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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 Frank C. Clapp 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.

F. J. Alway
Chairman

John T. Stewart.

E. C. Stakman

May 29 1916

PRODUCTIVITY OF CERTAIN PEAT SOILS AS RELATED TO THEIR CHEMICAL COMPOSITION

By Frank C. Clapp

A THESIS

Submitted to the Graduate School of the University of Minnesota in partial fulfillment of the requirements

For the Degree

of

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INTRODUCTION

The origin of peat, the composition of peat soils and the results of experimental work on these, as reported extensively by the various European Peat Land Experiment Stations, and, to a slight extent, by American Experiment Stations, having been so fully treated in previous theses from the Division of Soils of the University of Minnesota[1-2-3] that it appears superfluous to here discuss these topics.

The author in 1915 spent the summer examining peat areas and collecting samples for analysis. Many of these samples were analyzed and reported upon by Mr. Harmer[2]. The analyses of many others have not yet been published. The summer of 1915 was spent partly in a continuance of such field work in northern Minnesota and partly in directing the preparation of a tract of virgin peat land north of Duluth as a peat land experimental area for plot work. Several weeks were spent in Pennington County during September. In this county the peat areas had shortly before been definitely located by the U. S. Bureau of Soils, and a great number of fields on this type of soil had been put into crop. Accordingly, it had been hoped that it would be possible to collect much valuable data as to the relation of the success of the different crops to the depth of the peat, but the extremely unfavorable weather with excessive amounts of rain, unusually late frosts in June and early frosts in August ruined most of the crops on the low-lying lands, independent of the character of the soil. It is doubtful whether a more unfavorable season for such a field study has occurred during the past 40 years. The rest of the summer and early autumn was spent in field studies on a very large bog north of Duluth, where the Duluth, Missabe and Northern Railway is preparing a peat experimental farm which is being financed by the railway company, but operated under the direct supervision of the Division of Soils of the University of Minnesota.

With the advent of cold weather the chemical analysis of the samples collected was begun. Pot experiments on bulk samples collected during the summer from different bogs were also initiated. Sufficient time has so far elapsed to yield data on only the first crop from these pots.

The European Peat Experiment Stations recognize the chemical analysis of peat soils, in distinction from that of mineral soils, to afford exceedingly valuable information as to the fertilizer and cultural needs of the soils. Some of the European Experiment Stations, notably that at Jönköping in Sweden and that at Admont in Austria, attach much importance to pot experiments with peat soils. The present studies which are intended as a basis for the comparison of the results of field experiments with what might be anticipated from the chemical abalysis and the results obtained in pot experiments.

Pot experiments on which different amounts of ash, resulting from the burning of peats, were added to the pots before planting barley, others in which the subsoil was kept at different depths from the surface and still others in which the water was supplied entirely from below and the water-table kept at different depths from the surface, were not completed in time to permit of the in-

corporation of the data in this thesis.

The work was undertaken at the suggestion of, and carried out under the direction of Professor F. J. Alway. The author wishes to acknowledge his indebtedness to Professor J. T. Stewart for many valuable suggestions, and to Mr. L. B. Arnold, Land Commissioner of the Duluth, Missabe and Northern Railway for his generous support in the investigations. He also wishes to express his appreciation of the work of Mr. F. A. Hammargren, who assisted in the pot experiment work.

FIELD INVESTIGATIONS IN PENNINGTON COUNTY

The peat deposits of Pennington County, according to a recently published geological survey by Leverett, covers an area of 97 square miles or 16 per cent of the total area. Their formation is due to accumulations in poorly drained areas left in the lake-bed of the glacial Lake Agassiz. In the western part of the county these deposits are small in area and are controlled in location and shape largely by the numerous lake beaches, which extend from north to south, lying, as a rule, in long, more or less narrow, strips just to the east of the beaches, while the eastern part of the county, where the old lake bottom was more level and beaches absent, the bogs are large and irregular in shape. With but one or two exceptions they are all grass bogs with no indications of sphagnum moss or tamarack growth and all may be classified as "low" bogs.

The artificial drainage of the peat lands of the county forms only a part of the extensive land drainage projects thtoughout the whole Red River Valley. At the present time, computing from drainage maps secured from the County Surveyor of Pennington County, there are about 350 miles of ditches in the county, so that in the flat and swampy regions there is a ditch on practically every section line. These ditches are of three main sources, State, County and Judicial. In many cases additions and extensions have been made in such numbers that the original outlet and main ditches have not been adequate to care for the increased volumes of water. In the year of 1915 many farmers in the northeastern part of the county had their lands flooded for this reason and more damage than benefit was derived from the ditches. Thus, at the present time, although the average drainage conditions have been greatly improved there is much to be desired in the matter of adequate main ditches and outlets. It would seem, then, that the solution of the problem, in so far as ditches are concerned, lies in the enlargement of the ditches and the outlets and the straightening of Red Lake River so as to increase the fall.

Another important problem which confronts the peat farmer is that of temperature. From temperature records averaging over ten years or more the Director of the Minnesota Section of the U.S.

Weather Bureau[4] gives May 25th as the average date of the last killing spring frost and September 15th as that of the first killing frost in the fall, thus leaving a growing season of about 110 days or the same as that for the region 50 to 100 miles southwest of Duluth. Making allowances for lower temperatures on the low land the growing season would probably not exceed 90 days on the peat farm. This factor limits the crops grown to grasses and small grains almost entirely. Even flax is sometimes caught by late or early frosts on the bog lands. The average annual precipitation is about 20 inches with a little the heaviest rainfall in June and but little difference between May, July, August, September and October, but with fully two-thirds of the annual precipitation evenly distributed over the entire growing season, so that so far as rainfall is concerned this section of the state usually has sufficient, and also at the time when it is most needed for crop production.

Outside of drainage practically nothing has been done toward the improvement and proper utilization of the peat lands in this county. Homesteaders have been induced to take up peat lands with the assurance that they were adequately drained and very productive. The result has been that most of the homesteaders of peat lands have deserted their claims and the degree of poverty of those remaining is directly proportional to the proportion of peat lands which they are attempting to cultivate. This is due to inadequate drainage, frosts, lack of fertility and improper methods of cultivation. In studying this problem many typical peat areas over the entire county were visited by the author. Notes were made as to the crops grown, the yields, the methods of cultivation employed and the difficulties encountered. Later letters of inquiry were sent to all the peat land owners not previously visited in the county - about 400. These letters requested information concerning total acreage of peat on the farm, the portion of this plowed, the crops tried, and the yields per acre during the years 1912 to 1915. Replies were received from only 60 while 135 letters were returned unopened. Among those answering there were 17 who had never raised crops on their peat land or else did not furnish the desired information. Thus, replies of value were received from 43 who had peat land under cultivation. In all about 30 farmers were interviewed and 36 others reached by letter, so that the following information is based on data secured from 66 farmers who have actually tried to raise crops upon their peat lands.

In figure 1 there are indicated 78 peat areas which have been brought under cultivation, which means that there are 12 areas concerning which information was given by someone else than the owner, or concerning which no information other than that obtained by personal visit, without an interview with the owner, was secured. As will be seen from Figure 1 practically all of these bogs were visited by the author.

Due to the heavy floods in June and to the late frosts in the spring and the early frosts in August, there were no crops not more or less injured by frosts and only a very few which had not been partially or almost wholly destroyed on account of defective drainage conditions. For this reason, only the records for the years of 1912, 1913 and 1914 are considered in this thesis.

Figure 1 - Map of eastern portion of Pennington County, showing cultivated peat areas, and portions visited by the author.

Figure 1

EASTERN PENNINGTON COUNTY

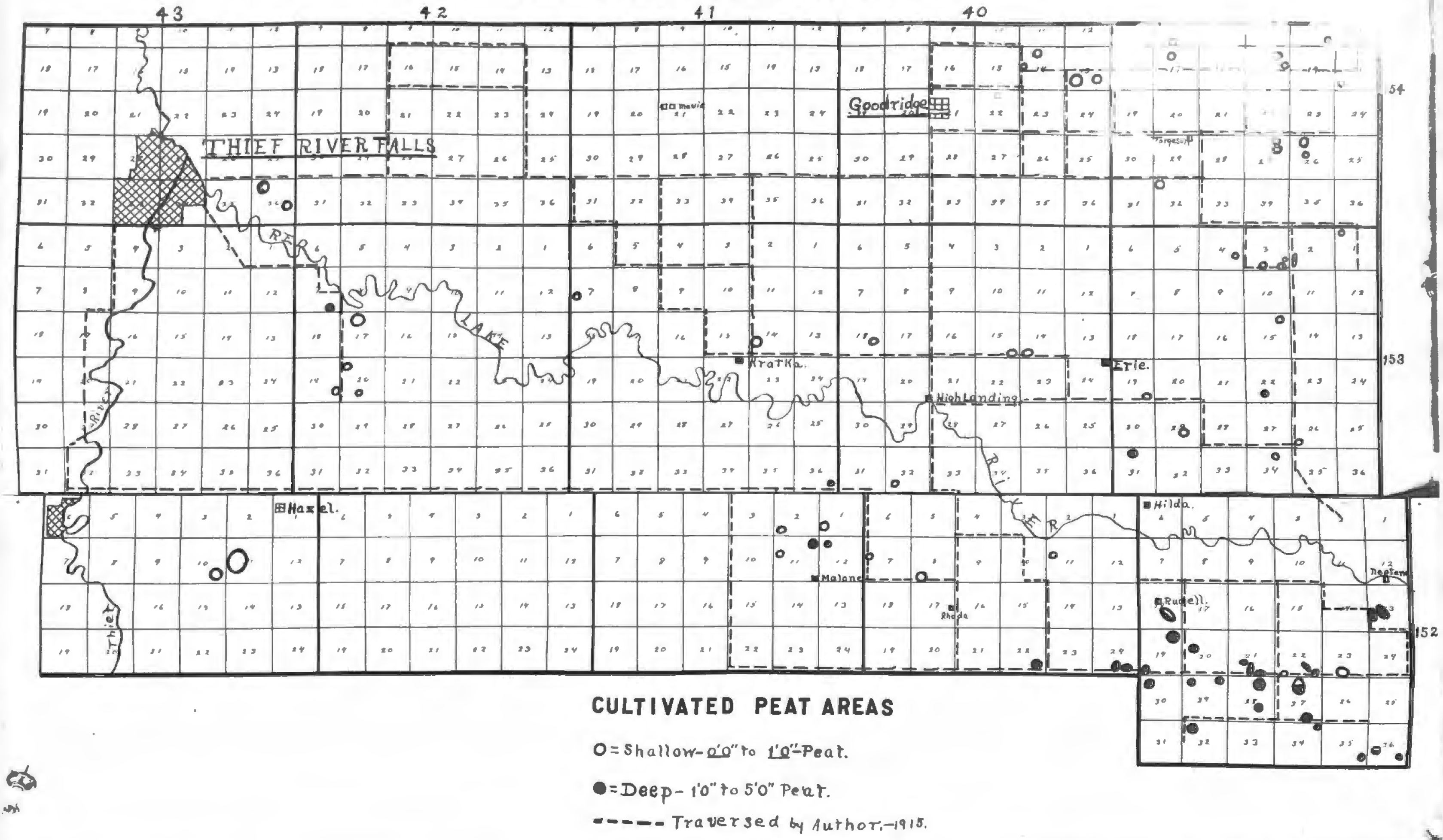

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Table 1 Average crop yields of Pennington County peats and acreage of cultivated peat lands.

Crop	Depth of peat Inches	1912 Acreage Total	1912 Yield Average Bushels	1913 Acreage Total	1913 Yield Average Bushels	1914 Acreage Total	1914 Yield Average Bushels	3 Year Average Yield
Flax	0-6	-	-	33	11.5	94	8.36	9.9
	7-12	77	11.4	164	7.5	97	9.1	9.3
	13-18	46	13.7	133	9.1	217	4.4	9.1
	18 & more	17	6.0	38	7.8	108	5.96	6.6
	Total	140		368		516		8.7
Barley	7-12	10	25	15	19.5	39.5	13.5	19.3
	13-18	-	-		-	6	30.0	30.0
	18 & more	-	-		-	13.0	1.3	1.3
	Total	10		15		58.5		16.9
Oats	7-12	-	-	8	38	87.0	18.7	28.4
	13-18	-	-	19	38	47.0	14.0	26.0
	Total	-		27		134.0		27.2
Timothy	7-12	-	-	-	-	10	2 T.	2.0 T
	13-18	-	-	-	-	6	1.25T	1.25
	Total	-		-	-	16		1.63
Total peat lands Cultivated		150		410		724.5		

In Table 2 all crops grown on peat land on which any record of yields is available are treated separately and the average yields for the three years, 1912 to 1915, given according to depth of peat on which they were grown. It is interesting to note that in every case following the custom for upland practice, flax has been the pioneer crop and having been found satisfactory has been grown in ever increasing amounts in succeeding years, while barley and oats have been used only where the flax had to be abandoned on account of wilt. In 1914 the ratio of the different crops to the total stood as follows: flax - 71.2, oats - 18.5, barley - 8.1 and timothy 2.2 per cent.

It is instructive to note that in the averages no appreciable decrease in yield appears until a depth of 18 inches occurs. This agrees closely with frequent statements on the part of farmers in that district, except that their usual testimony is that peat, deeper than 12 inches, is of but little value.

By summing up all peat lands of which we have secured records of plowing or cultivating, regardless of whether or not crops have been grown or harvested thereon, we obtain results indicated in Table 4 It will be seen that far the greatest area of peat land cultivated falls within the class of 7-12 inches in depth, with about equal amounts in 13-18 inch and 18 inch and above class. The small acreage reported on shallow peat is doubtless due to the farmers not considering it as peat where it is so thin, or to the fact that it has become viturally the same as mineral soil by cultivation.

Table 2 Maximum, minimum and average yields of crops on different depths of peat in Pennington County.

Crop	1912 No. of farms	1912 Max. Bu.	1912 Min. Bu.	1912 Av. Bu.	1913 No. of farms	1913 Max. Bu.	1913 Min. Bu.	1913 Av. Bu.	1914 No. of farms	1914 Max. Bu.	1914 Min. Bu.	1914 Av. Bu.
Flax												
0-6 ins.					2	13	10	11.5	5	14	5	8.3
7-12 "	7	18	7	11.4	13	13	2	7.5	8	15	3	9.1
13-18 "	3	14	13	13.7	7	17	4	9.1	7	11	0	4.4
18+ "	1	6		6.0	3	16	2.5	7.8	7	16	0.75	5.96
Barley												
7-12 ins.	1	25	-	25.0	2	21	18	19.5	6	35	0	13.3
13-18 "									1	30	-	30.0
18+ "									2	2.5	0	1.3
Oats												
7-12 ins.					1	38		38.0	11	40	0	18.7
13-18 "					2	41	35	38.0	2	22	6	14.0
Timothy												
7-12 ins.					1	2.0		2.0				
13-18 "					1	1.25		1.25				

Table 3 Peat land cultivated and uncultivated on farms investigated. (Digest of Tables 1 and 2)

	Depth of Peat 0-6 Ins.	7-12 Ins.	13-18 Ins.	18 & above Ins.	Total
Date derived entirely from correspondence					
Total peat, Acreage	690	1881	586	428	3585
Peat, Cultivated acreage	260	613	250	167	1290
Percentage cultivated	37.7	32.6	23.4	25.0	36.0
Average acreage of peat per farm	98.6	67.2	65.1	53.5	69.0
Average acreage of peat cultivated	35.7	21.9	27.8	20.9	24.8

Table 4 Total peat lands cultivated (Plus field records)

	Depth of Peat 0-6 Ins.	7-12 Ins.	13-18 Ins.	18 & above Ins.	Total
Total peat cultivated	260	722	481	475	1938
Average per farm, cultivated	35.7	19.5	25.3	25.0	23.6

Plate I

Figure 1 - Deep (24-inch) traction-drawn plow, used on peat soils in Pennington County.

Figure 2 - Appearance of freshly plowed land after the traction plow has passed. The furrow slice is seen to have been completely inverted.

In Table 3 is given the totals of peat under cultivation as secured from correspondence plus additional areas located and examined by the author.

It will be seen that the proportion of cultivated peat lands on farms where any work has been done at all with peat, is very low, or about one-third. Probably the total cultivated peat in the county would not be more than 2 per cent of all the total peat area[5] so that at the present time the agricultural use of peat lands in Pennington County has hardly begun.

METHODS OF HANDLING PEAT

Very numerous observations were made by the author of places where shallow peat, less than 6 inches, had been brought under cultivation and had lost its peaty characteristics by becoming mixed with the subsoil and also where satisfactory crops were growing or had been grown on shallow peat. Observations by the author and repeated assertions on the part of the farmers in the peat district all indicate that the deep peat, at least where it is unfertilized, is not productive and also the advisability of deep plowing where, by so doing, some of the mineral subsoil may be mixed with the peat. In fact the practice of deep plowing in the shallow peat districts is becoming quite general. Several 24 inch, traction-drawn, plows, like the one shown on Plate 1 are already in use. This plow does excellent work with peat, as the furrow slice is sufficiently wide to "lay over" of its own weight, even when 8 or 10 inches thick. Two 18 inch plows drawn by one engine are coming into favor also because 1.5 times as much work may be done without much additional expense. However, but few of the farmers have, as

Plate 2

Poorly prepared peat land in Pennington County. The crop had been planted immediately after breaking without either rolling or discing. The photograph was taken in September.

yet, given the peat land a fair trial. Too much of the work is done like that shown in Plate 2 Where the land is left in this condition the capillary connection with the subsoil is broken and the furrow slice readily dries out. Some farmers have rolled, manured and properly cultivated their land, and have been amply rewarded when floods and frosts have not interferred.

Numerous and divergent theories as to proper methods of cropping and treating the peat soil were encountered but the greater proportion of the best peat farmers advocate much the same things, namely: deep plowing and thorough rolling, pasturing previous to plowing if possible, manuring, thorough preparation of the seed-bed, the use of flax as the first, and possibly second crop, followed by grass.

Crops of grass were reported by only three farmers, although the author has seen some excellent growths of timothy and clover on small sections of shallow peat lands. Timothy seems to be the favorite crop, but clover seems to do well where tried. Potatoes and root crops have not been tried on peat lands, except in three or four places where they were reported to have done very well.

If any lesson is to be learned from the experience of the Pennington County peat farmers, it is this - the necessity of raising more grasses and cattle to furnish manure for application to the peat lands. Flax is undoubtedly a very profitable crop for peat when temperature conditions are favorable, but it cannot be raised successively on the same land, and is apt to be damaged by late or early frosts. Oats and barley are very seldom profitable unless the peat is shallow and well drained or unless manure is applied. Wheat was never found profitable on any kind of peat, even though manured. But few instances of rye being grown were observed, so that its value, as a peat crop, in this district is not known. If any suggestion as to procedure might be made it would be this: - Pasture for two, three or more years, put in to flax one or two years, manure, plow, put into oats with grasses and leave for pasture or meadow for two or three years.

DIBBELL TRACT INVESTIGATIONS.

The so-called Dibbell Tract is situated about 50 miles northwest of Duluth in Township 55 and Range 18, St. Louis County. The tract investigated consisted of a row of sections in Range 18 and lying east of the Duluth, Missabe and Northern Railway. This tract is situated in a very large bog extending about 6 miles to the northeast and somewhat farther to the southwest. From north to south at the point in question it extends about 10 miles, viz. from Kelsey to Zim. Dibbell is a station on the railway mentioned just south of the north line of 10-55-18.

This area lies entirely on the Young Grey Drift sheet, the mineral soils being of till in most places with many stones. The bog under study forms only part of a large area thickly interspersed with bogs, large and small, extending for many miles southwest and west into Aitkin, Cass and Itasca Counties. The gradual slope of the whole bog to the southwest, the presence of tamarack stumps at all depths over the whole of the bog and the remarkable uniformity of the peat, all are evidence in support of the conclusions that the bog has been built up in a forested area and has not resulted from the filling up of a lake. The natural slope to the bog has furnished a good opportunity for drainage, which has been taken advantage of by the county. In 1915 a system of about 40 miles of 5 to 8 foot dredge dug main ditches and 25 miles of 3 foot hand laterals was completed and put into operation with very satisfactory results so far as the removal of excess water is concerned.

Plate No. 3.

Shelter containing maximum and minimum thermometers in potato patch on peat at Dibbell.

TEMPERATURE AND PRECIPITATION

This region has a mean temperature for January of about 9° F. or the same as that for south central Minnesota in Meeker, Kandiyohi, Swift and Bigstone Counties, while the mean temperature for July is about 65° F. or the same as that for the extreme northern part of the state. On mineral soils the average date of the last killing frost is May 30, or the same as for northern and northwestern Minnesota, while the first killing frost in the fall comes about September 12, which leaves a growing season of about 105 days, which is the same as that for the extreme northern part of the state away from the lake region, as compared with 140 to 160 with the corn belt of south central and southeastern Minnesota. When we consider furthermore that the minimum temperatures on peat lands are apt to be lower than those on the surrounding mineral soils we must count upon an even shorter growing season.

During the latter part of the summer and early fall of 1915, daily records of minimum temperatures were made. Thermometers, standardized and accurate to within one degree were placed about 10 inches above the surface of the ground in boxes like the one shown on Plate 3 They were so constructed that while free circulation of air was permitted through the top they were protected from the sun and rain. The distribution of the three thermometers is shown in Figure 2 No. 1, on the experimental plot, was placed in sphagnum moss and grass two rods from the ditch where there was good drainage, No. 2 in the grass meadow just north of the McKay buildings and No. 3 about three-eighths of a mile west in a potato patch.

It will be noted that on July 26 a light frost occurred followed by nearly a month when the temperature fell scarcely below 40°. On August 18 a very heavy killing frost occurred, followed by another on the next night and another heavy one on the 26th. In September the freezing point was reached several times, but no serious damage was done to crops until the 21st. Cold weather with almost nightly frosts did not begin until October 4.

Table 5 Minimum air temperatures over peat soils at Dibbell during part of season of 1915.

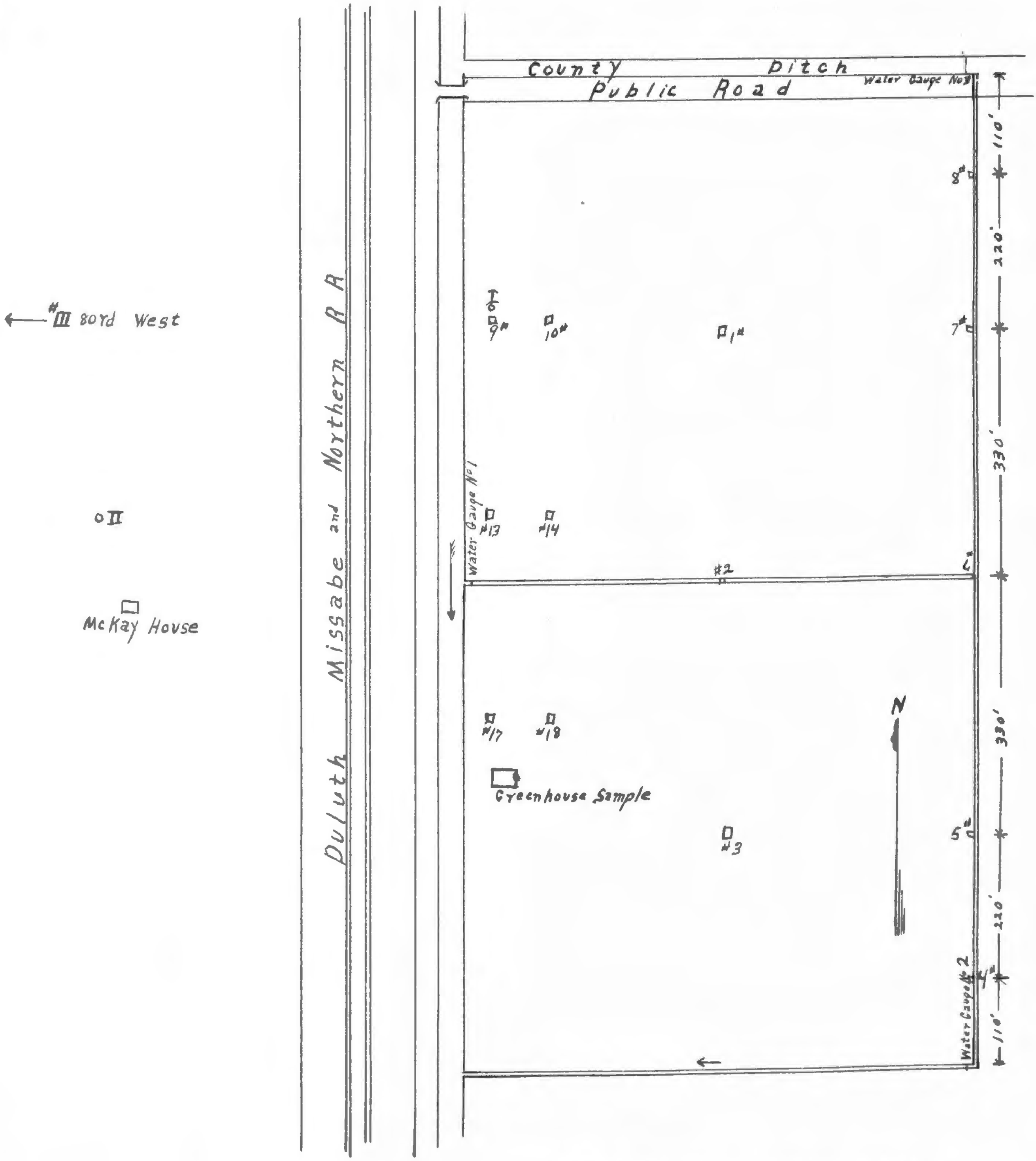
Date of reading		Minimum temperatures in degrees Farenheit. Location No. 1. Sphagnum moss	Location No. 2 Meadow	Location No. 3 Potato Patch
July	26	28.5	33.0	31.5
"	27	52.0	54.0	53.0
"	28	41.5	40.0	44.5
"	29	51.0	50.0	49.0
"	30	46.0	50.0	49.5
"	31	41.5	44.0	43.0
Aug.	1	40.0	45.0	44.5
"	2	49.0	50.0	
"	3	43.0	45.0	45.5
"	4	44.0	45.0	47.0
"	5	50.0	51.0	52.5
"	6	41.0	45.0	44.0
"	7	44.5	48.0	47.0
"	8	41.0	45.0	44.5
"	9	47.0	50.0	50.0
"	10	44.0	47.0	45.5
"	11	44.0	47.5	46.5
"	12	45.0	49.0	47.5
"	13	47.0	50.0	
"	14	50.5	53.0	
"	15	50.0	55.0	52.0
"	16	52.0	53.0	53.5
"	17	36.0	40.0	36.5
"	18	23.0	26.0	26.5
"	19	27.5		32.0
"	20	31.5		34.5
"	21	37.0	42.0	41.0
"	22	43.0	46.0	45.0
"	23	58.0	58.5	
"	24	46.0	46.5	49.5
"	25	29.5	36.5	32.5
"	26	25.0	28.0	
"	27	21.5	30.0 ?	
"	28		43.0*	
"	29		38.0	
"	30		32.5	
"	31		47.0	
Sept.	1		39.0	
"	2		49.0	
"	3		44.0	
"	4		43.0	
"	5		47.0	

*Thermometer No. 1 changed to location of thermometer No. 2 on Aug. 28. Corrections made accordingly.

Table 5 (Continued)

Date of reading		Minimum temperatures in degrees Farenheit Location No.2 Meadow
Sept,	6	45.0
"	7	49.0
"	8	33.5
"	9	47.0
"	10	31.5
"	11	46.0
"	12	39.0
"	13	50.0
"	14	26.5
"	15	32.5
"	16	50.0
"	17	42.0
"	18	31.5
"	19	35.5
"	20	31.5
"	21	25.5
"	22	39.5
"	23	39.0
"	24	
"	25	
"	26	32.5
"	27	38.5
"	28	39.5
"	29	40.0
"	30	43.0
Oct.	1	31.0
"	2	43.0
"	3	37.5
"	4	33.0
"	5	29.0
"	6	
"	7	
"	8	27.0
"	9	15.0
"	10	28.5
"	11	32.5
"	12	24.5

Figure 2



DIBBELL EXPERIMENTAL PEAT TRACT

Scale 1 in = 100'

Note: Wells No 2, 4, 5 6 and 7 destroyed in constructing ditch.

I, II & III = Thermometors ; arabics = wells

Sec 10-56-18

A Study of the Variation in the Water-table in a Drained Portion of the Dibbell Bog.

