil was normal it is probable that the frosts are altogether normal, and that we must expect to experience these on the bogs in northern Minnesota in any month of every year. This practically excludes the use of such lands for any except the hardier crops.

IV. The moisture content of the uncropped peat soil remained practically constant, except at the immediate surface, during a period of prolonged dry weather, and was independent of the level of the water-table. On the potato plots the moisture content fell during the dry weather, the change being much more marked where the water level was low.

V. The driest peat soil was found under oats on shallow peat just as the crop was reaching maturity. Even here the moisture content did not fall below 100 per cent, calculated on the dry basis, while in a corn field on the adjacent mineral soil, even after very wet weather, not one-sixth as high a percentage was found.

VI. The potato crop showed a distinct benefit from a high level of ground-water. This makes it appear probable that there may be serious danger of depressing the water-level too much in the case of the northern bogs.

VII. Near the end of June a torrential rain flooded all of the experimental area. Such rains are normal in the vicinity of Grand Rapids. Such rains are liable to carry, to a greater or less extent, the nitrates and potash salts from the fertilized plots to those intended as checks. Accordingly, all experimental peat areas should be provided with protecting ditches before any potash salts or nitrates are applied.

VIII. Potatoes gave a fair yield on all plots, but the best yields were secured where both lime and potash or phosphates were used. The yields in general were far above the average obtained on good Minnesota mineral soils. As neither lime nor phosphate is liable to appreciable transfer in flood-water it appears that neither of these was essential to the successful growth of potatoes on such peat. On account of the probability of transfer of potash and nitrates by the water from the above mentioned storm the experiment fails to indicate whether these must be added.

IX. Injury to the potatoes from summer frost seemed to not be lessened by potash, except as this promoted the vigor of the plants. A higher level of ground-water, probably because of the increased moisture content of the soil,lessened the damage.

X. The potatoes from the peat soil contained somewhat more water than those from the adjacent mineral soil, but were fully equal in cooking quality, including both flavor and appearance.

XI. Oats proved practically a complete failure on all the plots, even in the rows where the weeds were removed by hand, except where manured, or where treated with lime together with either nitrates or potash or these two together, with or without bone meal. The lime alone failed to produce any satisfactory yield.

XII. Clover and timothy was similar in their response to the different fertilizer treatments. Both did well only where lime was applied, no matter what other fertilizers were employed.

XIII. Rolling was found extremely beneficial in securing a stand of clovers and grasses.

Literature Cited.

1. Weber, C.A., Vegetation und Entstehung des Hochmoors von Augstumal, P. Parey, 1902.

2. Rimpau, T.H., Die Bewirthschaftung des Rittergutes Cunrau, P. Parey, 1887.

3. Davis, C.A., Private communication to F. J. Alway.

4. Fleischer, M. Mitteilungen über die Arbeiten der Moor-Versuchs-Station in Bremen. Landw. Jahrbucher XII, p. 1. (1883).

5. Fleischer, M., Ibid, XV, p. 47 (1886)

6. Tacke, B. Ibid, XXV, sup., (1898).

7. Tacke, B., Ibid, XLIV, Sup., (1913).

8. Von Feilitzen, Carl, Gödslingsförsök u.a. Svenska Mosskulturföreningen, Göteborg, 1901.

9. Baumann, Berichte über die Arbeiten der Kgl. Bayr. Moorkulturanstalt, Munich. (1901 et folg.)

10. Bersch, W., Oester. Moorzeitschrift, Vienna (1904 et folg.)

11. Hungerford, DeF., Minnesota Peat Soils, Thesis for M.Sc., University of Minnesota, 1914.

Literature Cited (continued)

General References from which information was obtained, but which are not specificly cited.

12. Bersch, W., Nachweis der Moore, W. Frick, Vienna, 1911.

13. Bersch, W., Handbuch der Moorkultur, 310 pp. W. Frick Vienna and Leipzig. 1912.

14. von Seelhorst, C., Handbuch der Moorkultur, 336 pp. P. Parey, Berlin, 1914.

15. Central-Moor-Kommission, Protokolle der 1-67, Sitzung, 1877-1911.

16. Svenska Mosskulturföreningens, Tidskrift, Vols. 1-XXVIII, 1886-1914.