From a study of Figure 2 the Experimental Tract, situated just east of the Duluth, Missabe and Northern Railroad tracks in the NE$\frac{1}{4}$ NE$\frac{1}{4}$ Section 10-55-18, has an area of 20 acres drained on the north and west by 6 foot dredge ditches and on the east, south, and through the center by 3 foot hand ditches. It is situated on the meadow type of low timber peat, varying in depth from 7 to 11 feet and underlain by a heavy blue clay. The vegetation to the northwest is chiefly grass and sphagnum moss, while the remainder is mostly sphagnum moss with about equal parts of heath plants and grass. The trees are all tamarack, from 15 to 20 feet tall and easily removed. The peat itself is fibrous and poorly decomposed, having a weight of only 5.54 pounds per cubic foot for samples from the surface 8 inches, as compared with 10.46 pounds for a sample of compact grass bog peat from Anoka County.

Beneath the surface the peat is filled with stumps, roots and logs from a somewhat heavier timber growth than is found growing there at present. A typical cross section would be something like the following: 6 to 18 inches of sphagnum moss filled with woody roots of heath plants, 4 or 5 inches of loose, partly disintegrated fibrous peat composed chiefly of sphagnum moss remains, supporting the tamarack growth, 3 feet of partially decomposed fibrous peat, filled with tamarack stumps, roots and logs, still perfectly sound, 4 to 7 feet of slightly better decomposed peat with but few roots or stumps.

Eight wells and three water gages were placed as indicated in Figure 2 and readings of water-tables were recorded for about 40 days covered by the periods July 28 to August 26 and September 25 to October 5. The location and distance from ditches of the eight wells are given on Figure 2. During the greater part of August there was practically no rain so that an excellent opportunity to determine the rapidity of lowering of the water-table, unaffected by precipitation, was afforded. In Table 6 a series of wells extending north from Well No. 4 (110 feet north of hand ditch) to Well No. 8, which is 110 feet south of the Lateral No. 7 with water-table readings are given. The north end of the line of wells is about one foot higher than the south end so that the effect of greater depth of water-table in the north ditch is partly offset by difference in elevation. It will be observed that the fall of water-table is very gradual but constant, both in wells and ditches, except for August 7, when there was a fairly heavy rain.

In Table 7 are given all the water-table readings, taken during the season. It will be observed that wells 10, 14 and 18 record water tables from 10 to 16 inches. These wells are only 115 feet from a 6 foot ditch. Whether or not this is any indication of drainage requirements, it plainly shows the wonderful tenacity of this type of peat for water.

Precipitation records, given in the same table, show the influence of rainfall to some extent upon water-table. The records show that but little dependence may be placed on records kept only a few miles away, as, on the 24 and 25 of September, when 2.7 inches of water fell at Dibbell, only 0.58 inch are recorded at Virginia..

With no heavy rains it would appear that, with a difference between ditch water level and the ground surface of 3 feet on

Table 6 Water-table at different wells on Dibbell Experimental Tract for July 27 to October 5, 1915.

Well Numbers

Date	1 Inches	2 Inches	3 Inches	4 Inches	5 Inches	6 Inches	7 Inches	8 Inches	Precipitation Inches
July 27	1.5	0.5	0.0	2.5	0.3	0.0	0.5	3.8	
" 28	2.0	0.9	0.5	3.1	0.3	0.0	1.0	4.5	
" 29	2.6	1.4	1.0	3.5	0.4	0.3	1.5	5.5	
" 30	3.0	2.0	1.5	4.4	1.0	0.6	2.1	5.5	
" 31	3.1	1.9	1.4	4.4	1.1	0.6	2.0	5.6	
August 1	3.4	1.5	2.0	3.5	1.3	-	2.0	6.0	
" 2	4.0	2.4	2.5	5.4	2.0	1.4	2.8	6.4	
" 3	4.5	2.8	3.0	5.5	2.5	1.6	3.1	6.6	
" 4	4.6	2.9	3.1	5.5	2.5	1.8	3.4	6.8	
" 5	5.1	3.5	3.8	6.0	3.0	2.1	3.8	7.3	
" 6	5.5	3.6	4.1	6.5	3.5	2.8	4.0	7.6	
" 7	4.8	3.0	3.1	5.4	2.5	1.9	3.5	7.0	Rain
" 8	5.5	3.6	4.0	5.8	3.1	2.3	4.0	7.5	
" 9	6.1	4.4	4.6	6.6	3.8	2.9	4.9	8.0	
" 11	7.0	5.1	5.6	7.8	4.5	3.8	5.8	8.9	
" 14	7.5	5.5	6.1	8.0	5.1	4.3	6.1	9.5	
" 19	8.9	7.4	7.9	10.0	6.8	5.9	7.9	11.1	
" 26	9.8	7.9	8.3	10.6	7.3	6.5	7.8	12.0	

Well Numbers+

Date	1 Inches	9* Inches	3 Inches	10 Inches	13 Inches	14 Inches	17 Inches	18 Inches	Precipitation Inches
August 26	9.8	31.3	8.3	16.0	26.3	12.0	-	-	
Sept. 25	6.0	-	5.6	12.9	25.8	10.8	24.3	9.9	2.70
" 27	7.3	-	7.0	14.5	25.4	13.1	24.8	11.1	
" 29	6.3	-	5.9	13.4	26.1	13.0	25.0	10.8	0.35
Oct. 1	6.6	-	6.4	13.9	27.4	14.3	25.9	11.5	
" 3	-	-	-	-	-	-	-	-	2.52
" 4	0.9	-	0.0	4.9	15.5	4.3	14.1	3.5	
" 5	1.8	-	1.0	6.3	16.0	6.3	15.1	4.1	
" 7	-	-	-	-	-	-	-	-	0.25
" 8	-	-	-	-	-	-	-	-	0.29

Note: - The precipitation records at Virginia for 1915 are as follows for May - 2.98 inches; June 7.28; July 2.61; August 1.11 and September 2.36.

+Wells 2, 4, 5, 6, 7 and 8 removed by ditches in first part of September.

*Burned out last of August.

Table 7 Relation of water-table to height of water in ditches from July 28th to September 26, 1915.

Readings at weekly intervals on east side of Experimental Tract - Measured from surface.

Date	Height of water in ditch	Height of water in wells: Well 4	Well 5	Well 6	Well 7	Well 8	Height of water in ditch	Precipitation
	Inches	Inches	Inches	Inches	Inches	Inches	Inches	
July 27	35.0	2.5	0.3	0.0	0.5	3.8	61.0	*
July 30	35.0	4.4	1.0	0.6	2.1	5.5	62.3	
August 6	36.5	6.5	3.5	2.8	4.0	7.6	67.8	
August 7	35.5	5.4	2.5	1.9	3.5	7.0	67.0	Heavy rain
August 14	37.0	8.0	5.1	4.3	6.1	9.5	68.3	
August 19	37.5	10.0	6.8	5.9	7.9	11.1	68.8	
August 26	37.5	10.6	7.3	6.5	7.8	12.0	72.0	
Fall for month	2.5	8.1	7.0	6.5	7.3	8.2	11.0	

*Heavy rains preceded the first records (July 27) so that the water-table had had no time to lower.

the south and 5 feet on the north the drop in water-table would be approximately 8 inches at the wells 110 feet from ditches and 6.5 inches for the center well, which is 660 feet from any ditch. Thus with the water-table at the surface in the spring it would appear that the present drainage system would not be adequate to lower the water-table to 20 inches in an ordinary season, which must be done to make tillage practical and crop growing most profitable.

A qualifying statement might well be made here, however. The drainage system installed had not been in operation previous to the season of 1915, and much more water was in and on the peat on that account in the spring than would have otherwise been the case, and furthermore it must be borne in mind that the precipitation for June at Virginia, 19 miles to the north, was almost twice the average for the Lake Superior region.

Plate 4.

View of partially shaded high timber type of peat at Dibbell, Aug., 1915, showing typical vegetation - tamaracks, ferns, etc.

VEGETATION OF DIBBELL BOG

The most striking feature is the almost universal presence of tamarack trees and the variation in height, shape and rapidity of growth of these found at different places. Sphagnum moss is at all places abundant. The timber question will be considered more in detail later on, so, for the present, we will consider it only where it is related to other vegetative growths. The vegetative areas may be classified into two general groups, depending upon the height and density of stand of trees and these two may again be subdivided as follows:

I High timber areas:
- A. Partly shaded.
- B. Almost completely shaded.

II Low timber areas:
- A. Sphagnum moss-covered type
- B. Grass-covered type.

The first class, I, is characterized by tall tamaracks with occasional black spruce, alder and white cedar, the almost universal presence of ferns, an abundance of Laborador Tea and an absence of grass. The second, II, bears only dwarfed tamaracks, an abundance of sphagnum moss, more or less grass and a large amount of dwarf birch and heath vegetation. The two high timber sub-types are quite easily distinguished. The <u>partly shaded</u> type has all the vegetative forms enumerated under the general description with many black spruce and white cedar, while the <u>more shaded</u> type has practically nothing except a thin covering of moss with few other plants. The vegetation of the more prevalent partially shaded high timber type is well illustrated by Plate 4

The two types of low timber vegetation are less distinctly

Plate 5

Low timber type of peat at [illegible]ibbell

Figure 1 - Sphagnum-covered hummock in the fore-ground.

Figure 2 - Grass-covered area.

marked, they blending more or less. The sphagnum covered type is by far the more prevalent and is characterized by a dense matting of moss from 12 to 18 or more inches deep which rises in hummocks as shown in Fig.1 Plate 5. Usually it has a more or less thick growth of heath vegetation, dwarf birch, pitcher plants, cranberries and water avens. The less common grass type is characterized by a very sparse growth or entire absence of tamaracks, less moss and the predominance of grass which forms a more or less tough sod. Any, or all of the plants found in the moss type may be found in the grass type, but form only a minor part of the vegetation. The grass type is well illustrated by the Experimental Tract at Dibbell as shown in Plate5 Fig.2. One might still further enumerate types if he were to include those immediately adjoining the high land where, in places, black spruce furnishes about one-half of the tree growth and the shrubs consist almost entirely of laborador tea and sphagnum moss or still another type by itself near the high land where alder, dwarf birch, heath shrubs and some upland weeds abound. The last type is prevalent about Stony Lake to the north of Section 1-55-18. At no place, however, except in the bed of the blind rivers which run out of Stormy Lake into the bog, and bordering the lake are found the true acquatic types, including the water-lilies, rushes, cattails, sedges and coarse marsh grass. Thus the great bog is mainly covered by the types of vegetation enumerated above.

STRUCTURE OF DIBBELL PEAT

Here again we have a very wide variation in the peats from the different areas. The high timber peats are uniformly darker, more decomposed and compact, and have a crumb structure, while the low timber peats are light in color, poorly decomposed, fibrous and

Plate 6

A recently constructed ditch through the low timber type of peat at Dibbell, showing the small size of the roots and stumps buried beneath the surface.

very loose. Where large trees are growing on the surface we find evidences of previous large trees for three or four feet or even more down in the ground, and where low timber growth occurs only the roots and stumps of small trees were found. Two exceptions to this rule should be noted, however, - a 200 acre grass meadow in the NE¼ NE¼ Section 18-55-17 and the NW¼ NW¼ Section 17-55-17 and one of about the same size in the center of section 1-55-18. In each case the meadows were surrounded on all sides by tamarack trees and the peat in the meadows was so full of roots of tamarack trees of a considerable size that it was difficult to put an auger through. The meadows at Dibbell are more or less artificial. These perhaps may be accounted for by accidental fires having killed the former tamarack growth. A considerable uniformity exists in the depth to which stumps and roots occur in large numbers. Usually, after the auger has been sunk from 3 to 4 feet, no more difficulty is encountered in reaching the subsoil, but this rule is not without many exceptions. Frequently roots and stumps have been struck just above the subsoil and at all depths. Ditching operations show a great number of poorly decomposed roots, stumps and logs in the surface three feet and a comparatively small number at greater depths. Beneath the depth mentioned the vegetation either had not been made up so largely of tree growth or else these woody residues have become more thoroughly decomposed. In some cases the latter explanation is borne out by the fact that numerous well rotted roots have been extracted from depths greater than five feet. In the typical low timber areas, the peat beneath the surface has but very small roots and stumps, as shown in Plate 6, where the road fill from the ditch reveals what roots and stumps there what roots and stumps there were in the peat at greater depths. In certain places, as, for example, two miles south and two miles east of Dibbell, there are so few roots and the peat is so soft that it has spread out for some distance at the side of the ditch, and the bottom of the latter has partially filled with muck-like material from the sides and below. Doubtless, however, practically the whole bog has supported more or less tamarack growth from its earliest days up to the present time.

The practical value of a knowledge of the nature of the surface vegetation and of the peat itself may be appreciated by an enumeration of difficulties encountered in each type. With the partly shaded, high timber peat the enormous timber growth and numerous large stumps with interlocking roots and the numerous roots beneath the surface render clearing and cultivating extremely difficult.

The densely shaded high timber areas have such a dense growth of trees that it would be expensive to remove these and the stumps on account of the numbers, although the operation would doubtless be cheaper and simpler than for the other high timber type, because the trees are much smaller and the moss covering is more shallow.

In the low timber moss type the heavy matting of moss and heath vegetation is the chief difficulty, while the cost of removing the trees would be very small. If the moss could be burned off, exposing the tamarack roots this type of land could be cleared very cheaply and, is, in fact, the most promising type from the standpoint of economical clearing. This type is represented by the

Plate 7

Low timber, sphagnum-covered type of peat near Dibbell.

area to the east of Wallace, Plate 7. The grass type of low timber peat, although from outward appearance the easiest of all to prepare for the plow in reality is perhaps the most difficult, as a firm sod has been formed about the roots and stumps and any attempt at pulling stumps or roots is like trying to pull them through a hair mattress. The timber can be easily disposed of and if plowing is not contemplated a permanent meadow may be easily secured. If, however, the land is to be plowed the sod must first either be removed by burning or be cut up with a disc so that the roots may be extracted before attempting to plow.

THE EXPLANATION OF THE DIFFERENCES IN THE SIZE OF THE TREES

Any one passing through this bog, even on the train cannot avoid being struck by the variation in timber height, and the question naturally arises as to why there should be such a difference. One familiar with peat bogs might suggest that the depth of the peat was the controlling factor. With this question in mind a traverse of upwards of 40 miles with soundings was made, covering a large part of the area which formed the center of interest. Several places were found where there was an apparent relation between the depth of the peat and the height of the trees. One very interesting point is that found in the southeast corner of Section 2-55-18 Figure 3 where a neck of very high timber extends along a ridge where the subsoil comes nearly to the surface, with a falling off in the height of timber on both sides, this being accompanied by an increase in the depth of peat. Numerous are the cases where, along the border of the bog where the peat is shallow, high tamarack prevails. Without going farther one might conclude that the depth of peat is the controlling factor. But, if one goes farther, he will find numerous and very clear cases where the lowest type of tamarack skirts closely the mineral soil with no area with trees of intermediate height, and also some of the highest and most vigorous timber growth on the deepest peat. An excellent illustration of where low timber borders directly on the mineral soil is found about the island at the northeast corner of the SW$\frac{1}{4}$ SW$\frac{1}{4}$ Section 23-55-18. The lack of relationship between high timber and depth of peat is very pronounced in all cases, as shown in Figure 4 When this possible explanation had to be abandoned, another line of investigation was started. While tramping over the bog it was observed that the water seemed to stand higher in the low timber areas than in the high and that plants of more distinctly aquatic nature were more abundant among the low timber than the high. The fact that the bog appears perfectly flat and that but very little attention has been paid to elevation in ditching operations tended to discourage any belief in the possibility of elevation and drainage being causal agents in influencing the height of timber, but never-the-less profiles drawn by the County Surveyor from surveys of the bogs made for ditching purposes were secured and a contour map of the area in question constructed. From this, Fig 5 the fall in feet per mile was easily computed. Immediately a very definite relationship between the fall and the height of timber appeared. For the sake of graphic representation a cross line running east and west south of sections 1, 2 and 3 55-18 between the main ditch at Dibbell and the center of the south line of Section 1 was taken as an illustration. The average height of the trees and the average

Plate 8 High and low timber types of peat

Figure 1 - Typical low timber vegetation taken from the stand west of center of Section 25-55-18, showing lack of rise in timber height as the highland is approached.

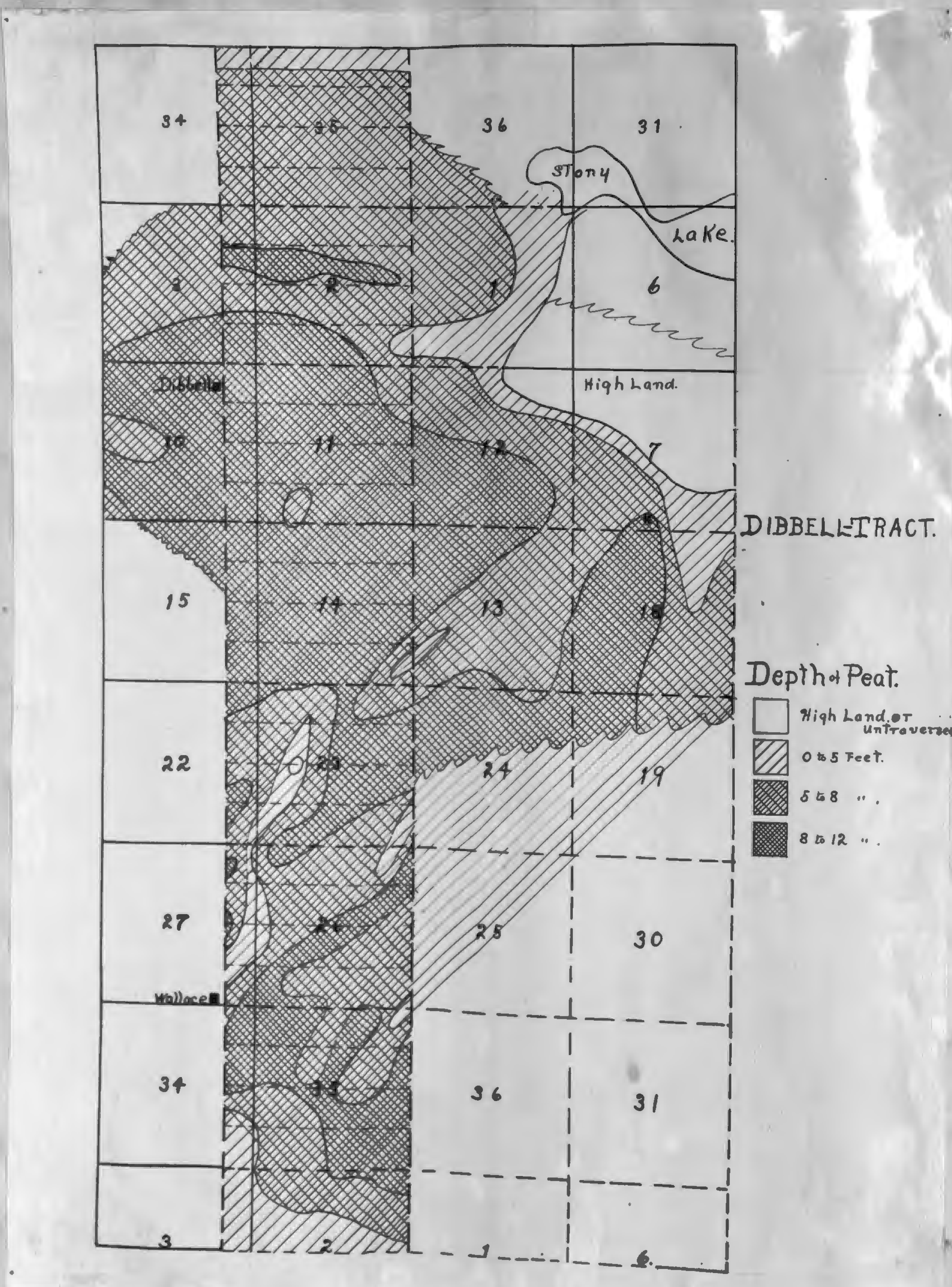
Figure 2 - Typical high timber trees, looking north from the center of Section 2-55-18.

Plate 8.

Fig. 1

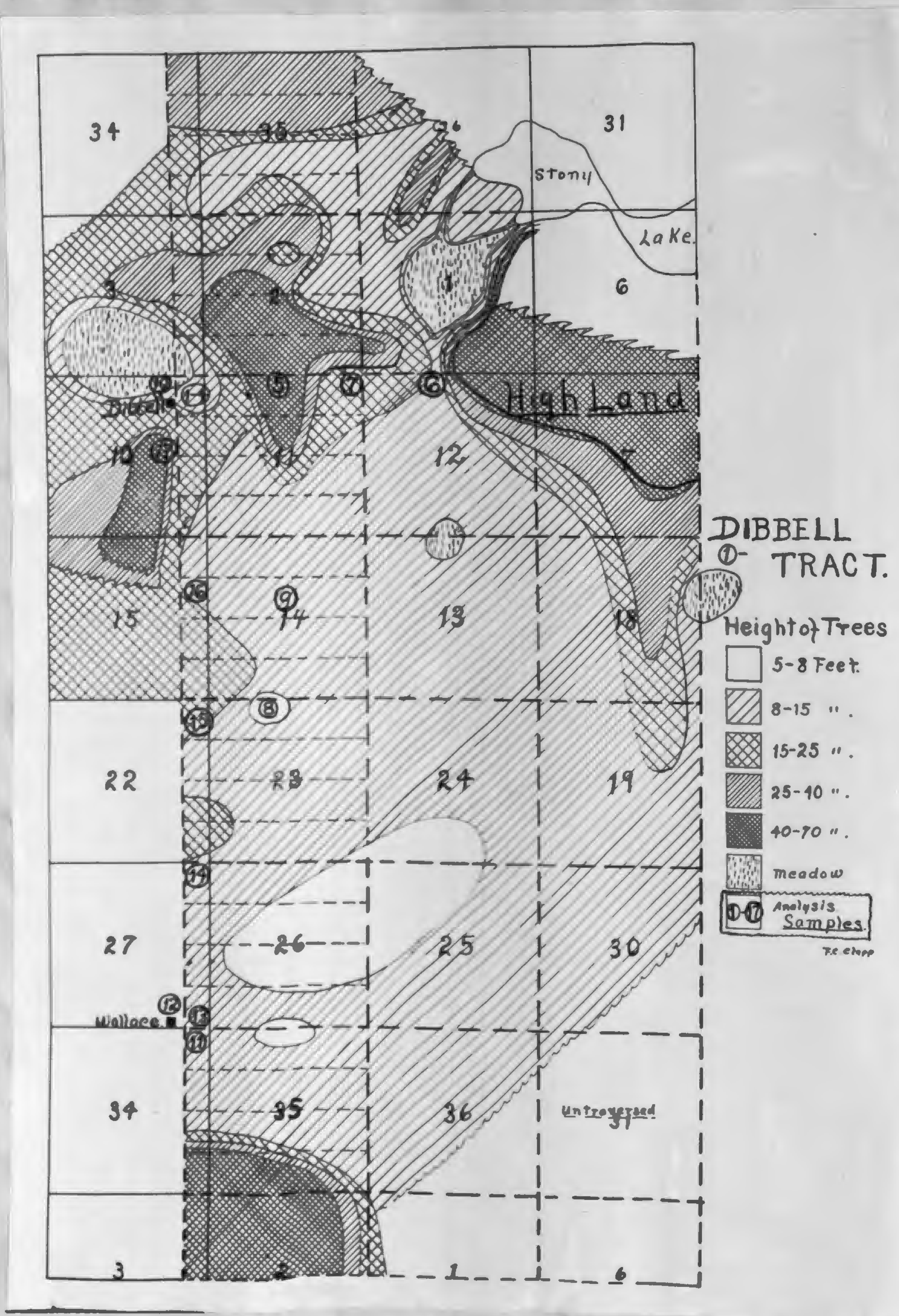
Fig. 2

Figure 5



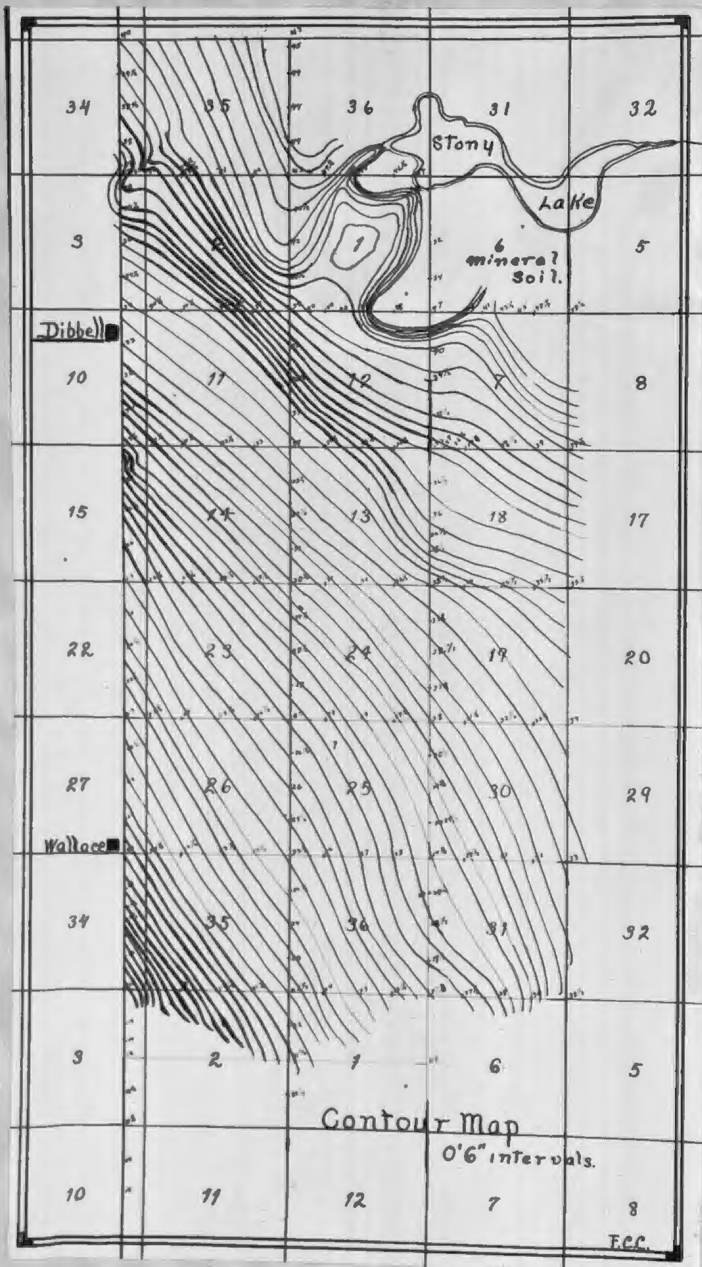
Distribution and depth of peat on Dibbell Tract.

Figure 4



Distribution of low timber and high timber areas on Dibbell tract.

Figure 5.



Contour map of Dibbell tract.

Figure 6

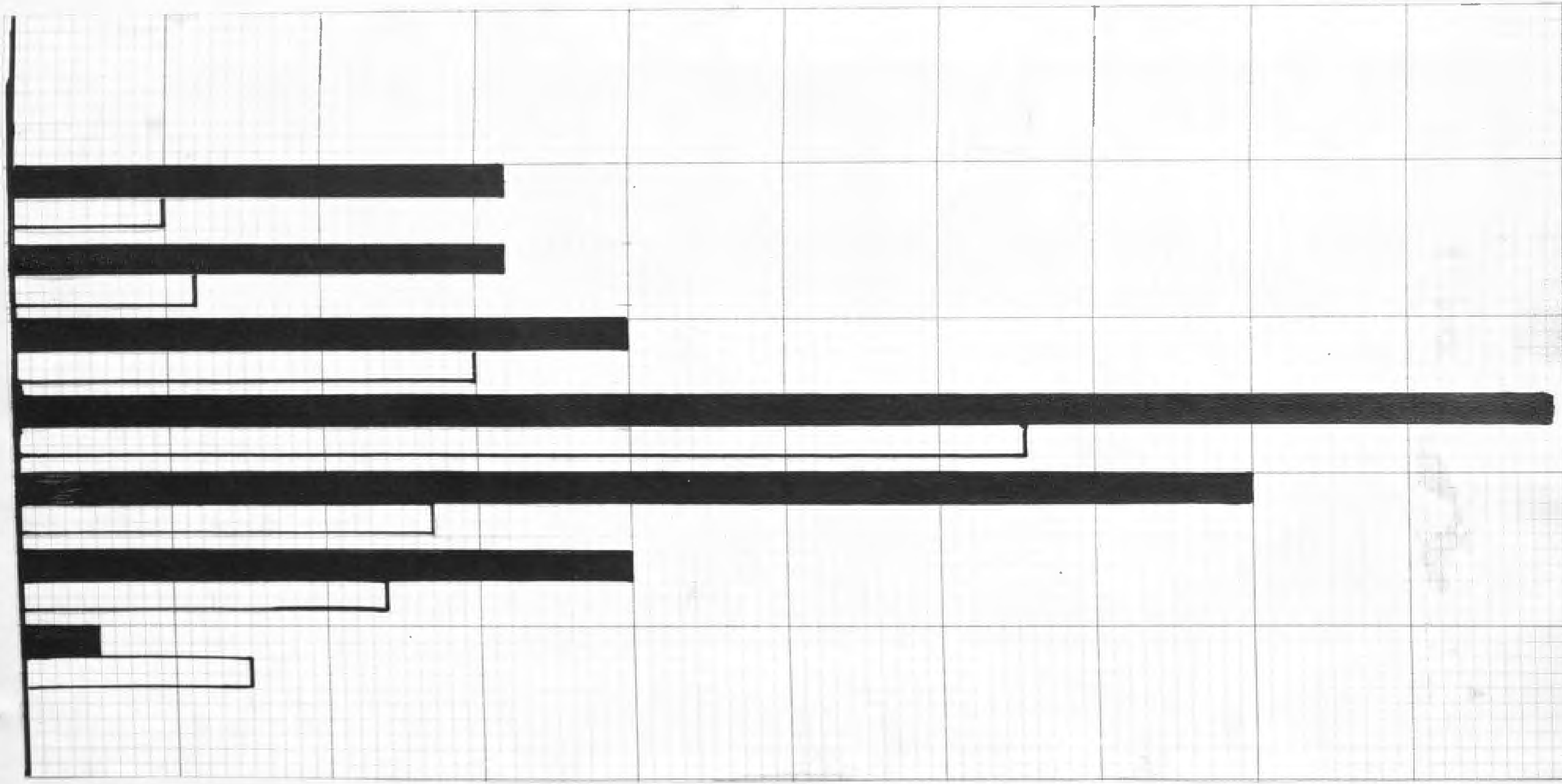


Diagram showing relation of the average height of trees to natural gradient on the deep peat at Dibbell.

fall per mile are graphically represented in Figure 5 This is a more or less extreme type and the relationship may not be as marked in other places, but the general proposition holds true in all cases. The crowding of contour lines running northwest and southeast through the center of Section 2 the northeast of Section 11 and southwest of Section 12-55-18 is associated closely with the high timber belt shown in Figure 4 The crowding of lines in the south of Section 10 and north of Section 15-55-18 is exactly coincident with the high timber tract found there. Also in the south of Section 35-55-18 and north of Section 54-18 the same conditions obtain. It will also be observed that the large low timber tract in the east central part of the area is characterized by widely spreading contour lines.

More emphatic evidence is found in the center of Section 1-55-18. Here we find a large open meadow with few trees, exceedingly wet and almost level as shown by the contour lines, another is found among the wide-spreading lines in the northwestern part of Section 18-55-17 and northeastern part of Section 13-55-18.

Another piece of evidence in favor of the defective drainage theory is found in the stage of decomposition of the peat. A well drained peat decomposes much faster than one continuously under water. The high timber peats are uniformly better decomposed than the low timber peats. An unqualified deduction could not be made until all other possible contributory causes have been eliminated. As was demonstrated in the section on chemical analysis, the high timber peats are high in lime. Lime favors decay so that one might reason that it is the lime rather than better drainage which causes the greater decomposition. It appears more reasonable, however, to the author that better drainage is the chief cause with lime as a contributory agent, since the increase of lime of the high timber peats over that of the low timber peats is not more than one per cent and since lime, without sufficient drainage, does not cause decomposition.

RAPIDITY OF TREE GROWTH IN DIFFERENT AREAS.

Another importance consideration heretofore assumed is that of comparative rapidity of tree growth. One not familiar with the method of growth of the tamarack tree might say that the differences in height and size were due entirely to a difference in the age of the different trees. In some cases this is largely true. Thus, for example, the trees are younger on and bordering the experimental tract than the high timber trees which accounts largely for their being smaller, but in general the trees of the low timber type are of nearly the same age as those of the high timber, varying from 100 to 200 and a few reaching even 300 years. One tree, 18 feet tall was found to be 406 years old. The high timber of the average size runs close to 175 years with some large ones 250 or 300 years. An easy way of distinguishing between old and young trees is by the manner of growth. An old short tree has a guarly umbrella shaped top with but little decrease in diameter of trunk from bottom to top, while a young, short tree tapers gradually to the top, has straight branches, resembling the balsam in shape.

In the study of tree growth sixty-six sections taken two feet above the ground were secured. The height of each tree sectioned was recorded and the age determined from the rings. These data are reported in Table 8. In order to secure an index of growth

Table 8 Relation of height of trees and rapidity of growth to the depth of peat.

Tree No.	Age Years	Height Feet	Diameter Inches	Rate of Growth: Years per 1/24 inch radius	Rate of Growth: Years per 1 foot of height	Rate of Growth: Growth per year cu. ins.	Depth of peat ft. ins.
	A - Trees 5 to 15 feet in height.						
3	140	12	27/12	5.2	11.7	4.1	9'6"
4	151	10	27/12	5.6	15.1	3.2	8'0"
6	115	15	28/12	4.1	7.67	6.7	6'0"
7	103	12	28/12	3.7	8.6	6.0	6'0"
8	95	15	26/12	3.7	6.3	6.9	7'0"
9	103	15	27/12	3.8	6.9	7.0	9'0"
10	103	15	27/12	3.8	6.9	7.0	9'6"
11	138	12	26/12	5.3	11.5	3.9	8'0"
12	90	10	25/12	3.6	9.0	4.5	10'3"
14	76	11	26/12	3.9	6.9	4.8	7'0"
15	100	12	27/12	3.7	8.3	5.6	9'0"
16	186	12	42/12	4.4	15.5	7.5	9'0"
17	124	11	31/12	4.0	11.3	5.6	9'0"
19	125	10	31/12	4.0	12.5	5.1	7'6"
27	106	15	32/12	3.3	7.1	9.5	7'9"
28	148	12	32/12	4.6	12.3	5.5	7'0"
33	145	15	41/12	3.5	9.7	11.8	7'3"
41	95	11	31/12	3.1	8.6	7.2	9'6"
42	49	11	23/12	2.1	4.5	8.2	9'6"
43	127	9	35/12	3.6	14.1	5.7	9'10"
44	60	8	22/12	2.7	7.5	4.3	9' 10"
45	134	7	30/12	4.5	19.1	3.1	9'6"
46	46	7	18/12	2.6	6.6	3.2	9'6"
47	105	14	32/12	3.3	7.5	8.9	6'10"
48	165	15	37/12	4.5	11.0	8.1	7'6"
52	125	14	33/12	3.8	9.0	8.0	5'0"
53	100	13	30/12	3.3	7.7	7.7	5'0"
57	185	15	39/12	3.8	12.3	12.7	5'6"
Av.	115.7	12.1	2.5	3.84	9.83	6.59	8'0"
	B - Trees 16 to 25 feet in height						
1	46	20	27/12	1.7	2.3	20.8	10'0"
2	63	20	27/12	2.3	3.2	15.4	8'0"
5	86	18	28/12	3.1	4.2	10.7	9'6"
18	83	18	29/12	2.9	4.6	11.8	9'6"
20	69	17	27/12	2.6	4.1	10.8	8'6"
21	128	18	31/12	4.1	7.1	8.9	2'0"
22	82	18	26/12	3.2	4.6	9.6	2'9"
23	156	25	35/12	4.5	6.2	12.7	2'9"
26	86	20	35/12	2.6	4.3	16.6	10'0"
35	131	18	35/12	3.7	7.3	11.1	9'6"

Table 8 (Continued)

Tree No.	Age Years	Height Feet	Diameter Inches	Rate of Growth: Years per 1/24 inch radius	Rate of Growth: Years per 1 foot of height	Rate of Growth: Growth per year cu. ins.	Depth of peat ft. ins.
			B - Trees 16 to 25 feet in height (Continued)				
36	406	20	71/12	5.7	20.3	16.6	6'0"
39	124	20	42/12	3.0	6.2	18.3	7'0"
40	164	21	50/12	3.3	7.8	20.8	11'0"
51	123	24	28/12	4.4	5.1	10.0	5'6"
54	163	18	45/12	3.6	9.1	14.7	5'6"
Av.	127.4	19-2/3	35-6/12	3.38	6.43	12.64	7'2"
			C - Trees 26 to 40 feet in height				
24	171	40	57/12	4.6	4.3	22.0	4'3"
25	205	40	66/12	3.1	5.1	55.8	4'3"
34	141	30	49/12	2.9	4.7	53.2	8'0"
38	56	30	41/12	1.4	1.9	57.5	6'6"
49	134	27	39/12	4.6	5.0	15.3	3'6"
Av.	141.4	33.4	46.4	3.32	4.2	36.76	5'3"
			D - Trees 41 to 70 feet in height				
29	165	54	52/12	3.2	3.0	57.5	10'9"
30	204	63	96/12	2.1	3.2	188.6	10'9"
31	154	57	54/12	2.9	2.7	70.7	7'0"
32	165	50	64/12	2.6	3.3	80.6	3'9"
37	230	71	117/12	2.0	3.2	275.8	8'0"
55	181	48	68/12	2.7	3.8	79.2	7'6"
58	234	45	88/12	2.7	5.2	96.0	7'10"
Av.	190.43	55.43	6.42	2.6	3.5	121.2	7'10"

whereby to compute the yield, so to speak, of the land, the volume of wood formed by each tree was roughly computed as follows. The tree was considered as a cone, the surface of which would be given by one-half the height multiplied by the circumference. The volume was then secured by multiplying by the thickness of the layer added in one year. This gives a more accurate indication of the comparative productivity of the different types of peat than either the height or diameter alone. All of the samples secured were arranged according to height in separate groups. From Table ? it will be seen that the depth of peat bears no relation to any of these constants, that the yield of timber increases directly with the height of timber and that the very high timber is by far the most productive. The years required to form a layer one-twenty-fourth inch thick is quite constant and there is slight, but by no means, proportional increase in age with the height of timber. However, the important thing to observe is the enormous productivity of the high timber peat in comparison with that of the low timber type, the former producing more than 18 times as much as the latter per unit area.

As to the reason why these more productive, better drained, high lime areas should arise at all, situated with no apparent relation to depth of peat or conformation of the bottom of the bog, is still open to conjecture. Further thorough surveys of depths may furnish a solution of the problem, but, from the work thus far done, no reasonable hypothesis has as yet appeared.

Plate 9 Tamarack wood samples.

Six wood samples are given collectively and individually, showing different types and rapidity of growth, followed by enlargements with the same figure numbers.

Fig. 1 - Strictly low timber type, slow and stunted growth.

Fig. 2 - Low timber, but natural growth, such as found on the Experimental Tract.

Fig. 3 - Intermediate type of medium rapid growth.

Fig. 4 - High timber type of exceptionally rapid growth. Secured in high timber south of Dibbell.

Fig. 5 - Average high timber type of average growth rapidity.

Fig. 6 - Extreme type of slow-growing timber.

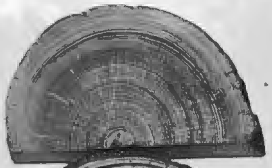


Fig. 1

Fig. 2

Fig. 3

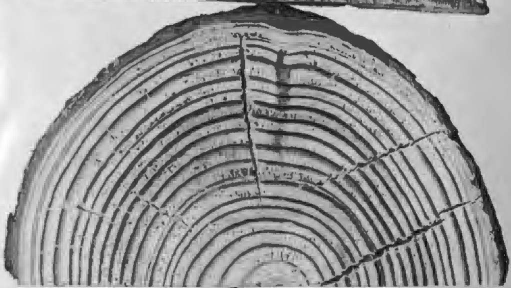


Fig. 4

Fig. 5

Fig. 6

Fig. 1

Fig. 2

Fig. 3

Fig. 4.

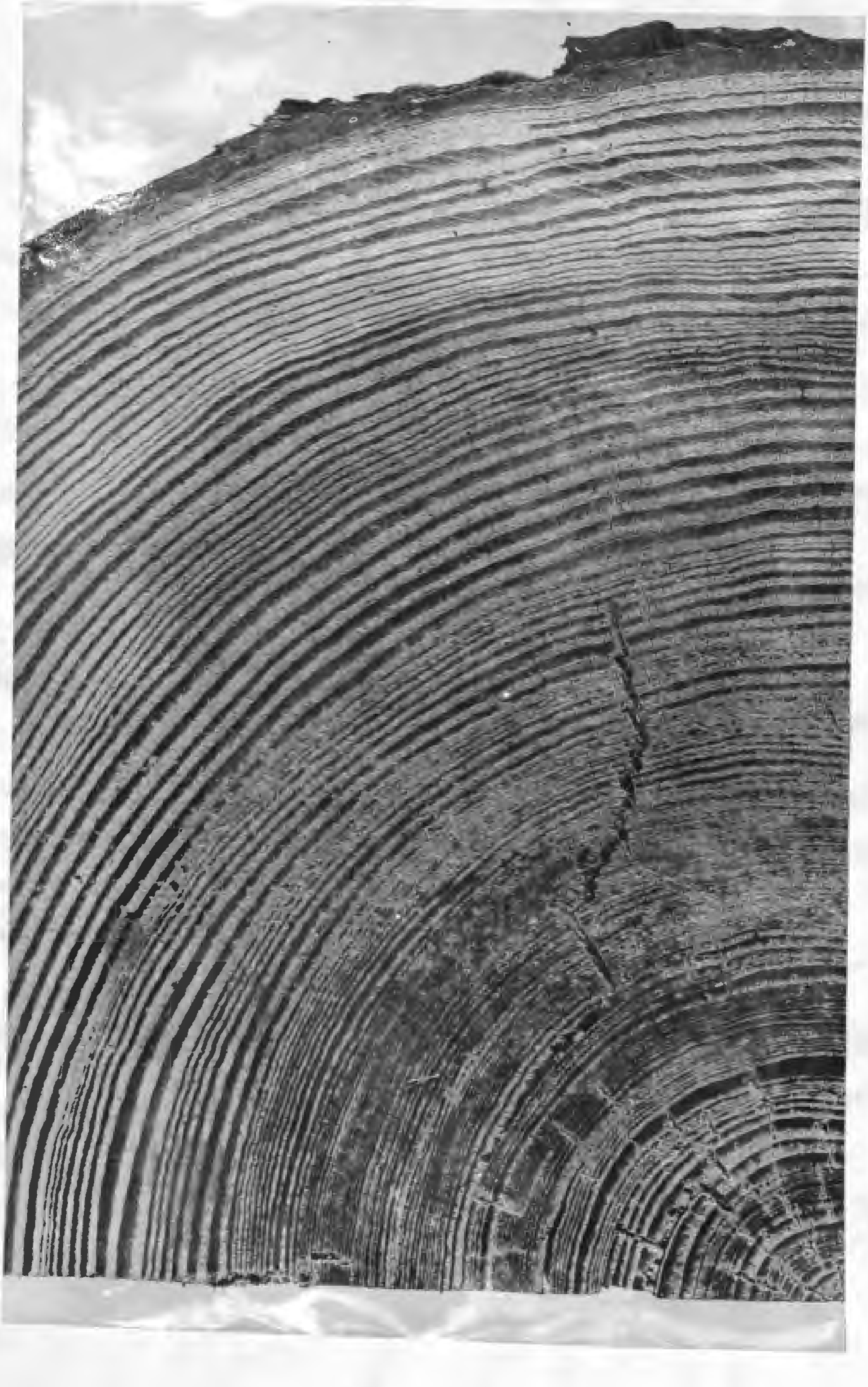


Fig. 5.

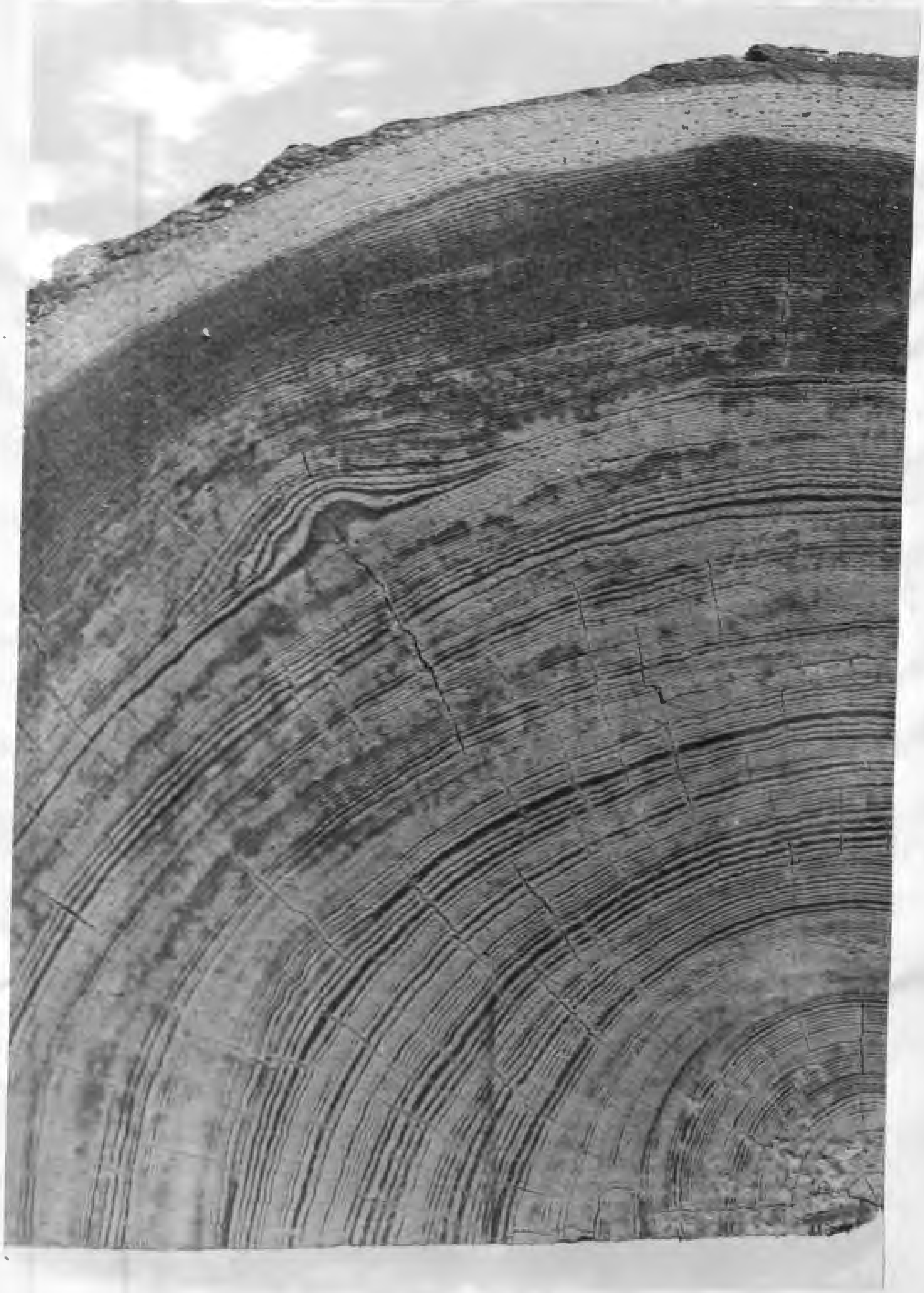


Fig. 6

Table 9 Summary of data on growth of tamarack trees.

Height group	Age Years	Height feet	Diameter of trunk inches	Years per 1/24 inch in radius	Years per 1 foot in height	Growth per year cu. ins.	Depth of peat ft. ins.
5 to 15 ft.	115.7	12.10	2.50	3.84	9.83	6.59	8'0"
16 to 25 ft.	127.4	19.67	2.97	3.38	6.43	12.64	7'2"
26 to 40 ft.	141.4	33.40	3.97	3.32	4.20	36.76	5'3"
41 to 70 ft.	190.4	55.43	6.42	2.60	3.50	121.20	7'9"

CHEMICAL ANALYSIS.

I. Method of Sampling.

After looking the bog over to secure a representative area, unaffected by deposition of mineral soil, ditching operations, etc. a strip 100 yards long was selected for sampling. From experiments on a bog near the University Farm at St. Anthony Park, it was found that a composite of ten samples was sufficient to give a representative analysis. It may be that, on some bogs of unusually uniform composition, a composite of five individual samples would be representative, but in the present study ten samples were taken in each case.

For sampling a flattened 18 inch tiling spade was used. The width of the spade was 6.9 inches. With this spade well sharpened a section 6 x 2 x 16 inches may, after a little practice, be easily and accurately removed from any peat which will bear the weight of a man. After the block of peat was removed it was cut in two in the center for the so-called "first 8-inch section" and "second 8-inch section". The ten samples were then worked up with the hand, or, in the case of a tough sod, by means of carding board made with 20 penny nails. After this was thoroughly mixed a sample of from 5 to 10 pounds was taken from each section for chemical analysis.

II. Preparation of Sample for Analysis.

All of the samples from the peats used for greenhouse experiments were dried over steam coils at a temperature below 100°C. and then ground in a meat chopper, until the material passed a 2 mm. sieve. What failed to go through this sieve after the first grinding, was ground until it passed through. This ground and sifted peat was then thoroughly mixed and transferred to a glass container.

The other samples used for chemical analysis were prepared in the same way, except that they were simply air-dried before grinding.

III. Method of Chemical Analysis.

In all the samples analyses were made for organic matter, ash, both soluble and insoluble, calcium oxide (CaO), phosphoric acid (P_2O_5), nitrogen and acidity.

After drying the sample in a water-oven at 100°C. for 12 hours or longer, according to the bulk of the sample and moisture content, exactly 5 grams was weighed out as rapidly as possible, and, in a quartz or platinum dish, slowly ignited over a very low flame until all fumes had disappeared. The heat was then increased gradually to full blast. After heating for about half an hour the dish was removed to a muffle where the igniting was continued for an hour to an hour and a half. Some samples, which did not crack readily on first ignition, were stirred with a platinum rod which facilitated the operation. After cooling for an hour in a dessicator the ash was weighed and recorded as "Total Ash". The difference between the weight of the ash and the 5 gram sample represents volatile matter, or, for all practical purposes with peats, the organic matter.

The ash was then carefully removed from the dish to a 300 cc. porcelain casserole, treated with 10 cc. of concentrated nitric acid and 15 cc. of concentrated hydrochloric acid, and evaporated to dryness on a steam bath. The operation was then repeated to insure dehydration of the silica.

The residue in the casserole was then treated with hydrochloric acid and allowed to remain on the steam bath for a few minutes to insure solution, transferred to a filter, washed free from chlorides and ignited in a porcelain or quartz crucible. This gave the <u>insoluble ash</u>, and, by difference, the <u>soluble ash</u> was computed.

The filtrate was then made up to 500 cc and aliquots used for lime and phosphoric acid determinations.

For each determination of lime 100 cc of the acid solution, corresponding to 1 gram of dry soil was taken. Two methods were used for the first ten samples and one alone on the others.

Method I

This is the ordinary method (Washington, pp. 97-103). The iron and aluminum are removed by double precipitation with ammonia and the calcium secured by a precipitation as calcium oxalate (Washington, pp. 126-129). The calcium oxalate is then dissolved in sulphuric acid and titrated with standard potassium permanganate. The results of Method II checked so closely with those of Method I that the former was abandoned in favor of the shorter method.

Table 10 Comparison of methods for calcium determination.

Source of peat	CaO by Method I Per cent	CaO by Method II Per cent
Grand Rapids (Chapman's)	.65	.60
Experimental Tract	1.58	1.62
Grand Rapids (Clapp's)	.54	.54
Anoka	1.64	1.72
Golf Links	1.10	1.12
High Timber	2.59	2.65
Pennington	3.71	3.69
8601	1.49	1.55
8602	1.65	1.75
8603	1.68	1.72

METHOD II.

This is a rapid method, devised by Dr. R. A. Gortner.[5] The 100 cc of acid solution is, as in the ordinary method, made strongly ammoniacal to precipitate all of the iron and aluminum, brought to a boil on a hot plate and while boiling treated with 10 cc of freshly made, saturated solution of ammonium oxalate.

After standing at least 3 hours the precipitate is washed with <u>warm</u> water and removed to a 7 or 9 cm filter paper and washed until 5 cc of the filtrate fails to reduce a hot, faintly colored acid solution of permanganate.

The filter is then punctured and washed through with hot water into the original beaker. The filter is washed two or three times with hot 1:5 sulphuric acid and then with hot water until the washings are free of sulphates.

To insure complete solution, 10 cc of concentrated sulphuric acid is then added to the filtrate, which is heated to boiling and titrated with a standard potassium permanganate solution.

PHOSPHORIC ACID.

100 cc of the hydrochloric acid solution described above was evaporated to dryness twice with nitric acid, to expel the chlorine. The residue was taken up with nitric acid, transferred to a beaker, and precipitated with ammonium molybdate. After standing 12 hours the precipitate was filtered out, washed with a washing solution (one part 50% nitric acid and one part 1:5 ammonium nitrate solution) dissolved in 2.5 per cent ammonia and precipitated with magnesia mixture.

NITROGEN

Nitrogen was determined by the ordinary Gunning Kjeldahl method, a crystal of copper sulphate being used in the acid digestion instead of mercuric oxide.

ACIDITY.

The degree of acidity was determined on all samples by two different methods - the Truog hydrogen sulphide method[6] and the Diakuhara nitrite method[7]. In the application of the Truog method, only one-half gram of oven-dried peat in all but one case, that of Grand Rapids, was used. This was placed in an Erlenmyer flask, 100 cc of water added, the mixture brought to a boil and allowed to stand for 24 hours to completely moisten the peat. By this method, as pointed out below, it was found that results comparable with those obtained with soils direct from the field could be obtained. The object of the boiling before allowing to stand was to fill the pores of the peat with water so that it would be completely saturated when the test was made. Instead of preparing lead acetate paper as directed by Truog, the paper was cut into strips exactly one inch wide, saturated with a 10 per cent solution of lead acetate, placed over the top of a 300 cc. Erlenmyer flask after the contents had boiled one minute and, as directed by Truog, left there two minutes. The paper used was just wide enough to permit a little steam to escape on each side. When too wide the steam disturbs the paper and uneven results are obtained. In every case a strong flame was used to bring the solution to a boil and another smaller flame, kept at a constant height, was used for the determination, because the rapidity of boiling affects to a slight degree the evolution of hydrogen sulphide. It was found that where any evidence of acidity could be found by other methods, one-half fram of dry peat was sufficient to give a satisfactory test with the Truog method.

DAIKUHARA METHOD

In the application of the Daikuhara method one gram of oven-dried peat was weighed out roughly, transferred to a 4 cm. crucible, 3 cc. of water added from a burette and thoroughly mixed with the peat until it assumed a <u>very</u> thick, pasty condition. This is very important as the action of nitrite will take place only after 3 or 4 hours if the mixture is so moist that the sodium nitrite will not be taken up with the peat. If 3 cc. of water made the mixture too fluid more peat was added till the proper consistency was secured. Then, 2 cc. of sodium nitrite solution was added from a burette. Immediately a strip of moistened starch iodide paper was placed over the crucible, allowing it to dip down in the center almost to the peat and holding it in place by a small watch glass, just large enough to completely cover the top of the crucible.

When the first traces of blue color appeared a record was made and the degree of acidity determined by the intensity of the color. If no color appeared at the end of 40 minutes, the peat was considered as neutral. The time scale used for determining the degree of acidity was as follows:

	Color	at	0	to 1 1/2	minutes	= Intense	acidity
	"	"	1 1/2	to 5	"	= Strong	"
	"	"	5	to 10	"	= Medium	"
	"	"	10	to 20	"	= Slight	"
	"	"	20	to 40	"	= Faint	"
No	"	"		40	"	= Neutral	

For the sake of comparison the same scale of intensity is used to describe the Truog tests.

PEAT SAMPLES USED FOR GREENHOUSE WORK

Seven different peats from different parts of the northern and central portions of the state, and representing different types of bogs, one from Pennington County, and Grand Rapids in Itasca , two from St. Louis, one from Anoka, and two from Ramsey, were used in this work. All were taken from the surface 8 inches only. Below is given a detailed description of each bog, together with the chemical analyses.

PENNINGTON COUNTY PEAT

Practically all the bogs in Pennington County are grass bogs. The bulk sample was taken from SE¼ SE¼ Sec. 24-152-40 at a point 25 yards north of the ditch and just to the right of the road leading to the home of Mr. Olaf Sundrud, as indicated on the diagram and in Plate

This area is a part of the irregular grass bog covering the greater part of 7 or 8 sections in Pennington and Red Lake counties and varying in depth from 6 inches to four or five feet. The particular area from which the sample was taken has four feet of peat underlain by greyish-white sand. The ditch to the south is from 5 to 6 feet deep, extending below the peat into the sand so that the water-table was lowered to about that depth at the time of sampling. The peat in the field, due to 3 years of cultivation, was in good firm physical condition, being finely divided, partially decomposed, easily worked and fairly retentive of moisture.

This area, including 12 acres, was first plowed in the fall of 1913, and seeded to flax in 1914, giving a yield of 9 bushels per acre. In 1915 the land was disced, without plowing, and again put into flax.

Due to the floods along the last of June, when the land was under water or very wet for two weeks, and also to the frosts on the nights of August 17 and 26, which killed many immature heads, the yield was not more than 7 or 8 bushels per acre. If the frost had held off for two or three weeks longer, undoubtedly the yield would have been upwards of 12 bushels.

By a study of the following analysis and comparative analyses on page 63 it will be seen that this peat is of a good grade, compared with others used in the greenhouse insofar as the chemical composition is concerned, being high in total ash, soluble ash, phosphoric acid and especially in lime.

This peat ranks unusually high in soluble ash and lime. The per cent of nitrogen is about the average, but, like all other Pennington samples analyzed, the phosphoric acid is comparatively low.

Chemical Analysis

	Per cent	Rank comparative with other peats
Organic matter	86.20	
Total ash	13.80	3
Insoluble ash	6.69	
Soluble ash	7.11	2
Lime (CaO)	3.70	1
Phosphoric acid (P_2O_5)	0.191	6
Nitrogen	2.92	3
		Average 3
		Rank 3
Acidity		
1. Truog Method	Faint	
2. Daikuhara	Neutral	

GRAND RAPIDS PEAT

The Grand Rapids bog is situated on the farm of the North Central Experimental station near Grand Rapids, Minnesota. It was occupied by a growth of heath plants, cotton-grass and sphagnum moss. It is 8 to 15 feet deep and covers about eleven acres. Several years ago Professor J. T. Stewart put in a tile drainage system there, and for the past two years experimental work has been conducted on the south end of the bog. The sample for greenhouse work was taken from a strip about 150 feet long and 18 inches wide next to the fence running east and west, just north of the experimental plots. This area had just been "pulled" preparatory to plowing, but had never received treatment of any kind.

Chemical Analysis

	Per cent	Rank
Organic matter	91.93	
Total ash	8.07	6
Insoluble ash	6.26	
Soluble ash	1.81	7
Lime (CaO)	.54	7
Phosphoric acid (P_2O_5)	.227	4
Nitrogen	2.32	7
	Average	6.2
	Rank	7
Acidity		
1. Truog Method	Intensely acid	
2. Daikuhara	" "	

EXPERIMENTAL TRACT PEAT

This peat, from St. Louis County, was taken from a point just south of the experimental acre near the main ditch as indicated on the map of the area on page 24 about 50 rods south of the north line of Section 10-55-18.

This bog, which is about 50 miles north and slightly west of Duluth, is one of considerable area. It is covered chiefly by tamarack trees, sphagnum moss, heath plants and wild grasses. The area sampled is part of the deep area, as shown on page 42, being from 8 to 9 feet deep, underlain by a heavy blue clay with a little admixture of sand in places. In 1915 a large drainage system was completed and the bog has just begun to show the effects of it. The area sampled, belongs to the so-called low timber area with trees 15 to 25 feet high and is also on the border of a large artificial meadow to the northwest where grass forms the chief growth.

In structure the peat is very poorly decomposed, having much tough grass, sod, heath roots and some tamarack, so that it represents probably the poorest type of peat on the bog, so far as structure and ease of working are concerned. Compared with the other peats used for greenhouse work it was most difficult to work up, and, with the possible exception of the Golf Links bog, the least decomposed.

Chemical Analysis

	Per cent	Rank
Organic matter	93.12	
Total ash	6.88	7
Insoluble ash	2.89	
Soluble ash	4.00	5
Lime (CaO)	1.60	5
Phosphoric acid (P_2O_5)	0.217	5
Nitrogen	2.73	4
	Average	5.2
	Rank	6
Acidity		
1. Truog Method	Slightly acid	
2. Daikuhara Method	" "	

This peat ranks lowest in total ash, fifth in soluble ash, lime and phosphoric acid and fourth in nitrogen, giving it sixth place among the seven peats used for greenhouse experiments. One thing worthy of notice is that a very high percentage (58%) of the

The peat is only very slightly acid, and was completely neutralized in the greenhouse boxes by the addition of 4000 pounds of limestone per acre, as shown by Truog tests.

HIGH TIMBER PEAT

The High Timber Peat I have designated on account of the height of the tamarack growth now standing on it. It was taken from the northwest corner of the NE¼ Sec. 11-55-18 about three-quarters of a mile east of the experimental tract, just described. The area is typical of the high-timbered sections on the bog, having characteristic heavy sphagnum moss with many ferns, some heath vegetation and scattering alders and dwarf birch. The peat is ten feet deep with a heavy blue clay subsoil, is very dark in color and comparatively very well decomposed.

Chemical Analysis

	Per cent	Rank
Organic matter	88.31	
Total ash	11.69	5
Insoluble ash	5.61	
Soluble ash	6.08	3
Lime (CaO)	2.62	3
Phosphoric acid (P_2O_5)	0.171	7
Nitrogen	2.55	5
Average		4.6
Rank		5
Acidity		
1. Truog Method	Faintly acid	
2. Daikuhara		

Chemically, the outstanding features of this peat are its comparatively high lime content (2.62 per cent) and high percentage of total ash soluble (52 per cent) and low per centage of phosphorus.

ANOKA PEAT

The Anoka greenhouse sample was taken from a bog of 16 acres, situated west and just across the road from the farmstead of Mr. Geo. D. Dayton, as shown on the chart in the of Sec.

This is a grass-covered bog, varying in depth from 6 inches to 12 feet with an average of about six feet. A shallow ditch 3 to 4 feet deep runs northeast and southwest of the west side and another almost north and south on the eastcentral side, furnishing only partial drainage facilities, the water being from 18 inches to 2 feet from the surface at the time of sampling, November 5, 1915. The peat is a brownish color, comparatively well decomposed, easily workable and free from tough roots and stumps.

Several acres were plowed in the fall of 1915, but no crops had ever been raised on any of it, other than wild hay which, for some time back, had been cut each year.

The peat is from 7 to 8 feet deep and underlain by a fine white sand where the sample was taken.

CHEMICAL ANALYSIS

	Per cent	Rank
Organic matter	83.58	
Total ash	16.42	2
Insoluble ash	10.79	
Soluble ash	5.63	4
Lime (CaO)	1.68	4
Phosphoric acid (P_2O_5)	.258	3
Nitrogen	3.13	1
	Average Rank	2.8 2

Acidity
1. Truog Method Slightly acid
2. Daikuhara " Medium "

Chemically this bog approaches an average between the other greenhouse bogs. It runs highest in nitrogen, second in total ash and third in phosphorus.

The lime content and acidity tests place it on the questionable list with regard to advisability of lime application. The removal of successive hay crops may account for the comparatively low percentage of soluble ash to the total (34.3 per cent).

GOLF LINKS PEAT

This bog, situated near the University Farm, one-half mile north of Larpenteur Avenue and about one-quarter mile west of Cleveland Avenue in Ramsey County, is a grass bog of about four acres in area and having an average depth of about 15 feet and a maximum of 39.5. The bog is circular in shape, receiving drainage from upland to the southeast and draining out from the west side. No attempt at cultivation has been made. There is a small hand ditch, 2 to 3 feet deep dug around the outside which is not suf-

Plate 10

Golf Links Bog, near University Farm.

ficient for drainage so that the water stands at, or very near, the surface for the greater part of the year. Mr. P. M. Harmer[2] has made many analyses of this bog and comparative data is secured from his thesis, published in 1915. The peat is of a coarse, fibrous nature filled with grass roots and is very poorly decomposed.

The sample for the greenhouse work was taken from a little north of the center of the bog, where it is from 20 to 25 feet deep, in May of 1915 and allowed to stand on the neighboring high ground until along in November when it was brought to the station and worked up.

CHEMICAL ANALYSIS.

	Per cent	Rank
Organic matter	86.33	
Total ash	13.67	4
Insoluble ash	10.40	
Soluble ash	3.27	6
Lime (CaO)	1.11	6
Phosphoric acid (P_2O_5)	2.81	2
Nitrogen	2.54	6
	Average	4.8
	Rank	4

Acidity
1. Truog Method Medium acid
Daikuhara Method Strongly acid

Chemically the bog stands very low. Although the ash is fairly high compared with the Grand Rapids and Experimental Tract peats the percentage of soluble ash is very low, being only 1.46 per cent higher than Grand Rapids and 0.73 per cent lower than the Experimental Tract peat. The phosphoric acid is high, but the lime and nitrogen are sixth in rank.

This was the only peat, other than the Grand Rapids, in which the acidity is at all marked.

BELT LINE BOG

A detailed description of this bog has also been reported by Harmer[2]

The bog of about 5 acres is situated just west of the Belt Line R. R. and south of the Como Avenue near boundary line between St. Paul and Minneapolis. It varies in depth from a few inches to six feet, is poorly drained and has been used only as a meadow, hay having been cut annually for many years.

The peat is the best decomposed of all in the series used, being black, heavy, easily worked and having a crumb structure. Doubtless the bog has received washings from the uplands at different times, as the surface is streaked with lighter material in spots and is uneven in composition. The sample taken, was from a point about 50 yards south of Como Avenue and 50 yards west of the Belt Line Railroad on peat about 3 feet deep.

CHEMICAL ANALYSIS

	Per cent	Rank
Organic matter	76.44	
Total ash	23.56	1
Insoluble ash	12.16	
Soluble ash	11.40	1
Lime (CaO)	3.58	2
Phosphoric acid (P_2O_5)	.619	1
Nitrogen	2.93	2
	Average	1.4
	Rank	1
Acidity 1. Truog	Neutral	
2. Daikuhara	Neutral	

This bog is far superior to most of the other bogs sampled, ranking first in total ash, soluble ash and phosphoric acid, and a close second in lime and nitrogen. The very high percentage of phosphorus is noteworthy even for a peat soil.

A study of Fig. 7 and Table 11 leads to the following conclusions with respect to the chemical composition of the different peats used in the greenhouse. All true peats are exceedingly rich in organic matter, which is the result of partial decomposition of plant residues. The percentage of organic matter depends both on the extent of decomposition and the infiltration of mineral soil, so that either one or both of these causes may influence the percentage of organic matter in the peats used. But the most vital consideration is that of the percentage of soluble ash, so that in the following comparisons organic matter will not be considered except in its connection with total ash.

The seven peats might be classified in three divisions with respect to this. Belt Line stands far above all the others with 23.5 per cent, nearly as high as the average of the Blue Earth County bogs, 29.39 per cent[2]. Anoka, Pennington, High Timber and Golf Links, in another class between 11 and 16.5 per cent, while Experimental Tract and Grand Rapids are in a class by themselves, between 5 and 8 per cent.

In soluble ash the fluctuation is also great. Grand Rapids is very low. Experimental Tract and Golf Links are also very low, although, in the Experimental Tract peat the percentage of soluble ash in total ash is very high (58%); Anoka, High Timber and Pennington peats are about alike. Here again Belt Line ranks high with 11.4 per cent.

In lime (CaO) Belt Line, Pennington and High Timber peats are well supplied, comparing favorably with the high lime bogs in Blue Earth County. The Anoka, Golf Links and Experiment-

Fig. 7

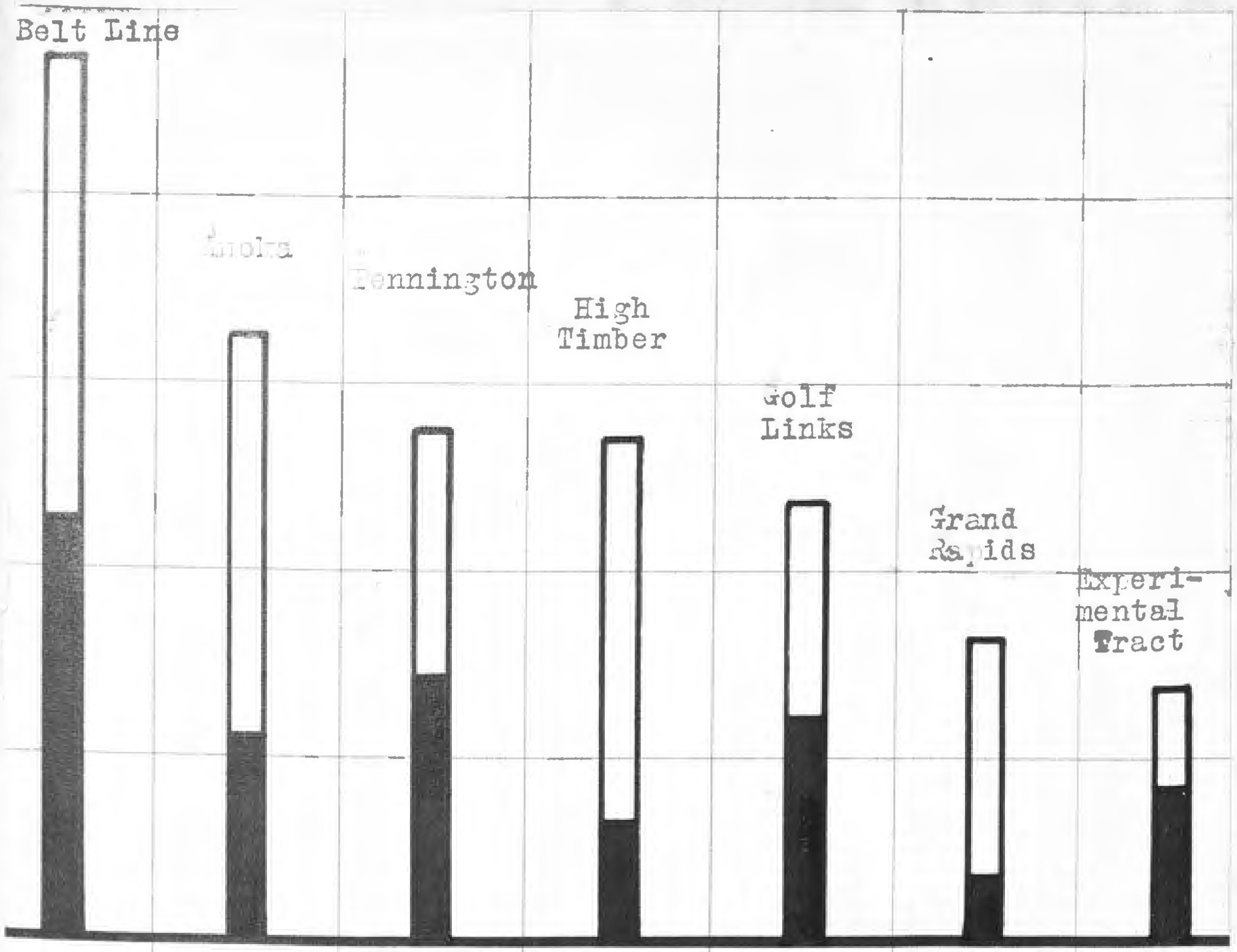


Fig. 1. - Total Ash - soluble in black

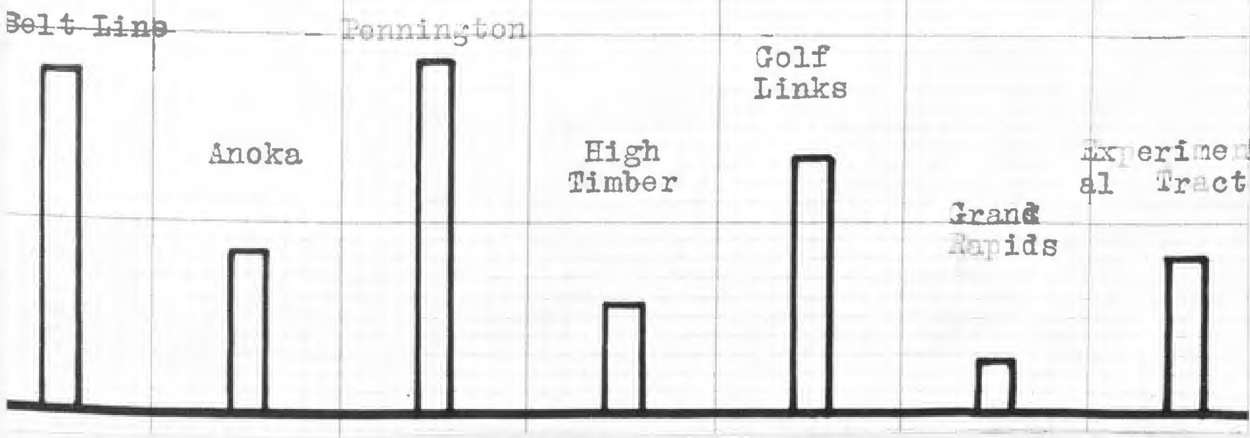


Fig. 2. - Lime

Figure 7 - Diagram showing relation of acid soluble to the total ash in each of the peat soils used in greenhouse work, as well as the relative amounts of lime, phosphoric acid and nitrogen.

Fig. 7 (continued)

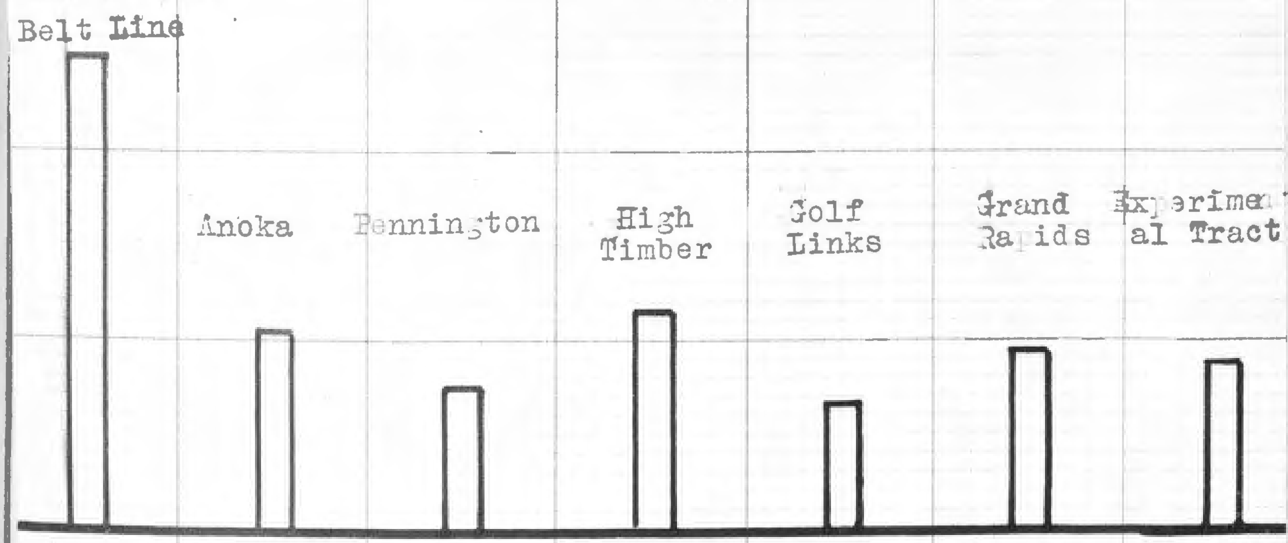


Fig. 3 - Phosphoric Acid

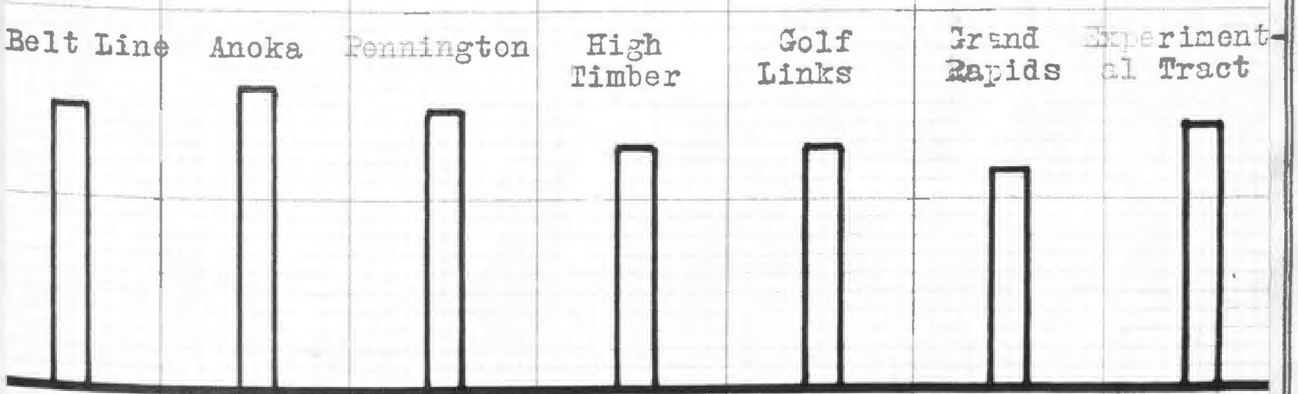


Fig. 4 - Nitrogen

Table 11 Composition of greenhouse peat.

Comparative Analyses.

Composition	Belt Line	Anoka	Pennington	High Timber	Golf Links	Experimental Tract	Grand Rapids
	P.ct.	P. ct.	P.ct.	P.ct.	P.ct.	P. ct.	P.ct.
Organic matter	76.44	83.58	86.20	88.31	86.33	93.12	91.93
Total ash	23.56	16.42	13.80	11.69	13.67	6.88	8.07
Insoluble ash	12.16	10.79	6.69	5.61	10.40	2.89	6.26
Soluble ash	11.40	5.63	7.11	6.08	3.27	4.00	1.81
Lime (CaO)	3.58	1.68	3.70	2.62	1.11	1.60	0.54
Phosphoric acid (P_2O_5)	.62	0.258	0.191	0.171	0.281	0.217	0.22
Nitrogen	2.93	3.13	2.92	2.55	2.54	2.73	2.32
Acidity							
1. Truog	Neutral	Slight	Faint	Strong	Medium	Slight	Inten
2. Daikuhara	Neutral	Medium	Neutral	Slight	Strong	Slight	Inten

Comparative Ranking

Composition	Belt Line	Anoka	Pennington	High Timber	Golf Links	Experimental Tract	Grand Rapids
Total ash	1	2	3	5	4	7	6
Soluble ash	1	4	2	3	6	5	7
Lime (CaO)	2	4	1	3	6	5	7
Phosphoric acid (P_2O_5)	1	3	6	7	2	5	4
Nitrogen	2	1	3	5	6	4	7
Average	1.4	2.8	3.0	4.6	4.8	5.2	6.
Rank	1	2	3	4	5	6	7
Rank excluding soluble ash	1	2	2	6	5	4	7
Rank excluding soluble ash	1	2	2	6	5	4	7

al Tract peats might be put on the doubtful list with regard to advisability of lime application for any crops other than legumes, while Grand Rapids, with only one-half per cent of lime, and exceedingly strong acidity, leaves one in no doubt.

Outside of the Belt Line, which runs unusually high, the variation in phosphoric acid is slight. The Pennington and High Timber peats are low, while Golf Links and Anoka are comparatively high.

In nitrogen, the variation is slight, and has but little significance. The question of availability is more important and cannot be satisfactorily determined, chemically.

If we assume that all of the components generally considered as valuable in peat have equal value and arrange the peats in order of abundance of these components, we secure the results shown in Table 11 page 72 It will be seen that if the peats be arranged in the order of their ash content that the combined rank runs in the same order with a very slight exception; whereas if we eliminate total ash, which is by no means so important as the soluble ash, the order is slightly changed so that 4 and 6 are reversed and 2 and 3 are tied. Not including potassium the seven peats may be classified as follows:

First class	Belt Line
Second class	Anoka Pennington
Third class	Experimental Tract Golf Links High Timber
Fourth class	Grand Rapids

PENNINGTON COUNTY BOGS.

In Pennington County samples were taken from different bogs, but only those from two bogs were analyzed in addition to that used for the greenhouse experiments.

The accompanying diagram shows the location of the sampled area in Section 1-153-39. The bog is uncultivated, but produces a heavy growth of wild hay, which shows no sign of ever having been cut. The depth over the central part sampled is very uniform, varying from 2 to 2.5 feet, overlying a sandy clay or blue clay containing small stones. The surface ten inches of peat is brown, fibrous and poorly decomposed, while that below is black and is better decomposed. The whole of the surface eight inch sample was of fibrous nature, while the second eight inch sample was mostly of the darker and more decomposed peat.

CHEMICAL ANALYSIS

	1st 8 inches	2nd 8 inches
Organic matter	90.15	86.21
Total ash	9.85	13.79
Insoluble ash	4.66	6.51
Soluble ash	5.19	7.28
Lime (CaO)	2.36	3.67
Phosphoric Acid (P_2O_5)	0.207	1.128
Nitrogen	2.52	2.98
Acidity		
1. Truog		
2. Daikuhara	Not acid	Faint

From the above analysis it will be seen that the total ash is much higher in the second eight inches than for the surface and also the percentage soluble is higher. The lime in both samples is high. Phosphoric acid is unusually low in the lower section. A faint reaction for acidity was observed.

The other bog is situated partly in Section 35-153-39. It covers the larger part of several sections. The depth is uniform, varying only from 4 to 5 feet over a large part of the central area. It is covered with grass. The bog has never been cultivated or the hay cut on account of the excess of water.

At the place sampled, the peat was from 4 to 5 feet deep. The surface 18 inches was brown, fibrous and poorly decomposed, while below that the peat was well decomposed and black as in the other area; so that the second 8 inches consists of about half of each.

CHEMICAL ANALYSIS

	1st 8 inches Per cent	2nd 8 inches Per cent
Organic matter	90.91	89.82
Total ash	9.09	10.18
Insoluble ash	5.80	5.89
Soluble ash	3.29	4.29
Lime (CaO)	2.33	2.54
Phosphoric acid (P_2O_5)	.160	.144
Nitrogen	2.44	2.79
Acidity		
1. Truog	Faint	Neutral
2. Daikuhara	Neutral	Neutral

As with the preceding samples the same characteristics are observed for the second 8 inches, viz. higher total ash, higher percentage of soluble ash, higher lime, lower phosphoric acid and higher nitrogen, although not to the same degree, since the proportion of black peat was not as large in this sample as in the first.

Table 12 COMPARATIVE ANALYSIS

Pennington Peats

	1-8 inches			9-16 inches	
	8629	8632	Bulk	8630	8633
Organic matter	90.15	90.91	86.20	86.21	89.82
Total ash	9.85	9.09	13.80	13.79	10.18
Insoluble ash	4.66	5.80	6.69	6.51	5.89
Soluble ash	5.19	3.29	7.11	7.28	4.29
Lime (CaO)	2.36	2.33	3.70	3.67	2.54
Phosphoric acid (P_2O_5)	.207	.160	.191	.128	.144
Nitrogen	2.52	2.44	2.92	2.98	2.79
Acidity					
1. Truog			Neutral		Neutral
2. Daikuhara	Neutral	Neutral	Neutral	Faint	Neutral

From Table 12 it will be seen that these Pennington peats are very high in lime and are either neutral or, in a few cases, only very faintly acid. The lime content compares favorably with the high lime bogs of Blue Earth County, which average 2.94 per cent. The variation in analysis between the samples is not great. It will be noted, however, that the bulk sample used for greenhouse work compares favorably with the well decomposed black second eight inches from Section 1-153-39. These two are practically the same throughout, and are uniformly higher than the others in total ash, soluble ash, lime and nitrogen, while the phosphoric acid is slightly lower than the highest. The outstanding features of the Pennington peats are the high lime and low phosphoric acid content. Below they are compared with peats from bogs in other parts of the state.

DIBBELL BOG.

In sampling the bog at different places an attempt was made to secure locations to which special interest attaches, and also those differing as much as possible. For the sake of convenience analyses of the samples from the same locality with practically the same environment will be treated together. All the samples are from the surface eight inches, since previous studies had shown that the variations according to depth in this bog are slight.

Seventeen samples in all were taken and their respective locations are indicated on Figure 4 by numbers 1 to 17.

SAMPLES FROM EXPERIMENTAL AREA 1,2,3,4 and 10.

Five samples, 1, 2, 3, 4 and 10 were taken from an experimental tract on which work was begun late in the summer of 1915. Their location is indicated on Figure 4. A detailed description of the area is given on page 25. It will be noted that the analysis of the Meadow (No. 10) sample is very similar to those from the Experimental Tract.

Sample No. 10 was taken 30 rods due north of the McKay barn and nearly on the west line of the NE¼ NE¼, Section 10 in the meadow. By way of explanation it might be said that the meadow is one, partly natural and partly artificial. Originally the tree growth on the meadow was sparse, similar to that on the Experimental Tract. Five years ago, and since then, clearing has been done by cutting off the trees at the ground so that a mower might pass over them. Since then hay has been cut each year and pastured after the first cutting. The grass is wild slinder rush, similar to wire grass, with, in the last two years, an admixture of volunteer red top. At one time tame grass was seeded over the larger part of the meadow, but it failed to do much on account of too much moisture. Small strips near the barn and next to the railroad which were manured at different times show considerable benefit from the application. The bog has always been wet, but the sod has improved so that now, in ordinary years, hay may be cut with a mower and hauled on a wagon without difficulty. During the years that the hay has been cut the yield of hay has varied between one-half and one ton per acre for one crop.

Table 13 Chemical Analysis

	1	2	3	4	10	Averages 1-4	Averages Total
	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
Organic matter	92.26	91.93	92.40	92.89	92.37	92.12	92.17
Total ash	7.74	8.07	7.60	7.11	7.63	7.68	7.63
Insoluble ash	3.51	3.33	3.16	3.31	3.49	3.33	3.36
Soluble ash	4.23	4.74	4.44	3.79	4.14	4.30	4.27
Lime (CaO)	1.52	1.70	1.70	1.62	1.58	1.64	1.63
Phosphoric acid (P_2O_5)	0.217	0.223	0.232		0.268	0.224	0.236
Nitrogen	2.69	2.65	2.53	2.53	2.88	2.60	2.66
Acidity							
1. Truog	Trace	Trace	Trace	Trace	Trace	Trace	Trace
2. Daikuhara	Trace	Trace	not acid	Trace	Trace	Trace	Trace

nature of the peat and depth of bog are very similar to samples 5 and High Timber bulk.

Table 14 Chemical Analysis

	Sample 5 Per cent	Bulk Sample Per cent	Sample 17 Per cent	Average Per cent
Organic matter	89.08	88.31	90.80	89.40
Total ash	10.92	11.69	9.20	10.60
Insoluble ash	5.11	5.61	4.48	5.07
Soluble ash	5.81	6.08	4.73	5.54
Lime (CaO)	2.69	2.62	2.06	2.46
Phosphoric acid (P_2O_5)	0.258	0.171	0.246	0.225
Nitrogen	2.29	2.55	2.76	2.53
Acidity				
1. Truog	Faint	Faint	Not acid	Faint
2. Daikuhara	Slight		Slight	Slight

INTERMEDIATE PEAT TYPES

Samples 6, 7 and Special Bulk belong to a type of peat intermediate between the High Timber and Low Timber varieties.

In this neighborhood, bordering on the high timber, these three sets of samples were analyzed, being so similar that they will be considered together.

Sample No. 6 was taken 53 yards east and 10 yards south of the northwest corner of NE¼ NW¼ Section 12-55-18. Here the trees are from 8 to 12 feet high, scrubby and dwarfed, probably due to too much water and other contributary causes. The other vegetation consists of sphagnum moss, dwarf birch, heath plants and a liberal admixture of wild grass. The peat, 3 to 4 feet deep overlying clay, is black as though charred by fire, but is filled with undecayed roots and dead stems of former shrub growths. The

SAMPLES FROM HIGH TIMBER AREA.

Samples 5, 17 and High Timber bulk are designated as High Timber on account of their being secured from an area having a tall and heavy growth of tamarack trees, and having a very distinct type of peat.

Sample 5 was secured from 10 yards south and 10 yards east of the northwest corner of the NE¼ of Section 11-55-18. This sample is truly representative of the high timber area, the trees being from 60 to 70 feet high and the small vegetation typical, consisting chiefly of sphagnum moss, ferns and Laborador Tea with some scattering dwarf birch, alder, young spruce and cedar. The peat is 10 feet deep, well rotted (having a crumb structure) and dark in color, overlying a blue clay subsoil. The growth of timber is very heavy at this place and the ground is well filled with roots and stumps, both below and at the surface. The character of the trees and other vegetation is well shown in the accompanying views. Plate 4

For the sake of comparison, the analysis of the bulk sample used for greenhouse experiments, which was taken at approximately the same place, is included below.

Although sample No. 17 was not secured from exactly the same locality as No. 5 and High Timber Bulk the trees are similar or even larger and the analysis is much the same. It was secured in the high timber south of Dibbell on the west side of the railroad tracks, 60 rods south of the south line of NE¼ NE¼ Section 10-55-18. Very little but a thin covering of moss was found here due to dense timber growth and pasturing, but otherwise the grass forms somewhat of a sod, but it is not so dense and matted as that on the Experimental Tract.

Sample No. 7 was taken 10 yards west and 8 rods south of the northeast corner of Section 11-55-18 from the intermediate high timber, 20 to 25 feet tall. Here the trees, although stunted to some extent, form a very dense growth and exclude the sun to such an extent that very little but sphagnum moss and a little wild grass grows. The peat itself is well rotted and contains but few roots other than those of tamaracks. The peat varies in depth from 7 to 8 feet deeptand overlies blue clay.

The Special Bulk sample was taken 120 rods north of the southeast corner of Section 2-55-18 from the low timber area, where the tamaracks vary from 15 to 20 feet in height. The other vegetation is chiefly sphagnum moss and heath plants with some grass sparsely intermingled. The peat is 6 to 7 feet deep, fairly well decomposed and comparatively free from roots or sod.

Table 15 Chemical Analysis

	Sample 6 Per cent	Sample 7 Per cent	Special Bulk Per cent	Average Per cent
Organic matter	92.01	91.34	91.93	91.76
Total ash	7.99	8.66	8.07	8.24
Insoluble ash	2.80	3.37	3.04	3.07
Soluble ash	5.19	5.30	5.04	5.18
Lime (CaO)	2.13	2.27	2.22	2.24
Phosphoric acid (P_2O_5)	0.278	0.271	0.182	0.247
Nitrogen	2.44	2.44	2.41	2.43
Acidity				
1. Truog	Slight	Faint	-	Slight
2. Daikuhara	Faint	Slight	-	Slight

In the analysis it will be seen that all are very similar except in phosphoric acid, which is low in the special bulk sample.

SAMPLE FROM LOW TIMBER AREA

Samples Nos. 8 and 9 are from much the same type of peat and were located near each other. No. 8 was taken 40 rods west and 10 rods south of northeast corner of the NW¼ Section 23-55-18, while No. 9 was secured 20 rods north of the center of Section 14-55-18. In both places the tamarack are scrubby, but near Sample No. 8 there are scarcely any at all. In each case sphagnum moss was dominant with considerable growth of heath plants, dwarf birch and numerous pitcher plants, water arums, etc.

The peat was very wet at the time, poorly decomposed, fibrous, light colored and loose. It is 7 to 8 feet deep and fairly well filled with roots and small stumps at all depths.

Table 16 Chemical Analysis

	Sample 8 Per cent	Sample 9 Per cent	Average Per cent
Organic matter	91.59	91.95	91.77
Total ash	8.41	8.05	8.23
Insoluble ash	4.33	3.88	4.61
Soluble ash	4.08	4.17	4.13
Lime (CaO)	1.65	1.92	1.79
Phosphoric acid (P_2O_5)	0.204	0.217	0.211
Nitrogen	2.64	2.76	2.70
Acidity			
1. Truog	Slight	Slight	Slight
2. Daikuhara	Medium	Slight	Slight+

LOW TIMBER TYPE OF PEAT NEAR WALLACE

Samples 11, 13 and 14 were taken on nearly the same type of peat with practically the same timber height. Briefly the description of the location is as follows:

No. 11 = 10 rods east and 40 rods south of bridge opposite Wallace, Section 34-55-18.

No. 13 = 10 rods east and 40 rods north of bridge opposite Wallace, Section 27-55-18.

No. 14 = 6 rods east and 30 rods south of bridge one mile north of Wallace, Section 27-55-18.

The trees on all of these areas are slightly dwarfed and from 10 to 20 feet high. Sphagnum moss and heath plants constitute the chief vegetation, together with some dwarf birch and grass. The depth where Nos. 11 and 13 were secured is more than 7 feet, while it is not deeper than 4 feet where No. 14 was secured.

The peat in all cases is light colored beneath the surface inch or two, very fibrous, filled with roots and poorly decomposed, being very wet in all cases. Plate 9 illustrates the type of vegetation quite accurately.

Table 17	Chemical Analysis			
	Sample 11 Per cent	Sample 13 Per cent	Sample 14 Per cent	Average Per cent
Organic matter	89.86	90.70	87.72	89.43
Total ash	10.14	9.30	12.28	10.57
Insoluble ash	6.33	5.61	8.30	6.75
Soluble ash	3.81	3.70	3.98	3.83
Lime (CaO)	1.48	1.52	1.52	1.51
Phosphoric acid (P_2O_5)	0.224	0.210	0.236	0.223
Nitrogen	2.47	2.70	2.34	2.50
Acidity				
1. Truog	Medium	Faint	Faint	Slight
2. Daikuhara	Slight+	Medium	Medium	Medium-

SAMPLE FROM CROPPED FIELD

Sample No. 12 was secured from an oat field 250 yards north of Wallace and 10 yards west of the west fence of the railroad, Section 27-55-18.

This area has been under cultivation for a few years, has received one or two applications of manures, and the peat is in a very well decomposed state. The peat is not more than 4 or 5 feet deep and is near mineral soil to the west. In 1915 oats yielded about 25 bushels per acre. A good quality of straw was formed and most of the heads filled satisfactorily. The potatoes to the south of the oats were of excellent quality and would have yielded well if the frosts and unusually wet weather had not cut them down. The grass, in which there was some timothy, to the north, yielded from one to one and a half tons per acre of hay. Clover seeded in with the oats was doing well and was well inoculated. Plate 11 shows the oat field sampled.

Plate 11

Fig. 1 - Shore and station at Wallace. Main ditch showing burned-over area to the right.

Fig. 2 - Oat-field on 5 to 6 feet of peat north of Wallace, where Sample No. 12 was secured. Tamarack trees in the distance.

Table 18 Chemical Analysis

	Sample 12, or Oat-field. Per cent
Organic matter	84.11
Total ash	15.89
Insoluble ash	11.10
Soluble ash	4.79
Lime (CaO)	1.51
Phosphoric acid (P_2O_5)	0.239
Nitrogen	2.56
Acidity	
1. Truog	Medium
2. Daikuhara	Strong

This sample is the highest in total ash of any taken on the bog, but otherwise the analysis resembled that of the other Dibbell peats, most strongly that of the Experimental Tract, in lime phosphoric acid, nitrogen and soluble ash.

INTERMEDIATE PEAT TYPES.

Samples 15 and 16 were secured as follows:

Sample 15 = 20 rods east and 4 rods south of the bridge 2 miles north of Wallace, Section 22-55-18.

Sample No.16 = 20 rods east and 15 rods south of the intersection with the main ditch of the first hand lateral to the south in Section 15-55-18.

The vegetation in both places was much the same with tamarack trees 15 to 25 feet tall, a predominance of sphagnum moss, many heath plants with a few ferns and dwarf birch. Both were from deep peat, more than 7 feet in depth. In each case the peat itself was much darker, more compact and better decomposed than the immediately preceding samples, it assuming more the appearance and crumb structure of the high timber peat of Sample No. 5. The water-table was a little lower and there appeared to be better drainage than in the low timbered sections.

Table 19 Chemical Analysis

	Sample 15 Per cent	Sample 16 Per cent	Average Per cent
Organic matter	88.43	90.09	89.26
Total ash	11.57	9.91	10.74
Insoluble ash	6.32	4.60	5.46
Soluble ash	5.25	5.32	5.29
Lime (CaO)	2.33	2.40	2.37
Phosphoric acid P_2O_5	0.236	0.224	0.230
Nitrogen	2.22	2.68	2.45
Acidity			
1. Truog	Faint	Not acid	Faint
2. Daikuhara	Medium	Faint	Slight

It will be observed that the two samples run almost identical in the important constituents.

COMPARISON OF THE DIBBELL PEATS

By a study of the peats represented in the five Tables it will be seen that there are three more or less distinct types of peat represented. Table 15 illustrates the grass bog type, having very fibrous and tough sod with sparse tree growth, and much grass along with heath plants and sphagnum moss. This type is characterized chemically by a low ash content with a high percentage of total ash, soluble, and a comparatively low lime content. Table 16 represents another type - the so-called low timber type. Where the tamarack trees are stunted and scattering and sphagnum moss is exceedingly abundant. This type of peat is fibrous, poorly decomposed, loose and light in color. Chemically it is very similar to the meadow type, being low in lime and comparatively low in soluble ash.

A third type which is represented by Table 14 and Table 15 has very marked characteristics setting it off from all others.

This type of peat supports a heavy, rapidly growing timber vegetation, is black, well decomposed and has a crumb structure. High and dense timber seems uniformlly to indicate the presence of this type of peat. It is set off chemically also from all other types by a comparatively high ash, high per centage of soluble ash and, more pronounced than anything else, by a high lime content. In fact we might class all of the peats into two groups - the high timber or high lime peat and the low timber, or low lime peat.

Table 20 Composition of the various classes of peat.

Sample No.	Organic matter P. ct.	ASH Total P.ct.	ASH Insoluble P.ct.	ASH Soluble P.ct.	Lime (CaO) P.ct.	Phosphoric Acid (P_2O_6) P.ct.	Nitrogen P.ct.
			EXPERIMENTAL TRACT				
1	92.26	7.74	3.51	4.23	1.52	0.217	2.69
2	91.93	8.07	3.33	4.74	1.70	0.223	2.65
3	92.40	7.60	3.16	4.44	1.70	0.232	2.53
4	92.89	7.11	3.31	3.79	1.62	0.-	2.53
10	92.37	7.63	3.49	4.14	1.58	0.268	2.88
Av.	92.37	7.63	3.36	4.27	1.63	0.236	2.66
			LOW TIMBER				
8	91.59	8.41	4.33	4.08	1.65	0.204	2.64
9	91.95	8.05	3.88	4.17	1.92	0.217	2.76
11	89.86	10.14	6.33	3.81	1.48	0.224	2.47
13	90.70	9.30	5.61	3.70	1.52	0.210	2.70
14	87.72	12.28	8.30	3.98	1.52	0.236	2.34
Av.	90.36	9.64	5.69	3.95	1.62	0.218	2.58
			INTERMEDIATE TIMBER				
6	92.01	7.99	2.80	5.19	2.13	0.278	2.44
7	91.34	8.66	3.37	5.30	2.27	0.271	2.44
Special Bulk	91.93	8.07	3.04	5.04	2.22	0.182	2.41
15	88.43	11.57	6.32	5.25	2.33	0.236	2.22
16	90.09	9.91	4.60	5.32	2.40	0.224	2.68
Av.	90.76	9.25	4.03	5.22	2.27	0.238	2.44
			HIGH TIMBER				
5	89.08	10.92	5.11	5.81	2.69	0.258	2.29
17	90.80	9.20	4.48	4.73	2.06	0.246	2.76
High Timber Bulk	88.31	11.69	5.61	6.08	2.62	0.171	2.55
Av.	89.40	10.60	5.07	5.54	2.46	0.225	2.53
			CULTIVATED FIELD				
12	84.11	15.89	11.10	4.79	1.51	0.239	2.56

Table 21 Summary of averages of peat types

Type of Peat	Organic matter	ASH			Lime (CaO)	Phosphoric acid (P_2O_5)	Nitrogen
		Total	Insoluble	Soluble			
	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.
Experimental Tract	92.37	7.63	3.36	4.27	1.63	0.236	2.66
Low Timber	90.36	9.64	5.69	3.95	1.62	0.218	2.58
Intermediate	90.76	9.25	4.03	5.22	2.27	0.238	2.44
High Timber	89.40	10.60	5.07	5.54	2.46	0.225	2.53
Cultivated field	84.11	15.89	11.10	4.79	1.51	0.239	2.56
Total Average	90.86	9.48	4.83	4.66	1.92	0.230	2.55

By grouping analyses according to the height of the trees where samples were taken, it was found that the increase of lime was concordant with the increase in the height of the trees, but the progression was so slight and the exceptions within groups so many that the coincidence of consistent progressive association may have been purely accidental. It would appear, rather, that the high lime is associated more closely with the high timber type of peat and the low lime with the low timber type of peat, as, in every case where the peat was black, well decomposed, and having a crumb structure, regardless of the height of timber, the lime content was high. As a rule, however, the high lime is directly associated with the high timber as well as with the high timber type of peat. There is probably a causal relation in here. The high lime doubtless favors decomposition of organic matter which renders the plant food more available which, in turn, results in a more rapid growth of the trees. This conclusion is also corroborated by the fact that the high timber peats have 1.27 higher percentage of soluble ash than the low timber peats and, as a rule, have a higher percentage of the total soluble ash. (The Experimental Tract is an exception, running the same as High Timber) By computing the percentage of soluble as to total ash in the typical low timber we find that the percentages of soluble ash to total ash are 56.43 and 41.00 respectively, or a difference of 15.43 per cent in favor of the High Timber. From all indications, then, we might say that high lime is a strong contributory factor in peat decomposition and consequent increased plant growth. This along with the greater fall and better drainage, as shown later, to all appearances account for the increased timber growth in certain more or less well defined areas.

Aside from the lime and soluble ash, there seems to be no logical relationship existing between the chemical analysis and the type of peat or the type of vegetation living on it. In fact, the fluctuations in nitrogen and phosphoric acid are very slight.

COMPARISON OF CHEMICAL COMPOSITION OF ALL PEATS ANALYZED.

All of the peat samples analyzed may be classified in groups according to source and chemical composition. In Table are reported only the averages from each area, or, where only the greenhouse samples were taken, the analyses of these have been given. In all cases only the surface 8 inches analysis is used.

Table 22 Comparison of all analyses.

Source of peat	No of samples	Organic matter	ASH Total	ASH Insoluble	ASH Soluble	Lime (CaO)	Phosphoric acid (P_2O_5)	Nitrogen	Acidity
		P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	Degree
Pennington	3	89.09	10.91	5.72	5.20	2.80	0.186	2.63	Faintly
Grand Rapids	1	91.93	8.07	6.26	1.81	0.54	0.227	2.32	Intensel
Dibbell	19	90.86	9.48	4.83	4.66	1.92	0.230	P.55	Slightly
Anoka	2	84.66	15.34	9.73	5.62	1.87	0.281	3.19	Slightly
Golf Links	1	86.33	13.67	10.40	3.27	1.11	0.281	2.54	Medium
Belt Line	I	79.02	20.98	9.76	11.23	4.70	0.619	2.93	Not Acid

The following are the outstanding features of the comparison: The Pennington peat is high in soluble ash and lime and low in phosphoric acid, while the Grand Rapids peat is low in all constituents, especially in lime and soluble ash, and is intensely acid. The Dibbell peat is almost an average sample in all respects. The Anoka peat is high in nitrogen and in both soluble and total ash. The Golf Links peat is low in soluble ash and comparatively low in lime along with rather strong acidity, while the Belt Line peat is high in all constituents, but especially so in lime and phosphoric acid, and is the only one showing no test for acidity.

If we make a comparison from the standpoint of desirable constituents, we get the results shown in Table

Table 23. Comparative rank of all peats analyzed.

Source	Total Ash Rank	Soluble Ash Rank	Lime (CaO) Rank	Acidity Rank	Phosphoric acid (P_2O_5) Rank	Nitrogen Rank	Acidity Rank
Belt Line	1	1	1	1	1	2	1
Anoka	2	2	4	4	2	1	2
Pennington	4	3	2	2	6	3	3
Dibbell	5	4	3	3	4	4	4
Golf Links	3	5	5	5	3	5	5
GrandRapids	6	6	6	6	5	6	6

It is worthy of note that the ranking of soluble ash is the same for the average ranking, while the ranking according to total ash is erratic. It would appear there that the soluble ash is a better index of the desirable chemical comparison than the total ash. Nitrogen also follows closely the average ranking, while lime and phosphoric acid are erratic. It is very interestint to note the complete concordance between the lime and acidity rankings.

The relationship of chemical composition to productivity will be discussed under another heading.

PHYSICAL CONSTANTS OF PEAT SOILS.

The work on the moisture equivalent and the hygroscopic coefficient, reported below, involved seventy different peats of widely differing nature; mostly from Blue Earth County, one from Grand Rapids and one from Ramsey county.

The study involved:-

1. Methods of arriving at the accurate moisture equivalents of peats.
2. Relation of color to moisture equivalents of peats.
3. Methods of determining the hygroscopic coefficient in peat.

DETERMINATION OF MOISTURE EQUIVALENT

Different investigators have observed that peats, after being completely, or oven-dried, not only take up water very slowly, but, even after apparent saturation, retain much less (when subjected to pressure) than when not previously dried.

As, usually, it is inconvenient and, sometimes, impossible to secure for moisture study samples in their natural moisture condition, a method of bringing oven-dried peats up to their natural moisture capacities, was sought for. Peat samples from a muskeg bog (Grand Rapids) and a grass bog (Golf Links), both of which are poorly decomposed and absorb water slowly from the dry state, were selected for this investigation. Duplicate samples of each were allowed to temper in contact with water for varying lengths of time (from one to twenty-seven days) and the moisture equivalents then determined.

Table 24 Relation of length of tempering periods to the moisture equivalent.

Source of Peat	1 day	3 days	13 days	18 days	27 days	Undried Peat
	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P. ct.
Grand Rapids	150	159	168	169	167	286
Golf Links	135	158	166	167	178	273

It will readily be seen that the moisture equivalent rises appreciably with the length of time that the dried peat is in contact with the water; but that, even after 27 days, it is only from 49.5 to 58.4 per cent of that found in the case of the naturally moist, or undried, samples, so that it would evidently require a long time to bring oven-dried peat up to the natural moisture conditions and too long for practical laboratory practice.

Next, samples of naturally moist and oven-dried peats, tempered in contact with water for 24 hours, were employed, to see what the relationship would be, if, perchance, a factor might be arrived at so that from the moisture equivalent, found for an oven-dried sample, the true moisture equivalent might be computed. Peats having a wide variation in water capacity were employed for this purpose.

Table 25. Relation of previous moisture conditions to the moisture equivalent.

Peat	Moisture Equivalents: Using dry sample Per cent	Moisture Equivalents: Using wet sample Per cent	Dry % of wet
6235	67	77	87
6234	84	105	80
6175	83	124	67
6176	89	141	62.9
6231	123	178	68.9
6232	109	185	58.9
6031	132	222	59.5
6034	135	273	49.4
Grand Rapids	150	286	52.4
Average	108	176.9	61.0

It will be seen that, in general, the higher the moisture holding capacity the lower the ability to hold a large percentage of its total capacity, or, in other words, the more nearly we approach a mineral soil the more nearly can we approximate natural soil conditions by a short tempering period. If only a rough indication of moisture equivalent be desired the oven-dry sample may be saturated for 24 hours, the determination made and multiplied by 2 for a very fibrous peat, by 1.5 for a fairly well decomposed peat, and by 1.2 for one approaching a mineral soil.

RELATION OF DEPTH TO MOISTURE EQUIVALENT

The samples of peat employed were from the first and second 8 inches. By making comparative tables it was sought to determine whether or not there is any consistent difference between the two depths. It will be seen from Table 26 that there is a very marked difference between samples from different depths, but that the difference is sometimes one way and sometimes the other. Although the average for the second 8 inches is 10.5 per cent more than for the first 8 inches, it cannot be said that there is sufficient uniformity to warrant any conclusions, as, in 15 cases, the first 8 inches had a lower equivalent than the second, in 9 cases a higher, while in 6 cases there was practically no difference.

Table 26 Relation of moisture equivalent to depth of sample

Soil numbers	1st 8 inches P.ct.	2nd 8 inches P.ct.
6043 & 4	286.5	284.5
6046 & 7	276.5	271.0
6054 & 5	149.5	146.0
6057 & 8	179.0	177.5
6060 & 1	257.5	280.5
6064 & 5	149.0	142.0
6067 & 8	177.4	242.0
6070 & 1	206.0	243.5
6073 & 4	288.5	320.0
6076 & 7	275.0	324.0
6079 & 80	309.5	309.5
6082 & 3	293.5	299.0
6160 & 1	220.5	237.0
6163 & 4	230.0	245.0
6166 & 7	234.5	250.0
6169 & 70	249.5	252.0
6172 & 3	182.0	182.0
6175 & 6	124.0	141.5
6178 & 9	155.0	190.0
6181 & 2	201.0	172.5
6184 & 5	160.5	179.0
6187 & 8	158.0	158.0
6190 & 1	198.0	160.5
6193 & 4	160.5	134.0
6231 & 2	178.5	185.0
6234 & 5	105.0	77.0
6237 & 8	135.5	172.5
6240 & 1	144.5	168.5
6243 & 4	186.5	206.0
6246 & 7	212.0	250.0
Average	202.8	213.3

In 15 cases the first 8 inches in less than the second 8 inches.

In 9 cases the first 8 inches is more than the second 8 inches.

In 6 cases the first 8 inches is the same, or nearly the same as the second 8 inches.

RELATION OF COLOR TO MOISTURE EQUIVALENT

In working with different peats it was observed that, as a rule, the lighter colored peats have the highest moisture capacities. While determining the moisture equivalents on the peats previously mentioned a third sample of each was saturated and centrifuged and, instead of drying, was packed tightly into a test tube to be used in a color comparison. The samples in the tubes were then arranged in order according to intensity of color, dried and again arranged in order of color. Two gradings and the true moisture equivalents are recorded in Table 27 in their color orders as determined in the oven-dry condition. Inasmuch as rather wide fluctuations occur, averages have been made of each ten in the order of the color of the oven-dry samples. By reference to the summary of Table 27 it will be seen that the averages of the groups of ten progress arithmetically with the decrease in intensity of color.

The progression in color of the oven-dry samples and the progression of the moisture equivalents are more comparable and consistent than the color of the moisture equivalent samples and the moisture equivalents showing the color of dry peat samples is a better indication of moisture holding capacity than that of the samples in a moist condition. This may be accounted for on the grounds that, with different soils, or the same soil, the color intensity increases as the moisture content, and, inasmuch as different peats of widely different moisture capacity show less color difference as water is added, the basis of comparison becomes more confined and less accurate.

Table 27 Color order for peats of Blue Earth County.

Soil No.	Moisture equivalent	Color Order Moisture equivalent	Color Order Oven-dry
6058	177.5	5	1
6067	177.4	4	2
6241	168.5	2	3
6179	190.0	11	4
6178	155.0	18	5
6052	98.0	23	6
6237	135.5	1	7
6065	142.0	7	8
6071	243.5	6	9
6243	186.5	16	10
Average	167.4	9.3	5.5
6246	212.0	17	11
6068	242.0	10	12
6240	144.5	3	13
6049	225.0	29	14
6238	172.5	8	15
6231	178.5	20	16
6070	206.0	15	17
6190	151.0	13	18
6191	198.0	12	19
6057	179.0	24	20
Average	190.85	15.1	16.5
6232	185.0	26	21
6076	275.0	40	22
6163	230.0	38	23
6063	84.0	14	24
6160	220.5	32	25
6164	245.0	30	26
6167	250.0	34	27
6064	149.0	25	28
6184	160.5	39	29
6161	237.0	28	30
Average	203.6	30.6	26.5

Table 27 (Continued)

Soil No.	Moisture equivalent	Color Order	
		Moisture equivalent	Oven-dry
6043	286.5	9	31
6187	158.0	21	32
6172	182.0	37	33
6170	252.0	36	34
6079	309.5	42	35
6044	284.5	47	36
6169	249.5	35	37
6073	288.5	43	38
6188	158.0	19	39
6244	206.0	22	40
Average	237.45	31.1	36.5
6185	179.0	29	41
6166	234.5	33	42
6247	250.0	31	43
6082	293.5	51	44
6046	276.5	48	45
6074	320.0	52	46
6060	257.5	46	47
6061	280.5	44	48
6047	271.0	41	49
6077	324.0	45	50
Average	268.65	42.0	46.5

Summary of Table

Color of Soils	Moisture Equivalent	Color	
		Moisture equivalent	Oven-dry
1-10	167.40	9.3	5.5
10-20	190.85	15.1	16.5
20-30	203.60	30.6	26.5
30-40	237.45	31.1	36.5
40-50	268.65	42.0	46.5

As regards the general principle of estimating the relative moisture capacity from the color the progression of moisture equivalents is uniformly consistent with progression of color when averages are employed, but, with individual samples, one may go astray as much as 150 per cent in basing his estimate on color alone.

With the principle in mind that a light colored peat usually has a higher moisture capacity than a dark colored one, and taking into consideration structure and percentage of inorganic matter one may easily make an estimate accurate within 50 per cent of the moisture equivalent of any peat.

DETERMINATION OF THE HYGROSCOPIC COEFFICIENT

With the hygroscopic coefficient, as with the moisture equivalents, the difficulty of securing an end point from dry samples again appears. To determine how long it is necessary to expose dry peat to a saturated atmosphere to secure the hygroscopic coefficient samples of Grand Rapids peat were taken and sifted through 1 mm. and 0.25 mm. sieves to be used as test samples. Both the fine and the coarse peats were placed in hygroscopic boxes for 1, 3, 6, 8, 24, 31, 38, 45, 52 and 59 day periods with the following results:

Table 28 Relation of hygroscopic moisture to length of tempering period.

Days tempered	Moisture percentage averages: Coarse peat 1 mm. size	Fine peat 0.25 mm. size
1	33.0	33.0
3	49.5	43.6
6	52.9	45.0
8	57.8	
24	69.2	64.8
31	67.1	66.9
38	70.0	64.8
45	79.0	74.8
52	79.6	73.0
59	81.5	70.6

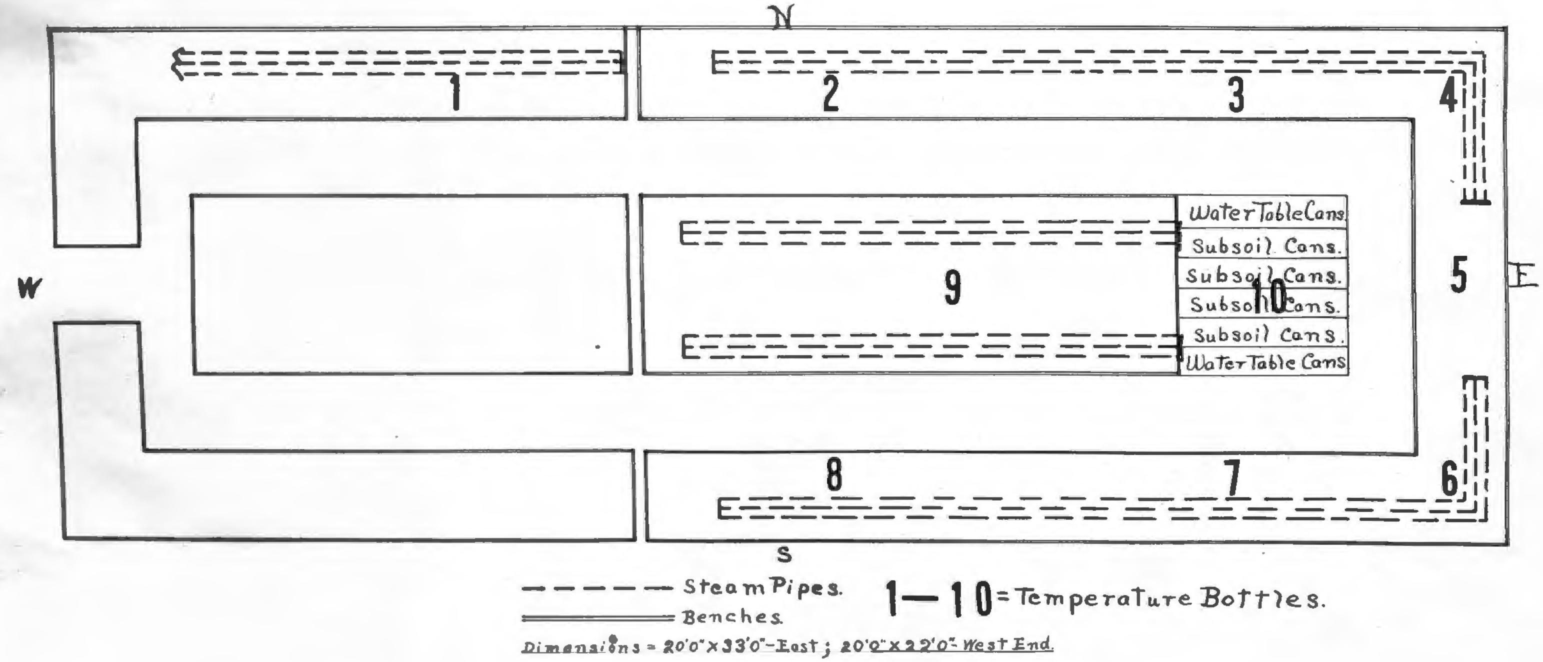
In 1915 the moisture content of this same peat (Grand Rapids) was determined from peat on which barley plants had practically died down, but which revived again on application of water. The percentage of moisture was found to be about 50, which is practically the same as that secured in the hygroscopic experiments at the end of a week. The figure of 50 per cent is undoubtedly somewhat lower than that which would be secured by the customary method of determining the wilting point, since 50 represents more closely the "dying" point than the wilting point. If, however, we assume that 50 per cent closely approximates the wilting coefficient and that the hygroscopic coefficient approximates the wilting coefficient we may say that the hygroscopic coefficient of peats may be secured by tempering in a saturated atmosphere for a week.

It will be seen that the coarsely ground peat, although the same as the fine at the end of 24 hours, is 2 to 5 per cent higher than the latter in the case of the other determinations and that in each series the maximum was reached in 45 days. It must be observed, however, that after a week of exposure to a saturated atmosphere, many molds and fungous growths appeared so that they may have vitiated the results , making them higher than they should be.

Plate 12 - Plan of greenhouse showing arrangement of temperature bottles with reference to the vegetation-pots.

Plate 12

GREEN HOUSE



GREENHOUSE WORK.

The general plan and dimensions of the greenhouse used may be seen from plate 12 The heating system, indicated by dotted lines, under the benches, was found to be slightly inadequate for the coldest weather, but no frosts were encountered. Temperature conditions will be discussed separately. The benches, 3 feet 6 inches wide, were filled to a depth of 3 inches with sand in order to furnish a slight absorbent for seepage and to maintain the humidity of the air. Sand was placed also under the benches for the same purpose.

THE POTS USED.

As pots wooden boxes were employed. Each box was a foot square on the inside and ten inches deep. It was coated with pitch tar on the inside and had for drainage four three-quarter inch holes in the bottom. With fine soil such holes must be covered with pieces of crockery or glass to prevent sifting, but, with most peats, this precaution is unnecessary.

The cylinders for experiments with subsoils and varying water-tables were of galvanized iron coated, on the inside, with pitch tar. The tarring was effected very neatly and rapidly by heating a considerable quantity of tar in a large kettle, pouring a quart of so of the hot fluid into the cylinder and then revolving this as the tar was poured back into the kettle. A large number of cylinders were easily and quickly coated in this way in half an hour.

THE FILLING OF THE POTS WITH SOIL.

A description of the peat, its source, structure, etc. has already been given on pages 58 to 74.

In all cases the peat had been from the surface 8 inches so that it might be strictly comparable to that which would support crop plants in the field. In all cases the large bulk sample was shipped in gunny sacks. In order to reduce the freight charges the peat from Grand Rapids was stacked in a shed and partially dried before shipment. In all other cases, however, the sample was shipped in its natural field moisture condition. As each sample arrived at the laboratory it was worked up as soon as possible and transferred to the pots in the greenhouse.

SHREDDING THE PEAT

The method of shredding peat without a power machine has always been a problem, especially where the turf is tough and fibrous. In this case several methods were tried. First it was chopped and cut with a spade, but this was found unsatisfactory as it is very laborious, tedious and gives a product lacking in uniformity. Next I tried a board studded with 30 penny nails driven through from the back, much the same as an old-fashioned carding board for flax. This became clogged up frequently, and required care to avoid injury to the hands. Finally the principle of the grater was applied, trying different sizes and kinds of wire netting. The following method was adopted.

A very heavy grade of two-inch hexagonal mesh, chicken netting was stretched as tightly as possible over a frame 2 feet 6 inches by 4 feet made of 2 inch by 6 inch material the long way

Plate 13

Chicken netting (2 inch mesh) used for shredding peat for greenhouse pot experiments.

of the mesh, running in the same direction as the long way of the frame. The last detail was found absolutely essential as may be readily seen by referring to the small diagram Plate 13. The peat being worked back and fourth over the frame is caught in the narrow angle, torn away from the main mass and falls down through the opening as shown in Plate 13.

For touch and fibrous peats the two inch mesh is small enough whereas for a well decomposed or mucky peat a one-inch mesh is more satisfactory. With all kinds of peat it is best to have two frames with different sizes of mesh for the most efficient work.

The chief advantages of this equipment are:- it costs but a few cents for material, can be easily made by one man in two hours, is easily transportable, can be operated by one man, does not become clogged, works all the peat up into shreds instead of chunks, produces a uniform product, may be used with any kind of peat and is fully three times as rapid as any other hand method I tried. Three thousand pounds of very tough peat were worked up satisfactorily by one man in 8 hours, while two or three times this quantity of ordinary grass bog peat may be thus prepared in the same time. All peats are most easily worked up when wet.

FILLING BOXES AND FERTILIZING

After thoroughly mixing all of the peat to be used for one series of boxes a trial filling was made to ascertain the amount of peat required to fill a box. After this amount was determined the same weight of moist peat was placed in each box. While filling, four small samples were taken from each different kind of peat and moisture content determined later. Table 29 shows the required information concerning the peat used, giving the dry and moist weights of the peat used for each box from the different bogs.

Table 29

	Weight of moist soil in each box Pounds	Moisture Content Per cent*	Weight of dry soil in each box Pounds
Anoka	35	462	6.24
Belt Line	36½	398	7.34
Golf Links	32	408	6.30
Experimental Tract	33	474	5.75
Grand Rapids	24	252	6.82
High Timber	33½	442	6.18
Pennington	23½	228	7.14
University Farm+	56	18.8	47.14

*On dry basis

+A silt loam soil used as a check

The Experimental Tract, High Timber, and Belt Line peats were saturated, the Golf Links and Anoka, nearly so, while the Grand Rapids and Pennington peats and the University Farm silt loam were comparatively dry with the percent moistures just given in Table

To insure the presence of bacteria to induce the decomposition of the peat, fresh manure was applied in suspension at the rate of 3 tons per acre (1½ tons of horse manure and 1½ tons cow manure). This was then thoroughtly mixed with the surface inch or inch and a half of peat.

APPLICATION OF FERTILIZER AND LIME

All fertilizer was thoroughly mixed in the dry state with the surface 3 inches, except in the case of the sodium nitrate and potassium sulphate which were applied in solution.

Table 30 indicates the fertilizer and rate per acre. This system was employed with all of the pots planted to barley or grasses and with 12 of the boxes with potatoes on Experimental Tract peat. The Anoka peat was given only lime and lime and potassium. Sunflowers and potatoes, other than experimental tract, received no application other than the manure for purposes of inoculation. University Farm surface mineral soil, used as a check, received no application whatsoever.

All fertilizers, except the sodium nitrate, which was applied one-half at the time of planting and one-half 6 weeks later, were applied before planting.

Table 30 Fertilizers used.

Reference Symbol	Potassium Sulphate Per box Grams	Ground Limestone Per box Grams	Acid Phosphate Per box Grams	Sodium Nitrate Per box Grams
O	0	0	0	0
K	4.5	0	0	0
L	0	45	0	0
KL	4.5	45	0	0
KLP	4.5	45	4.5	0
KLPN	4.5	45	4.5	5.6

Applications at the rate indicated in Table 30 would be at the rate of 400 lbs. per acre for potassium sulphate and acid phosphate, 500 lbs. for sodium nitrate and 4000 lbs. for ground limestone. The analysis of the dealers were taken for potassium sulphate, acid phosphate and sodium nitrate, while the limestone was analyzed by the author.

FERTILIZER ANALYSIS

Potassium sulphate	=	49.07%	K_2O
Acid phosphate	=	16.00%	P_2O_5
Sodium nitrate	=	15.00%	Nitrogen
Ground limestone	=	20.17%	Insoluble
		58.38%	$CaCO_3$
		16.78%	$MgCO_3$
		4.67%	Impurities
		100%	Total

PLANTING OF SEEDS

Before planting, sufficient water was applied to each of the boxes to bring the peat up to the state of saturation. However, as the Pennington and Grand Rapids peats were comparatively dry, they may not have been completely saturated at the moisture content as computed and recorded in the following table.

Table 31 Saturation of soil before planting.

Source of soil	Wet weight of soil per box Pounds	Moisture content Per cent*
Anoka	35	461
Belt Line	40	445
Golf Links	34	440
Experimental Tract	34	491
Grand Rapids	38	457
High Timber	34	450
Pennington	34	376
University Farm	61	29.4

*On dry basis.

After the peat had been saturated and then allowed to stand for two days the potassium sulphate and half of the sodium nitrate were applied in solution. Then all the seeds and tubers were planted on the same day, December 11, 1915.

Table 32 gives the number of boxes and crops used for each kind of peat or soil. A set referred to means a series of boxes in duplicate, fertilized as indicated in Table 30.

Table 32 Crops planted and fertilizers

Source of Soil	Barley and Alsike No. boxes	Grasses No. boxes	Potatoes No.boxes	Sunflowers No. boxes
Anoka	0	6-0,1,KL	0	0
Belt Line	0	12 or set	2	2
Golf Links	12 or set	12 " "	2	2
Experimental Tract	12 " "	12 " "	12 or set	2
Grand Rapids	12 " "	12 " "	2	2
	2 calcium chloride			
	2 " acetate			
	2 " sulphate			
	2 " oxalate			
High Timber	12 or set	12 or set	2	2
Pennington	12 " "	12 " "	2	2
University Farm	2 checks	2 checks	2	2

Total of 188 boxes

The crops used were an early variety of barley, alsike, clover, medium red clover, red top, timothy, Early Ohio potatoes and large, single flowering, sunflowers.

In planting the potatoes a core 1.5 inch in diameter and 1.5 inch in length was used so that each plant would have the same food supply to start with. Three were planted in each box about 2 inches below the surface.

The sunflower seed was planted at the rate of ten seeds per box and later thinned to a single plant.

The barley was planted 1 inch deep and the gressed and clovers 0.5 inch. The former was planted in two rows with 10 seeds in a row, counting on a stand of 20 plants per box. Alsike clover was planted in the barley rows and later thinned to 30 to 50 plants per box.

In the grass boxes the seeds were planted in four rows, giving one row each to red clover, red top, timothy and alsike clover in the order named. These were later thinned to approximately 20 plants per box. (The exact number of each is given in the tables on pages

The planter used was one devised for the purpose by the author. Detailed measurements are of little value as the shape and size of the tool must vary with the box in which the planting is to be done. The prongs are made from 3/8 inch dowel pins, set in a handle, and long enough to project one inch, more or less, below the body, varying with the nature of the crop being planted. Another piece with holes shown in the plate may be placed between the plunger frame and the body to make shallower holes. The object of the body is to regulate the distance between the row planted and the side of the box and also to hold the soil in place while the plungers are being withdrawn. With the planter illustrated there are ten plungers, a little more than an inch apart, set to project 1 inch below the body and 3 inches from the side.

The advantages of the planter are that, in one operation, it punches 10 clean holes of uniform depth and distance apart and the same distance from the side of the box. It will work in any kind of peat (if the peat is wet) and any kind of mineral soil equally well and greatly increased the rapidity of the operation.

WATERING

Due to the large amount of lime in solution in the ordinary tap water it was necessary to use distilled water or rain-water.

About 200 gallons of rain-water were collected in small receptacles and used. After this only distilled water was used for four weeks, it being secured from the nutrition laboratory. Finding this laboratory could not supply the increasing demand, an old still for condensing high pressure steam directly from the power house was fitted up and the water tested out on small plants in beakers and also on a couple of check boxes with barley and clover, in order to ascertain whether or not it was toxic. No bad effects were observed. Accordingly, after the middle of February water from this source only was employed. With a two coil condenser 10 gallons of water per hour could easily be secured.

At weekly periods analyses of the water were made, determining the lime. Upon computation it was found that the total application of lime during the growing season would be so small that it would not be perceptible. However, weekly samples were taken and analyzed by the usual volumetric method after evaporating 5 liters down to 100 or 200 c.c.

Table 33 Lime in water.

Source of water	Calcium oxide Per cent
"Condensed steam"	.00015
Nutrition Labroatory distilled water	.00007
Rain-water	.00019
1/2 snow and 1/2 distilled water	.00024
Condensed steam	.000246
" "	.000316
" "	.000582
" "	.000120
" "	.000054
" "	.000036
" "	.000234
" "	.000040
Average per cent =	.000185

Assuming that 100 lbs. of water were added, during the season, to each box, this would mean an application of .000185 lbs. of lime (CaO) per box, or 8.06 lbs. per acre. This would be equivalent to an application of 14.4 lbs. of pure limestone , or 19.2 lbs. of the grade applied in the boxes, considering Magnesium Carbonate as of the same value as Calcium Carbonate. This would be equal to an application of less than one two-hundreth of the 4000 lbs. per acre applied to the limed boxes.

If the tap water with 0.01 per cent of lime (CaO) had been used instead of distilled water we would have had the equivalent of 1038 lbs. of limestone per acre, which would be an very appreciable quantity when we consider that it is in solution and would be deposited in a very finely divided condition. The beneficial effects of the tap water in correcting acidity has been brought out in a comparison between Grand Rapids acid peat watered with tap water and the same peat watered with distilled water

The aim in watering was to supply an abundance of water to all boxes without causing too much leaching and consequent loss of potash and nitrate, and also to reduce the labor as much as possible. We first used check boxes for experiment to find out the weight of the peat when saturated. The boxes were saturated, allowed to stand over night, and then weighed. Table 34 gives the result of the trial.

Table 34 Saturation for weight basis in watering

Source of soil	Dry soil per box pounds	Saturated Weight pounds	Moisture per cent	Weight used as basis for watering pounds	Moisture as basis for watering per cent
Anoka	33½	6.24	437	30	400
Belt Line	35½	7.34	370	33	350
Golf Links	35½	6.30	463	32	425
Experimental Tract	32½	5.75	472	29	400
Grand Rapids	36½	6.82	420	34	400
High Timber	32	6.18	410	29½	375
Pennington	35	7.14	394	34	375

After April 19th the watering was discontinued until harvest time in order to hasten the ripening.

The following table gives the total quantities of water added to each box for the different bogs and different methods of fertilization after the peat had all been saturated at the beginning of the experiment. Due to the different moisture contents of the peats at the time of harvest the total amounts were from probably 5 to 15 pounds more than the totals given.

The sunflower boxes were not weighed at any time during their growth and water was added as appeared to be needed. These amounts are not recorded in the table, but varied between 36 pounds for the Grand Rapids and 64 pounds for the University Farm soil.

Table 35 Water applied up to first harvest (April 29)

	Check Pounds	K Pounds	L Pounds	KL Pounds	KLP Pounds	KLPN Pounds
On Grass Crop.						
Anoka	41		41	40		
	39		43	40		
Golf Links	69	57	58	52	68	69
	56	59	52	49	68	68
Experimental Tract	51	63	54	46	52	60
	53	53	48	44	47	65
Grand Rapids	36	35	39	44	48	41
	32	33	48	42	51	50
High Timber	48	50	40	42	56	53
	43	45	39	46	48	52
Pennington	45	53	45	52	49	47
	45	52	53	45	69	66
University Farm	31					
	30					
On Barley Crop						
Belt Line	48	53	47	46	47	88
	46	49	47	47	47	85
Golf Links	47	50	49	49	59	126
	49	53	45	51	54	117
Experimental Tract	63	66	41	43	30	65
	48	58	39	29	29	60
Grand Rapids	13	16	44	71	84	95
	13	15	50	47	72	104
High Timber	49	47	45	34	26	54
	44	42	38	38	25	56
Pennington	63	67	50	59	42	69
	41	55	42	54	63	69
University Farm	30					
	30					

Table 36 (Continued)

	On Potatoes					
	Check Pounds	K Pounds	L Pounds	KL Pounds	KLP Pounds	KLPN Pounds
Experimental Tract	47 46	54 55	41 40	40 41	42 42	45 45
Belt Line	44 47					
Golf Links	54 54					
Grand Rapids	50 49					
High Timber	50 46					
Pennington	53 56					
University Farm	30 30					

SOIL TEMPERATURE CONDITIONS

Due to the construction of the greenhouse and to the method of heating as seen from the accompanying drawing, page 108 the variation in temperature in different parts was very great. Accordingly, after the growth was well started, it was decided to rearrange the boxes every two weeks, so that all the results obtained might be strictly comparable.

Also to ascertain what, if any, effect the nature of the peat had upon the temperature of the soil fifty readings were made January 1, 1916, three weeks after planting, before any watering had been done other than the initial saturation, and before any changes had been made in the box arrangements. Temperatures were recorded at a depth of two inches beneath the surface of the peat. From a comparison of the comparable results on different peats it will be seen that the variation between peats was not more than one degree in most cases and almost exactly the same in practically all.

The temperatures of boxes containing different peats, yet placed next to each other on the benches are grouped in twos in Table

Table 36 Temperatures of peats compared.

Source of peat		Temperatures Degrees F.
I	Grand Rapids	$70\frac{1}{4}$
	High Timber	$68\frac{3}{4}$
II	Pennington	66
	High Timber	$65\frac{1}{2}$
III	Pennington	64
	Experimental Tract	64
IV	Experimental Tract	$63\frac{1}{2}$
	Belt Line	$63\frac{1}{2}$
V	Belt Line	$60\frac{1}{4}$
	Golf Links	$59\frac{1}{2}$
VI	Golf Links	$62\frac{1}{4}$
	Grand Rapids	$62\frac{1}{4}$
VII	Grand Rapids	$63\frac{1}{4}$
	University Farm	$61\frac{3}{4}$
VIII	University Farm	$63\frac{1}{2}$
	Grand Rapids	$64\frac{1}{4}$
IX	Grand Rapids	65
	Anoka	65
X	Anoka	$65\frac{1}{2}$
	High Timber	66
XI	High Timber	$68\frac{1}{4}$
	Pennington	$68\frac{1}{4}$
XII	Experimental Tract-	$71\frac{1}{2}$
	Golf Links	71

These records were made on a cloudy day, January 1, 1916, with a steady sleet and rain, and an outside temperature of about 32° F. It may be that, with the same moisture content, on a sunny day the temperature might vary more, but later readings on the temperature indicate that the variation is very slightly, if at all, perceptible.

In order to have a check on temperature conditions in the greenhouse ten 2.5 liter acid bottles, three-fourths full of water, were enclosed in white paper jackets and placed between boxes at the points indicated by Arabic numerals on page 108.

The water was at the same level as the soil in the boxes and would give a more accurate indication of temperature conditions than the soil since the latter would be influenced more or less by changes of position, watering, vegetative growth, etc. Never-the-less temperature records of the soil next to most of the water bottles were kept for the sake of comparison.

The temperature of water and soil, although more or less constant, within a few hours, varies as much as 8 or 10 degrees within a day, this depending upon the sunshine and the amount of steam in the heating system.

For this reason temperatures read in the morning and evening were recorded separately to determine the effect of faulty distribution of heat, but are combined to show the average conditions as affected both by steam heat and by sunshine. In March, the difference in temperature between the morning and evening was four degrees, while in April, with more sun and less steam heat, the difference varied from five to ten degrees.

The differences between soil and water temperatures were erratic, but seldom exceeded three degrees, this probably depending largely upon moisture conditions, shade and exposure to the sun. For the sake of final comparison, the morning and evening records were averaged except for January and February, no morning records being taken during these months.

It will be observed from Table 37 that the highest temperatures, except with Bottles IV, V and VI on the east end, were recorded during January and February, the coldest months. This may be accounted for by the fact that, cutting off the steam in March and April, an increasing dependence was placed upon the heat from the sun, so that the greenhouse became cooled down several times a day. By reference to Table 37 it will be seen that the greatest variation in temperature occurred in January and February, while in April the variation was not more than four or five degrees, which shows the superiority of the sun to steam for the purpose.

Table 37 Morning temperatures of water

Date of reading	Bottle I	Bottle II	Bottle III	Bottle IV	Bottle V	Bottle VI	Bottle VII	Bottle VIII	Bottle IX	Bottle X
Mar. 2	72	62	56	55	48	55	58	64	62	58
" 3	74	63	56	54	49	57	58	62	62	59
" 4	76	66	58	57	52	60	59	65	65	62
" 6	82	71	62	63	56	65	65	70	70	65
" 8	79	68	61	61	55	62	63	67	67	64
" 9	85	74	66	66	62	68	68	74	72	70
" 11	85	72	64	64.	60	67	68	71	72	68
" 13	84	72	68	64	58	65	70	-	72	69
" 14	78	67	62	56	48	59	64	66	67	63
" 16	84	74	67	68	60	68	70	74	73	70
" 17	76	67	62	57	49	61	66	70	67	64
" 20	80	73	68	66	62	64	67	71	73	70
" 21	88	77	72	72	66	72	73	76	74	78
Average	79.5	69.7	64.6	61.8	55.8	64.7	65.3	69.2	69	66.
Apr. 19	70	67	64	63	61	63	66	68	66	66
" 20	74	68	64	63	58	64	65	66	64	65
" 21	76	67	62	64	61	62	63	64	64	64
" 24	66	56	53	57	58	61	56	58	57	65
" 25	62	55	53	55	56	55	56	56	57	56
" 26	74	67	64	65	60	64	63	67	64	65
" 27	78	68	65	68	64	67	67	67	66	72
" 28	76	68	66	69	68	69	69	69	68	75
Average	72	64.5	61.4	63	60.75	63.1	63.1	64.4	63.25	66

Table 38 Morning temperatures of soil next water bottles numbered below.*

Date of Reading	Bottle I	Bottle II	Bottle IV	Bottle V	Bottle VI	Bottle VIII	Bottle IX
March 2	70	60	54	49	55	62	65
" 3	70	60	54	52	56	62	66
" 4	70	62	54	52	57	62	66
" 6	76	66	60	56	61	67	71
" 8	74	64	60	56	60	66	70
" 9	78	69	63	62	64	70	74
" 11	76	68	62	60	63	68	72
" 13	80	71	64	63	64	74	74
" 14	76	68	58	54	58	72	73
" 16	77	73	65		72	76	80
" 17	72	68	58	55	60	71	73
" 20	78	71	64	61	64	72	74
" 21	82	74	68	66	70	75	77
Average	75.3	67.2	60.3	57.2	62	69	72
April 19	72	67	62	62	64	68	68
" 20	71	66	60	59	62	67	66
" 21	72	66	60	60	62	66	66
" 24	66	58	55	55	56	60	59
" 25	64	58	56	56	57	61	59
" 26	70	64	60	60	61	66	65
" 27	74	65	64	63	65	68	69
" 28	75	68	65	65	66	70	70
Average	70.5	64	59	60	61.6	65.8	65.3

*The locations of water bottles are indicated by their Roman numerals on Fig. The soil temperatures were taken from the peat close to the bottles. All temperatures in degrees farenheit.

Table 59 Evening temperatues of water

Date of reading	Bottle I	Bottle II	Bottle III	Bottle IV	Bottle V	Bottle VI	Bottle VII	Bottle VIII	Bottle IX	Bottle X
Jan. 27	88	72	67	68	59	68	70	75	73	-
" 28	82	71	66	62	51	64	68	72	72	-
Average	85	71.5	66.5	65	55	66	69	73.5	72.5	
Feb. 3	85	71	65	63	58	67	70	76	73	70
" 8	80	70	64	62	56.5	65	67	72	72	68
" 10	76	69	65	62	56	64	68	72	73	68
" 14	78	70	65	65	60	68	69	72	73	68
" 16	84	76	72	70	68	74	78	82	80	74
Average	80.6	71.2	66.4	64.4	59.7	67.6	70.4	74.8	74.2	69.6
Mar. 3	74	68	60	58	55	68	68	70	68	66
" 4	78	70	64	62	58	70	72	74	70	66
" 8	80	74	68	66	64	74	78	79	78	72
" 13	78	72	66	63	55	66	69	73	72	69
" 16	74	73	68	64	60	73	72	76	74	72
" 20	80	78	72	72	70	83	78	82	78	76
" 21	78	70	66	62	58	64	66	70	70	68
Average	77.4	72.1	66.3	64	60	71.1	71.9	74.9	73.1	69.9
Apr. 10	72	70	68	70	68	74	72	76	68	71
" 24	76	64	62	68	66	69	66	69	67	70
" 26	80	70	69	67	68	71	72	74	72	72
Average	76	68	66.3	68.3	67.3	71.3	70	73	68.9	71

Table 40 Evening temperatures of soil next water bottles numbered below.

Date of reading	Bottle I	Bottle II	Bottle IV	Bottle V	Bottle VI	Bottle VII	Bottle IX
Jan. 27	86	71	64	58	62	70	73
" 28	80	70	61	56	61	69	72
Average	83	70.5	62.5	57	61.5	69.5	72.5
Feb. 3	76	66	58	57	61	68	70
" 8	76	67	58	56	61	68	70
" 10	76	73	62	64	67	72	74
" 14	75	70	61	60	64	70	72
" 16	82	79	70	72	72	78	80
Average	77	71	61.8	61.8	65	71.2	73.2
March 3	72	68	58	60	63	70	72
" 4	78	70	60	60	64	68	73
" 8	78	72	64	65	69	76	78
" 13	76	71	64	61	64	74	77
" 16	78	71	62		64	72	75
" 20	81	75	70	68	76	78	80
" 21	79	72	64	62	66	74	75
Average	77.4	71.3	63.1	62.7	66.6	73.4	75.7
April 10	70	67	68	66	69	72	72
" 24	74	64	64	61	61	68	66
" 26	80	71	69	67	68	74	74
Average	78	67.3	67	64.7	66	71.3	70.7

Table 41 Averages of morning and evening water temperatures.

	Bottle I	Bottle II	Bottle III	Bottle IV	Bottle V	Bottle VI	Bottle VII	Bottle VIII	Bottle IX	Bottle X
Jan.*	85.0	71.5	66.5	65.0	55.0	66.0	69.0	73.5	72.5	
Feb.*	80.6	71.2	66.4	64.4	59.7	67.6	70.4	74.8	74.2	69.6
Mar.	77.1	70.9	65.5	62.9	57.9	67.9	73.6	72.1	71.1	68.1
Apr.	74.0	66.3	63.9	65.7	64.1	67.2	66.6	68.7	66.1	68.5
				Fluctuations from maximum of VIII						
Jan.	+11.5	-2.0	-7.0	-8.5	-18.5	-7.5	-4.3	0	-1.0	-
Feb.	+5.8	-3.6	-8.4	-10.4	-15.1	-6.6	-4.4	0	-.6	-5.2
Mar.	+5.0	-1.2	-6.6	-9.2	-14.2	-4.2	+1.5	0	-1.0	-4.0
Apr.	+5.3	-2.4	-4.8	-3.0	-4.6	-1.5	-2.1	0	-2.6	-.2

*Evening temperatures only.

Table 42 Summary of greenhouse temperatures
Greenhouse water and soil, morning and evening.

Month	Bottle I	Bottle II	Bottle III	Bottle IV	Bottle V	Bottle VI	Bottle VII	Bottle VIII	Bottle IX	Bottl X
Mar. Water	79.5	69.7	64.6	61.8	55.8	64.7	65.3	69.2	69.0	66.
" Soil	75.3	67.2		60.3	57.2	62.0		69.0	72.0	
Difference	-4.2	-2.5		-1.5	+1.4	- 2.7		-.2	+3.0	
Apr. Water	72.0	64.5	61.4	63.0	60.8	63.1	63.1	64.4	63.3	66 .
" Soil	70.5	64.0		59.0	60.0	61.6		65.8	65.3	
Difference	-2.5	-.5		-4.0	-.8	-1.5		+1.4	+2.0	

Table 43 Evening Temperature averages.

Month	Bottle I	Bottle II	Bottle III	Bottle IV	Bottle V	Bottle VI	Bottle VIII	Bottle VIII	Bottle IX	Bott l X
Jan. Water	85.0	71.5	66.5	65.0	55.0	66.0	69	73.5	72.5	-
" Soil	83.0	70.5		62.5	57.0	61.5		69.5	72.5	
Difference	-2.0	-1.0		-2.5	+2.0	-4.5		-4.0	-.0	
Feb. Water	80.6	71.2	66.4	64.4	59.7	67.6	70.4	74.8	74.2	69.
" Soil	77.0	71.0		61.8	61.8	65.0		71.2	73.2	
Difference	-3.6	-.2		-2.6	+2.1	-2.6		-3.6	-1.0	
Mar. Water	77.4	72.1	66.3	64.0	60.0	71.1	71.9	74.9	73.1	69.
" Soil	77.4	71.3		63.1	62.7	66.6		73.4	75.7	
Difference	0	-0.8		-.9	+2.7	-4.5		-1.5	+2.6	
Apr. Water	76.0	68.0	66.3	68.3	67.3	71.3	70.0	73.0	68.9	71.
" Soil	78.0	67.3		67.0	64.7	66.0		71.3	70.7	
Difference	+2.0	-.7		-1.3	-2.6	-5.3		-1.7	+1.8	

In order to overcome the difficulties of uneven heating the boxes were rearranged periodically. From December 11, 1915 to February 26, 1916 no change was made. On February 26, the boxes in the coldest places were changed to the warmest and all were rearranged. On March 11 and March 25 they were again changed. After this they remained without change until harvest, since the variation of temperature in April was so slight as to make it negligible. During all of this time the sunflowers remained in the center near the east end, while the potatoes were transferred to the west end near thermometer I on February 26 and there remained until harvest.

INJURY TO PLANTS FROM DISEASES, INSECTS, RODENTS, ETC.

In the process of filling the boxes preparatory to planting, the Pennington County peat, High Timber and Experimental Tract peats were prepared first, and stacked up in boxes and left that way for nearly a month. This seems to have predisposed these boxes of peats to fungous growth, as some of them had fungi growing on them at planting time. These three sets were the only ones on which fungous growths appeared to any extent during the season. Mention will be made in a later section of their effect on the plant growth.

Considerable difficulty was experienced with mice in the early crop growth, especially with the sunflowers, some of which had to be replanted twice, and part three times, which accounts largely for their uneven development.

Aphids early put in their appearance and called for attention. At first hydrocyanic acid gas was used. This killed the aphids but also injured the plants, unless the greatest care was exercised in the amounts used. The maximum amount which could be used without injuring the plants was 42 grams of potassium cyanide for the east and 30 grams for the west end. The plants received one quite severe injury when the barley plants were about 6 inches high, after which nico-fume was used. The most satisfactory amount was nine or ten sheets for the east and seven for the west end. All treatments had to be varied more or less with wind, temperature and humidity. The nico-fume did not appear to hurt any of the plants, but killed the aphids just as well as the hydrocyanic acid gas.

During the later growth of the plants, the red spider appeared but did but little damage.

With the potatoes blight and scab bothered some.

Covered smut of barley took a few heads, but not more than two per box were ever found, and most of the boxes had none at all. Rust affected many boxes to a slight degree, but probably not enough to influence the yield materially.

Probably none of the above difficulties, except the fungous growth on some of the grass boxes affected the growth very materially, so that, for the most part, results should be strictly comparable.

GREENHOUSE CROPS AND YIELDS.

In the following discussion reference will be made to plates and figures found at the end of the thesis and to tables accompanying this discussion. Tables, pictures and graphs of different stages of growth are given for the barley, while only the pictures, graphs and tables of final heights are presented for the grasses. (Tables 44 to 47, pages 153 to 186).

With the grasses the arrangement of crops in the pictures are from left to right - red clover, red top, timothy and alsike clover. In the graphs the grain yields of barley and in grasses the ratio of clover to total are indicated in black. Comparative yields for the different treatments are given in the successive columns. From left to right they are: 1 - Check; 2 - Potash; 3 - Lime; 4 - Lime and Potash; 5 - Lime, Potash and Phosphoric Acid; 6 - Lime, Potash, Phosphoric Acid and Nitrogen.

ANOKA GRASSES, PLATES 14 and 15

The Anoka grasses with only checks, lime, lime and potash boxes are not conclusive in their indication of requirements as the differences are so slight between the yields, but there seems to be a more or less depressing effect of lime, with an increased proportion of clovers to the total yield for those receiving lime. This might naturally be expected from an acid peat. With this peat the acidity was not strong enough to depress the yield of the check or to show any benefit from liming.

BELT LINE PEAT, PLATES 16 and 17.

Belt Line peat, it will be remembered, is exceedingly high in plant food requirements and, as may be seen from Fig. 1 of Plate 16 the effect of fertilizer is not very apparent, except for the complete fertilizer. The strong growth of clover on the boxes having potash fertilizer should be observed.

GOLF LINKS PEAT, Plates 18, 19 and 20

The striking results shown by this series are the benefit derived from a complete fertilizer on barley and the enormous growth of grasses on the complete and complete minus nitrogen pots. The failure of correlation between chemical analysis and crop yields is well shown on this series as it will be seen that the check compares favorably with the fertilized in the case of grasses and is not far behind in barley. The increased proportion of clovers to total yield in the grass series, due to application of lime, is exceedingly marked. The apparent depressing effect of phosphorus with the grasses is worthy of note.

EXPERIMENTAL TRACT, Plates 21, 22 and 23

In this series, as with the other Dibbell peat, there are strikingly depressing effects of lime both in barley and grasses with an extrodinary depressing in phosphoric acid on the barley. Potash alone in both crops has a very marked beneficial effect on clover. The complete fertilizer failed with the barley and was not as good as potash alone in the case of the grasses.

GRAND RAPIDS PEAT, Plates 24, 25 and 26

In this series on an intensely acid peat the most striking effect is shown in the beneficial effect of lime and the almost consistent advance of yield with successive additional fertilizers. The complete and complete minus nitrogen with barley showed well in straw, but fell off in grains, while the complete in grasses was by far the best. The greater adaptability of red top to an acid soil is also very strikingly illustrated.

HIGH TIMBER PEAT, Plates 27, 28 and 29

The same general observations made for the experimental tract hold for this series as well, the most prominent being the depressing effect of lime.

PENNINGTON PEAT, Plates 30, 31 and 32

Alternate boxes in the grass series were depressed as shown by the split columns in the graphs. Fungous growths were everywhere directly associated with this depression and were probably the cause. If any deductions may be made they are these - potash shows the greatest benefit of any one fertilizer; phosphoric acid favors clover growth and lime has a depressing effect even on the clovers. It will be remembered that this peat already has a very high lime content.

SUMMARY OF GREENHOUSE CROPS.

The yields in greenhouse tests, using only the first crop, appear to have little relation to the chemical composition, provided the lime content is sufficiently high to eliminate any marked degree of acidity. The peat soils lowest in lime and nitrogen show most strikingly the benefit from fertilizer treatment. With peat not distinctly acid an application of ground limestone appeared to exert a distinctly depressing effect. This was shown most strongly in the case of the series from Dibbell, both on barley and grasses. The best illustrations of the beneficial effect of limestone are found on the Grand Rapids peat and on the Golf Links grass series.

All through the experiment the addition of phosphoric acid appeared to exert a strong beneficial effect on the clovers, while the addition of nitrogen favored slightly the timothy and red top.

Potash alone, as might be expected, exerted the most beneficial effect proportionately, of all, where the peat was not excessively acid. Phosphoric acid, for some as yet unexplained reason, showed a peculiarly depressing effect upon practically all barley crops, but the crops receiving it were usually as good, or better than those receiving the complete fertilizer where clovers and grasses were used.

Table 44

Height of Barley at weekly intervals and height of Alsike Clover at time of harvest.

Box No.	Treat-ment	No. Plants 2/19	2/19 cm.	2/26 cm.	3/4 cm.	3/11 cm.	3/18 cm.	3/25 cm.	3/31 cm.	4/10 cm.	4/17 cm.	4/17 Alsike Clover cm.
						BELT LINE						
379	O	19	30	40	43	50	55	60	60	70	65	15
380	O	18	25	35	40	50	55	65	70	75	75	15
381*	K	15	30	45	50	60	70	70	75	80	78	25
382	K	18	38	45	53	60	70	75	80	80	80	23
383*	L	19	28	34	38	45	50	65	75	75	75	16
384	L	15	35	43	47	56	65	75	90	85	90	15
385	KL	11	30	35	40	56	63	70	90	95	85	25
386	KL	11	32	40	45	58	63	73	90	95	90	27
387	KLP	16	32	42	48	56	63	75	85	85	85	28
388	KLP	16	35	45	48	58	65	75	90	85	90	26
389	KLPN	20	40	52	65	78	90	105	110	110	105	20
390	KLPN	20	42	53	65	75	90	100	105	105	110	17
						GOLF LINKS						
403	O	20	36	47	57	67	80	90	90	90	90	5
404	O	20	38	47	57	67	80	90	90	95	90	5
405	K	20	33	49	60	67	75	90	100	110	100	10
406	K	20	34	51	60	73	83	95	100	110	100	6
407	L	20	36	46	55	67	70	75	85	90	85	11
408	L	20	35	47	50	67	70	75	85	90	95	12
490	KL	20	38	47	53	66	75	85	90	95	95	15
410	KL	20	39	50	58	70	82	88	95	98	95	12
411	KLP	20	41	55	60	70	80	100	95	98	100	25
412	KLP	20	41	52	64	75	85	100	95	105	100	20
413	KLPN	20	45	58	72	90	105	110	120	115	115	5
414	KLPN	20	47	60	72	90	105	110	120	115	115	5

* On Dec. 30. 8 barleys replanted on box 381 and 18 on 383.

Table 44 (continued)

Box No.	Treatment	No. Plants 2/19	2/19 cm.	2/26 cm.	3/4 cm.	3/11 cm.	3/18 cm.	3/25 cm.	3/31 cm.	4/10 cm.	4/17 cm.	4/17 Alsike Clover cm.
							EXPERIMENTAL TRACT					
341	O	20	38	44	55	58	70	76	80	85	85	12
342	O	20	42	48	58	65	73	76	75	75	75	10
343	K	20	40	50	60	70	83	90	95	90	85	13
344	K	20	44	53	60	65	75	82	90	90	85	16
345	L	20	30	40	40	47	60	70	73	74	73	8
346	L	20	30	40	45	51	60	70	73	73	71	8
347	KL	20	34	38	45	50	60	72	73	75	71	9
348	KL	20	28	33	40	45	50	55	60	63	65	12
349	KLP	20	25	30	37	40	45	55	60	68	70	23
350	KLP	20	18	23	30	35	38	45	50	56	60	23
351	KLPN	20	35	50	55	58	65	65	60	85	80	11
352	KLPN	20	33	47	53	58	60	65	50	80	80	13
							GRAND RAPIDS BOG					
201	O	20	13	18	15	15-30	15	10-40	10-30	10-50	10e 50	9
202	O	20	15	16	20	15-30	15	15-40	10-40	10-50	10-50	13
203	K	20	16	15	15	20-40	20	10-40	10-40	10-50	10-50	13
204	K	20	16	18	15	20-40	20	10-40	10-40	10-50	10-50	14
205	L	20	33	34	45	60	50	60	60	65	65	8
206	L	20	38	38	45	55	60	60	60	70	70	7
207	KL	20	34	43	50	62	65	73	75	80	80	6
208	KL	20	38	43	48	55	55	70	75	90	85	6
209	KLP	20	33	43	50	58	65	70	70	80	75	12
210	KLP	20	33	45	50	60	65	70	70	70	70	16
211	KLPN	20	35	45	52	60	60	60	65	65	75	13
212	KLPN	20	40	48	60	70	74	75	75	75	70	11
435	$CaSO_4$	2/26 7 alive		5	8	dead						
436	$CaSO_4$	6 "		7	8	"						
437	CaC_2O_4	7 "		34	45	55	70-60	75	95	90	90	17
438	CaC_2O_4	7 "		50	65	70	85	85	95	95	95	17

Table 41 (continued)

Box No.	Treat-ment	No. Plants 2/19	2/19 cm.	2/26 cm.	3/4 cm	3/11 cm.	3/18 cm.	3/25 cm.	3/31 cm.	4/10 cm.	4/17 cm.	4/17 Alsike Clover cm.
						HIGH TIMBER PEAT						
283	O	20	40	47	55	65	75	80	80	77	75	7
284	O	20	40	50	57	70	78	82	83	80	70	12
285	K	20	40	45	53	64	75	75	80	70	75	16
286	K	20	43	50	65	72	84	85	85	85	83	12
287	L	20	36	45	47	55	70	80	85	85	80	8
288	L	20	37	45	52	55	78	82	85	80	75	10
289	KL	13	33	38	43	50	67	80	80	80	70	17
290	KL	20	35	44	50	55	75	85	85	85	85	14
291	KLP	20	25	24	22	20	23	30	20	23	28	21
292	KLP	20	26	28	27	25	30	30	30	30	33	23
293	KLPN	20	36	44	52	63	70	80	85	80	85	13
294	KLPN	20	38	47	57	65	73	85	90	85	90	15
						PENNINGTON SERIES						
311	O	20	32	35	43	52	65	80	85	85	85	5
312	O	16	32	40	43	54	60	70	75	80	78	8
315	K	20	38	44	50	66	78	90	95	95	95	5
316	K	20	38	45	48	69	80	95	95	95	95	8
317	L	20	35	40	48	57	74	85	80	88	80	7
318	L	20	32	36	43	50	63	75	70	75	73	5
319	KL	20	42	45	53	64	75	80	90	90	90	8
313	KL	20	42	53	57	68	83	95	105	105	100	8
321	KLP	20	28	29	30	32	40	40	40	50	50	20
322	KLP	20	40	50	60	67	82	90	90	100	90	20
323	KLPN	20	38	48	55	64	80	90	95	102	95	12
324	KLPN	20	40	50	57	68	84	95	105	107	100	11
						UNIVERSITY FARM CHECKS						
		2/26						4/27	4/3			
395	O	18		43	44	57	65	75	80	80	80	18
396	O	16		45	54	60	75	75	80	80	82	18

Table 45 Barley Yields

Dry weights for greenhouse fertilizer experiment

Box No.	Treatment	Yields: Grain grams	Yields: Av. wt. kernels	Yields: Straw grams	Yields: Total grams	Average Yields: Grain grams	Average Yields: Av. wt. kernels	Average Yields: Straw grams	Average Yields: Total grams	Per acre bushels
			A - Belt Line Peat							
379	0	9.6	32.0	20.4	30.0	10.0	32.6	20.0	30.0	19.9
380	0	10.3	33.2	19.7	30.0					
381	K	9.2	40.4	24.8	34.0	10.4	38.6	27.1	37.5	20.8
382	K	11.6	36.7	29.4	41.0					
383	L	13.0	29.1	22.0	35.0	12.3	32.1	22.8	35.0	24.5
384	L	11.5	35.0	23.5	35.0					
385	KL	9.4	37.2	25.6	35.0	12.0	35.5	26.1	38.0	23.9
386	KL	14.5	33.7	26.5	41.0					
387	KLP	11.4	32.8	16.6	28.0	14.8	33.9	19.2	34.0	29.6
388	KLP	18.2	34.9	21.8	40.0					
389	KLPN	28.4	30.3	52.6	81.0	23.5	33.0	54.5	78.0	47.0
390	KLPN	18.6	35.6	56.4	75.0					
			B - Golf Links Peat							
403	0	7.3	26.6	26.7	34.0	8.8	27.5	27.3	36.0	17.5
404	0	10.2	29.4	27.8	38.0					
405	K	8.6	27.7	36.4	45.0	10.7	28.2	40.4	51.0	21.3
406	K	12.7	28.6	44.3	57.0					
407	L	9.9	29.6	30.1	40.0	11.1	31.1	29.9	41.0	22.3
408	L	12.4	32.5	29.6	42.0					
409	KL	8.9	24.5	37.1	46.0	10.6	27.2	36.4	47.0	21.2
410	KL	12.3	29.8	35.7	48.0					
411	KLP	16.3	28.7	37.7	54.0	15.8	29.1	37.7	53.5	31.6
412	KLP	15.3	29.4	37.7	53.0					
413	KLPN	30.8	29.8	84.2	115.0	25.9	29.8	89.2	115.0	51.8
414	KLPN	20.9	29.7	94.1	115.0					
			C - Experimental Tract Peat							
341	0	11.9	29.0	37.1	49.0	9.1	29.8	31.5	40.5	18.2
342	0	6.2	30.6	25.8	32.0					
343	K	16.6	27.8	45.4	62.0	14.5	29.6	42.6	57.0	29.0
344	K	12.3	31.3	39.7	52.0					
345	L	6.4	30.1	19.6	26.0	5.7	33.5	19.8	25.5	11.4
346	L	5.0	36.9	20.0	25.0					
347	KL	6.1	28.7	20.9	27.0	5.9	25.9	17.1	23.0	11.8
348	KL	5.7	23.0	13.3	19.0					
349	KLP	8.1	30.0	16.9	25.0	5.2	27.0	13.9	19.0	10.4
350	KLP	2.2	23.9	10.8	13.0					
351	KLPN	2.5	32.4	43.5	46.0	2.0	30.2	43.0	45.0	4.0
352	KLPN	1.5	27.9	42.5	44.0					

Table 45 (Continued)

Box No.	Treatment	Yields: Grain grams	Yields: Av. wt. kernels	Yields: Straw grams	Yields: Total grams	Average Yield: Grain grams	Average Yield: Av. wt. kernels	Average Yield: Straw grams	Average Yield: Total grams	Average Yield: Per acre bushels
				D - Grand Rapids Peat						
201	0	0.0	.0	4.0	4.0	0.0	0.0	4.5	4.5	0.0
202	0	0.0	.0	5.0	5.0					
203	K	0.03	30.0	2.97	3.0	0.65	27.5	2.44	2.5	1.3
204	K	0.10	25.0	1.9	2.0					
205	L	3.2	34.4	19.8	23.0	4.8	33.9	21.8	26.5	9.6
206	L	6.3	33.3	23.7	30.0					
207	KL	12.2	33.3	33.8	46.0	9.6	29.7	30.5	40.0	19.2
208	KL	6.9	26.0	27.1	34.0					
209	KLP	0.4	27.7	35.6	36.0	0.5	26.8	36.5	37.0	1.0
210	KLP	0.7	25.4	37.3	38.0					
211	KLPN	0.0	.0	48.0	48.0	0.0	.0	57.5	57.5	0.0
212	KLPN	0.0	.0	67.0	67.0					
				E - High Timber Peat						
283	0	10.4	30.1	33.6	44.0	10.9	29.5	29.5	44.0	21.8
284	0	11.5	28.8	32.5	44.0					
285	K	3.4	26.2	18.6	22.0	7.8	27.3	32.3	40.0	15.6
286	K	12.1	28.5	45.9	58.0					
287	L	11.0	32.1	29.0	40.0	9.5	31.3	26.0	35.5	19.0
288	L	8.0	30.5	23.0	31.0					
289	KL	5.9	31.5	22.1	28.0	8.0	29.3	26.5	34.5	16.0
290	KL	10.1	27.0	30.9	41.0					
291	KLP	0.1	25.0	4.9	5.0	.13	25.0	4.88	5.0	.26
292	KLP	0.15	25.0	4.85	5.0					
293	KLPN	.0		46.5	46.5	2.5	16.2	50.8	53.3	5.0
294	KLPN	5.0	32.3	55.0	60.0					
				F - Pennington County Peat						
311	0	8.7	33.0	36.3	45.0	10.0	32.7	25.2	35.0	20.0
312	0	11.2	32.4	13.8	25.0					
315	K	10.4	32.0	54.6	65.0	15.0	30.7	42.0	57.0	30.0
316	K	19.6	29.3	29.4	49.0					
317	L	16.4	31.3	23.6	40.0	14.4	28.5	18.1	32.5	28.8
318	L	12.4	25.7	12.6	25.0					
319	KL	7.8	24.3	45.2	53.0	9.6	29.0	42.4	52.0	19.2
313	KL	11.4	33.7	39.6	51.0					
312	KLP	2.9	27.1	8.1	11.0	12.3	32.1	23.8	36.0	24.6
322	KLP	21.6	37.1	39.4	61.0					
323	KLPN	16.8	35.5	43.2	62.0	17.7	36.8	51.8	70.5	35.4
324	KLPN	18.6	38.0	60.4	79.0					

Table 45 (Continued)

Box No.	Treatment	Yields: Grain grams	Av. wt. kernels	Straw grams	Total grams	Average Yield: Grain grams	Av. wt. kernels	Straw grams	Total grams	Per acre bushels
				G - University Farm Loam						
395	0	10.3	35.5	21.7	32	14.3	34.4	25.7	40	28.6
396	0	18.3	33.3	29.7	48					
				H - Calcium Oxalate on Grand Rapids Peat						
437	$Ca6_2O_4$	9.7	34.6	31.3	41	10.7	32.9	31.8	42.5	21.4
438	CaC_2O_4	11.7	31.2	32.3	44					

Table 46 Final height of grass and clovers sown without nurse crop
December 11, 1915.

Box No.	Treatment	Alsike clover: No. Plants Feb. 19	Alsike clover: Height Apr. 17 cm.	Red clover: No. Plants Feb. 19	Red clover: Height Apr. 17 cm.	Timothy: No. Plants Feb. 19	Timothy: Height Apr. 17 cm.	Red Top: No. Plants Feb. 19	Red Top: Height Apr. 17 cm.
				ANOKA PEATS					
277	O	18	22	20	22	14	36	11	30
278	O	18	21	20	19	18	36	14	30
279	L	13	23	20	18	19	34	20	20
280	L	16	21	19	16	13	32	18	16
281	KL	19	17	20	16	16	18	16	14
282	KL	12	23	17	19	16	20	17	20
				GOLF LINKS PEAT					
415	O	15	13	19	13	5	40	14	40
416	O	14	13	19	13	10	40	20	40
417	K	15	23	20	18	4	45	9	45
418	K	14	15	20	16	15	40	14	40
419	L	18	24	20	16	11	45	17	45
420	L	18	24	20	17	10	45	18	45
421	KL	15	26	20	17	2	45	5	45
422	KL	13	27	20	19	9	45	7	45
423	KLP	17	32	20	26	12	45	5	45
424	KLP	17	31	20	24	8	45	9	45
425	KLPN	14	35	20	28	11	45	12	45
426	KLPN	16	34	20	26	6	45	10	45
				EXPERIMENTAL TRACT PEAT					
353	O	13	14	18	14	16	25	18	20*
354	O	13	18	20	20	19	35	14	40
355	K	15	24	20	21	11	30	15	33
356	K	18	22	20	19	17	35	17	40
357	L	15	17	20	12	16	22	19	18
358	L	16	14	20	11	16	23	15	14
359	KL	15	11	20	12	20	12	13	13
360	KL	12	12	20	11	18	13	18	15
361	KLP	12	30	18	25	13	40	6	?
362	KLP	12	27	20	23	19	40	12	40
363	KLPN	14	23	20	22	20	35	20	35
364	KLPN	14	25	19	19	14	35	12	30

*Many mushrooms present throughout growing period.

Table 46 (Continued)

Box No.	Treatment	Alsike clover No. Plants Feb. 19	Alsike clover Height Apr. 17 cm.	Red clover No. Plants Feb. 19	Red clover Height Apr. 17 cm.	Timothy No. Plants Feb. 19	Timothy Height Apr. 17 cm.	Red Top No. Plants Feb. 19	Red Top Height Apr. 17 cm.
				GRAND RAPIDS PEAT					
213	O	6	2	17	5	10	45	15	45
214	O	13	3	20	3	15	30	13	30
215	K	13	12	16	6	9	40	15	40
216	K	16	5	20	Died out	1 ?	?	10	30
217	L	12	20	15	13	8	35	9	35
218	L	12	20	20	12	10	40	11	40
219	KL	8	17	19	15	12	30	16	30
220	KL	13	22	20	18	16	45	7 ?	45
221	KLP	13	20	18	17	11	45	15	45
222	KLP	12	25	20	19	18	50	12	50
223	KLPN	13	25	19	19	11	45	12	45
224	KLPN	14	25	20	15	13	48	11	48
				HIGH TIMBER PEAT					
295	O	16	18	17	18	19	35	18	35
296	O	12	20	18	18	18	35	11	40
297	K	12	23	20	21	13	45	14	40
298	K	13	24	20	18	11	40	12	35
399	L	14	14	19	16	19	23	17	25
300	L	13	12	20	14	16	20	14	18
301	KL	19	18	20	20	16	30	11	25
302	KL	14	21	19	19	19	25	16	33
303	KLP	15	20	17	26	15	40	13	40
304	KLP	13	25	17	25	17	45	8	40
305	KLPN	9	25	20	22	12	40	10	40
306	KLPN	10	20	20	20	14	45	12	40
				PENNINGTON COUNTY PEAT					
325	O	17	7	20	10	11	22	20	20
326	O	12	12	20	12	10	25	18	20
327	K	16	17	18	16	12	35	12	30
328	K	14	23	20	16	7	40	14	30
329	L	15	12	19	14	3	10	20	11*
330	L	13	17	20	16	12	35	13	30
331	KL	11	15	20	15	8	35	13	35
332	KL	11	12	19	15	16	20	15	30*
333	KLP	10	20	20	24	17	30	12	20
334	KLP	8	25	19	25	15	55	14	50
335	KLPN	9	16	20	21	9	20	13	20*
336	KLPN	9	21	20	23	5	45	18	50

*Many mushrooms throughout growing period.

Table 47 Yields of clover and grasses with different treatments expressed as oven-dry material.

Box No.	Treatment	Red Clover	Alsike Clover	Total Clover	Red Top	Timothy	Total Red top & Timothy	Averages: Clover Total Av.	Averages: Red top & Timothy	Averages: Total grasses	Yield per Acre
		gr.	gr.	gr.	gr.	gr.	gr.	gr.	gr.	gr.	Tons*
			A - Golf Links Peat								
415	O	9.5	5.4	14.9	33.8	5.6	39.4	11.2	38.7	49.9	2.4
416	O	3.9	3.5	7.4	31.4	6.5	37.9				
417	K	7.2	7.8	15.0	25.4	10.2	35.6	10.5	36.4	46.9	2.3
418	K	4.3	1.7	6.0	16.2	20.9	37.1				
419	L	10.0	8.2	18.2	8.5	4.2	12.7	17.2	13.7	30.9	1.5
420	L	8.2	7.9	16.1	8.8	5.8	14.6				
421	KL	14.7	11.8	26.5	1.5	0.0	1.5	24.5	3.8	28.3	1.4
422	KL	13.8	8.6	22.4	1.5	4.6	6.1				
423	KLP	31.2	32.4	63.6	0.0	5.9	5.9	59.6	6.3	65.9	3.2
424	KLP	29.5	26.0	55.5	4.4	2.3	6.7				
425	KLPN	26.0	31.1	57.1	3.1	5.2	8.3	56.3	8.8	64.6	3.1
426	KLPN	25.9	29.5	55.4	9.3	0.0	9.3				
			B - Anoka Peat								
277	O	10.2	5.1	15.3	0.9	5.8	6.7	14.0	7.4	22.4	1.1
278	O	8.6	4.0	12.6	0.9	7.2	8.1				
279	L	8.0	4.0	12.0	0.8	5.3	6.1	11.1	4.5	15.6	0.8
280	L	6.1	4.0	10.1	0.0	2.8	2.8				
281	KL	7.0	2.1	9.1	0.0	1.5	1.5	13.0	3.0	16.0	0.8
282	KL	11.5	5.3	16.8	0.5	3.9	4.4				
			C - Experimental Tract								
341	O	4.5	1.4	5.9	1.7	2.6	4.3	13.2	8.8	22.0	1.0
342	O	14.5	6.0	20.5	3.3	9.9	13.2				
343	L	14.4	10.1	24.5	9.7	6.7	16.4	16.4	16.7	39.0	1.9
344	L	14.4	5.6	20.0	9.8	7.2	17.0				
345	K	6.5	2.3	8.8	3.4	2.8	6.2	7.9	5.9	13.8	0.7
346	K	4.6	2.3	6.9	1.8	3.8	5.6				
347	LK	4.5	0.7	5.2	0.3	0.6	0.9	5.3	3.6	9.1	0.4
348	LK	3.8	1.6	5.4	3.4	3.2	6.6				
349	LKP	18.0	10.4	28.4	0.7	6.3	7.0	27.8	7.6	35.4	1.7
350	LKP	21.0	6.2	27.2	1.9	6.2	8.1				
351	KLPN	6.5	4.2	10.7	8.1	12.4	20.5	13.9	23.0	36.9	1.8
352	KLPN	12.7	4.4	17.1	11.6	12.8	24.4				

*For yields comparable to field conditions add one-fifth.

Box No.	Treatment	Red clover	Alsike clover	Total clover	Red top	Timothy	Total Red top & timothy	Clover Total Av.	Red top & timothy	Total grasses	Yield per Acre
		gr.	gr.	gr.	gr.	gr.	gr.	gr.	gr.	gr.	Tons *
			D - Grand Rapids Peat								
213	0	-	-	-	23.1	1.6	24.7	0	22.1	22.1	1.0
214	0	-	-	-	13.4	6.0	19.4				
215	K	-	.9	.9	30.4	2.9	33.3	.9	27.2	28.1	1.4
216	K	-	-	-	19.2	1.9	21.1				
217	L	3.9	-	3.9	16.7	8.9	26.5	10.5	24.1	34.1	1.6
218	L	3.7	3.4	7.1	11.4	11.2	22.6				
219	KL	6.2	1.8	8.0	20.9	7.2	28.1	9.1	23.0	32.1	1.5
220	KL	7.6	2.6	10.2	-	17.8	17.8				
221	LKP	4.7	6.2	10.9	15.2	16.4	31.6	14.4	30.1	44.5	2.1
222	LKP	11.1	6.7	17.8	11.4	17.2	28.6				
223	LKPN	22.7	6.1	28.8	22.7	9.6	32.3	24.9	31.3	56.2	2.7
224	LKPN	11.2	9.8	21.0	11.2	18.1	29.3				
			E - High Timber Peat								
283	0	6.2	2.4	8.6	5.6	17.1	22.7	7.8	22.4	30.2	1.4
284	0	3.4	3.6	7.0	2.5	19.6	22.1				
285	K	5.6	4.5	10.1	6.9	14.7	21.6	9.6	20.1	29.7	1.4
286	K	3.9	5.1	9.0	6.7	11.9	18.6				
287	L	6.9	1.4	8.3	2.2	1.9	4.1	5.8	3.6	9.4	0.4
288	L	2.8	0.4	3.2	1.2	1.8	3.0				
289	LK	8.0	2.4	10.4	3.8	7.2	11.0	10.0	11.5	21.5	1.0
290	LK	6.9	2.7	9.6	3.4	8.6	12.0				
291	LKP	18.8	8.1	26.9	4.2	7.4	11.6	26.3	9.3	35.6	1.7
292	LKP	14.9	10.7	25.6	1.6	5.4	7.0				
293	LKPN	12.1	8.5	20.6	9.8	9.7	19.5	17.8	24.0	41.8	2.0
294	LKPN	10.9	4.1	15.0	13.5	14.9	28.4				
			F - Pennington Peat								
325	0	1.5	0.0	1.5	0.7	1.7	2.4	4.6	3.9	8.5	0.4
326	0	6.1	1.6	7.7	1.7	3.6	5.3				
327	K	6.4	1.8	8.2	3.2	6.4	9.6	13.5	12.8	26.3	1.3
328	K	15.4	3.6	18.8	10.2	5.7	15.9				
329	L	3.4	1.8	5.2	1.1	0.0	1.1	7.1	6.1	13.2	0.6
330	L	7.3	1.7	9.0	2.7	8.3	11.0				
331	LK	8.8	1.8	10.6	2.2	8.0	10.2	9.3	8.9	18.2	0.9
332	LK	6.8	1.2	8.0	3.2	4.3	7.5				
333	LKP	21.2	6.6	27.8	0.0	0.9	0.9	33.5	7.6	41.1	2.0
334	LKP	31.7	7.5	39.2	2.5	11.8	14.3				
335	LKPN	13.7	1.6	15.3	0.7	1.0	1.7	27.3	10.5	37.3	1.8
336	LKPN	25.4	13.9	39.3	19.4	0.0	19.4				
			G - University Farm Mineral Soil								
397	0	27.6	14.0	41.6	1.2	5.0	6.2	35.6	8.2	43.8	2.1
398	0	20.9	8.7	29.6	4.2	5.9	10.1				

* For yields comparable to field conditions add one-fifth

Plate 14

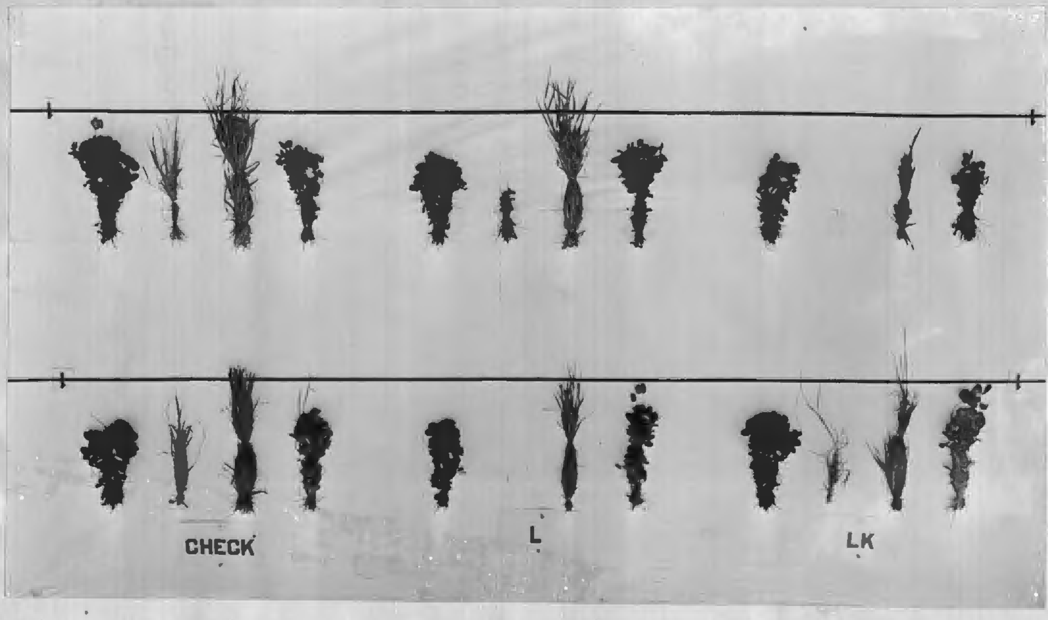


Plate 14

Anoka clovers and grasses harvested separately. From left to right, red clover, red top, timothy, alsike clover.

Plate 15

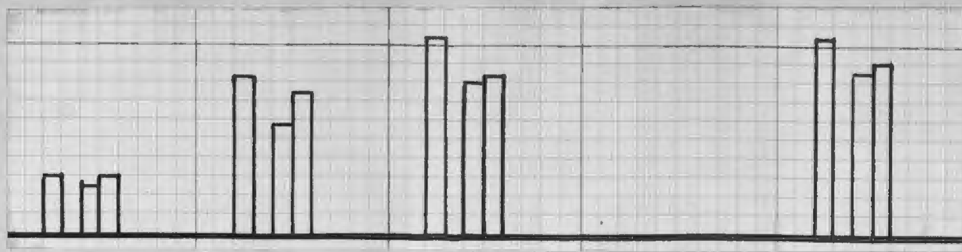


Fig. 1

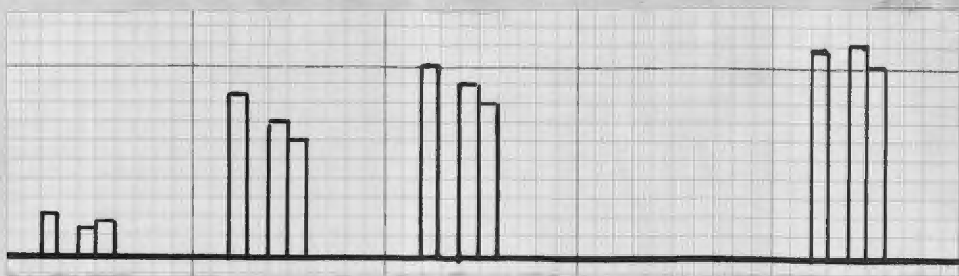


Fig. 2

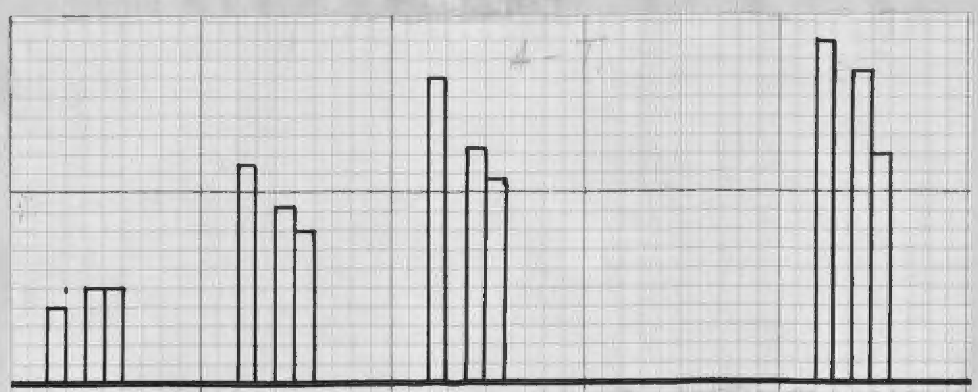


Fig. 3

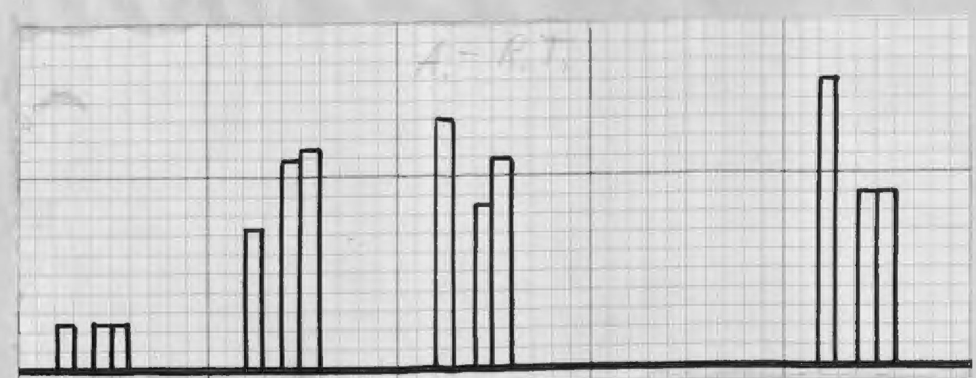


Fig. 4

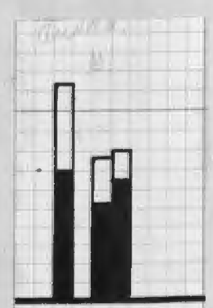


Fig. 5

Plate 15 Anoka Grasses and Clovers

Figure 1 - Showing relative growths of red clover.

Figure 2 - Showing relative growths of alsike clover.

Figure 3 - Showing relative growths of timothy.

Figure 4 - Showing relative growths of red top at bi-weekly intervals for Check, Lime and Potash, and Potash.

Figure 5 - Relative yields. Black indicates relative weights of clovers.

Plate 16

Fig. 1.

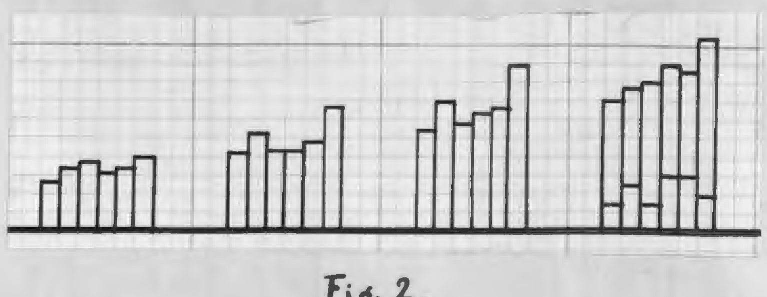


Fig. 2.

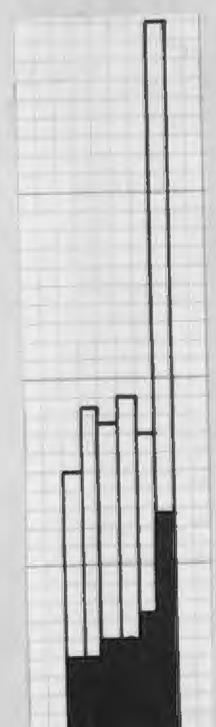


Fig. 3.

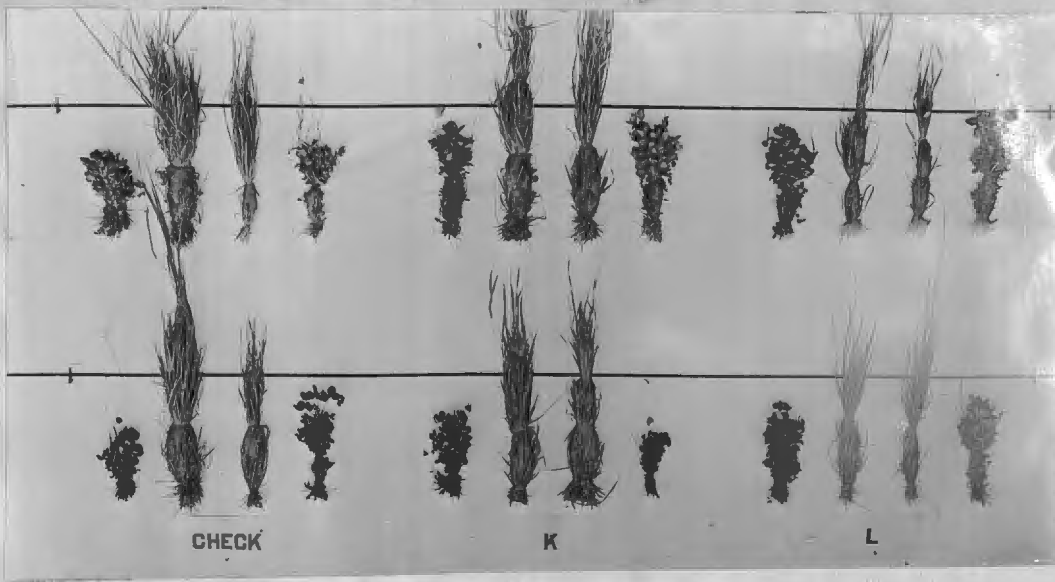
Plate 16 Belt Line Barley

Figure 1 - Pot Experiments

Figure 2 - Relative heights of barley at bi-weekly intervals.

Figure 3 - Relative total yields. Black indicates comparative weight of grain.

Plate 17



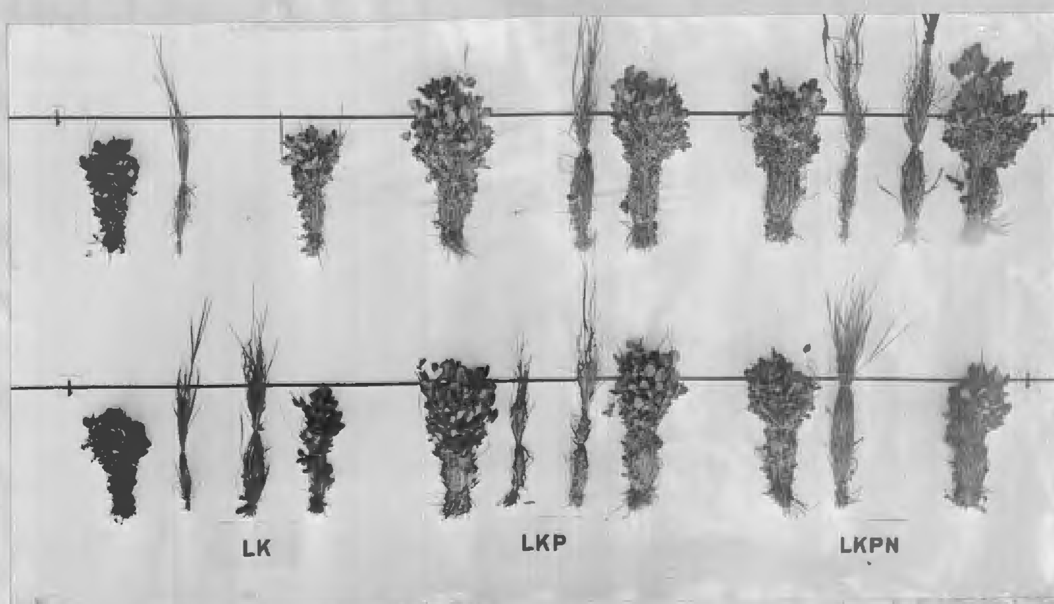


Plate 1[illegible]7 Golf Links Grasses and Clovers.

Crops harvested from pot experiments. Crops in order from left to right are red clover, red top, timothy, and alsike clover.

Plate 18


CHECK
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CHECK
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406
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407
L
408


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LKP
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CHECK
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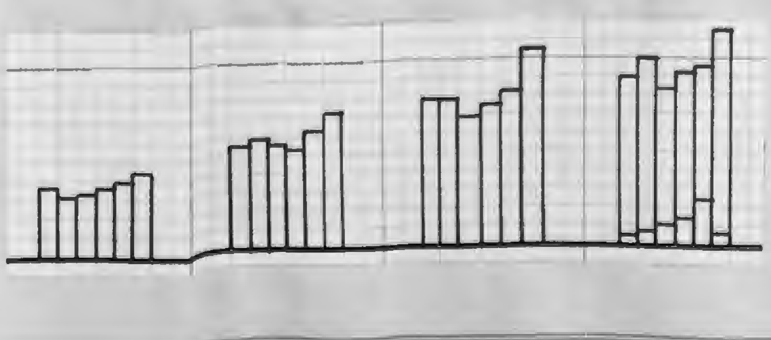


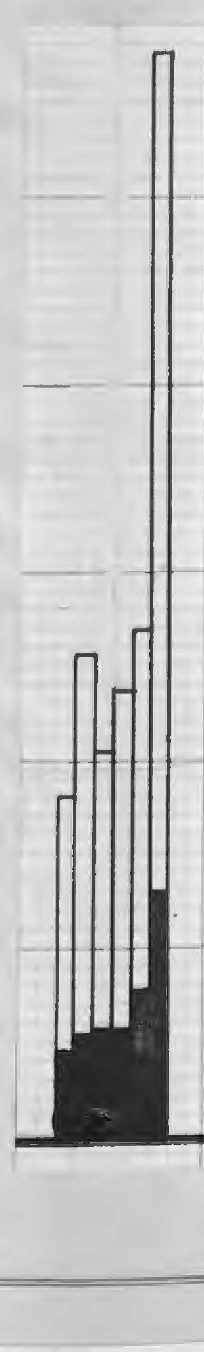


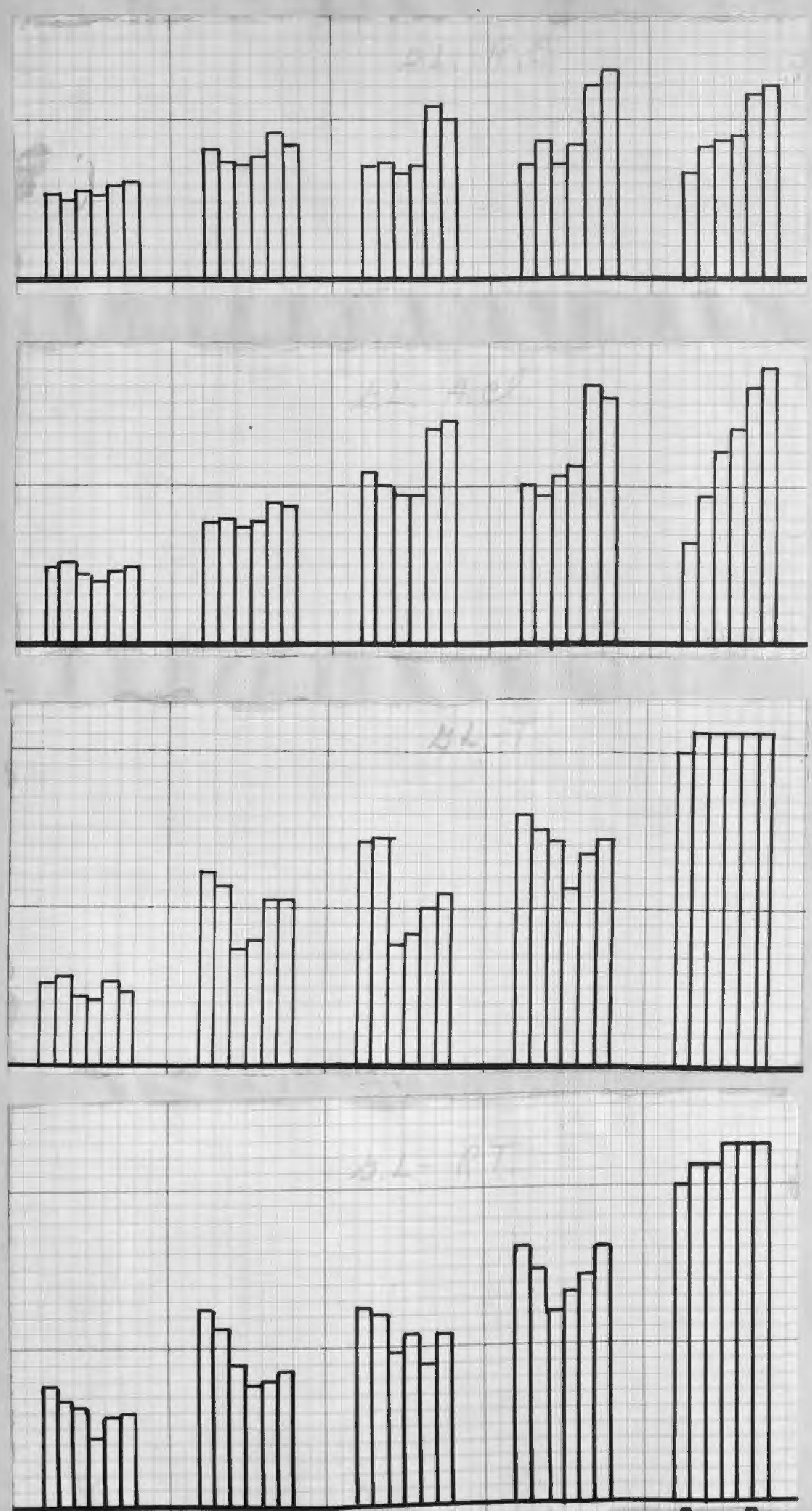
Plate 18 Golf Links Barley

Figure 1 - Pot Experiments.

Figure 2 - Barley from pot experiments harvested.

Figure 3 - Comparative heights at bi-weekly intervals.

Figure 4 - Comparative yields. Black indicates comparative weight of grain.



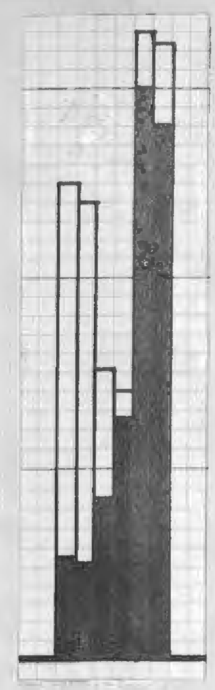


Plate 19

Plate 19 - Golf Links Grasses and Clovers.

Figure 1 - Relative growths of red clover at bi-weekly intervals.

Figure 2 - Relative growths of alsike clover at bi-weekly intervals.

Figure 3 - Relative growths of timothy at bi-weekly intervals.

Figure 4 - Relative growths of red top at bi-weekly intervals.

Figure 5 - Total yields. Black indicates relative weights of both clovers to the total.

Plate 20


CHECK
341
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LKPN
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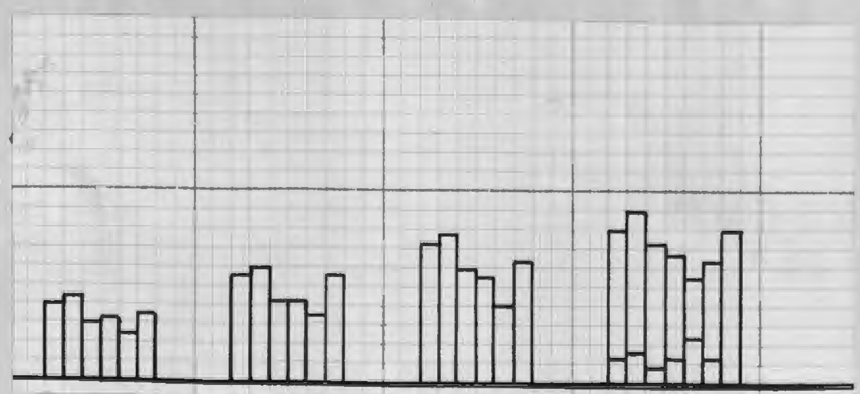
LKPN
352



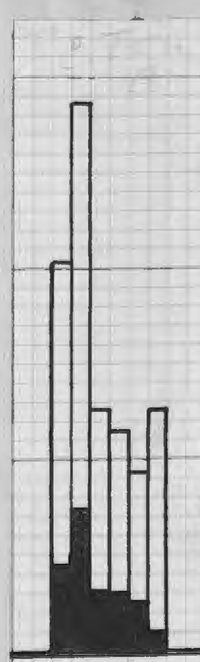


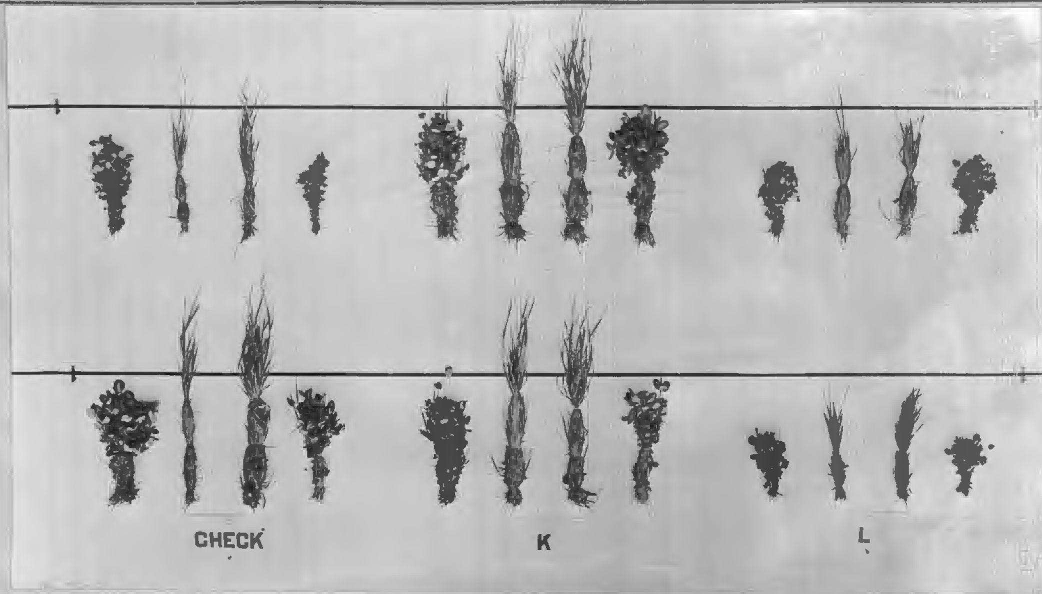
Plate 20 Experimental Tract Barley

Figure 1 - Pot Experiments.

Figure 2 - Comparative heights at bi-weekly intervals.

Figure 3 - Comparative yields. Black indicates yield of clovers to total.

Plate 21



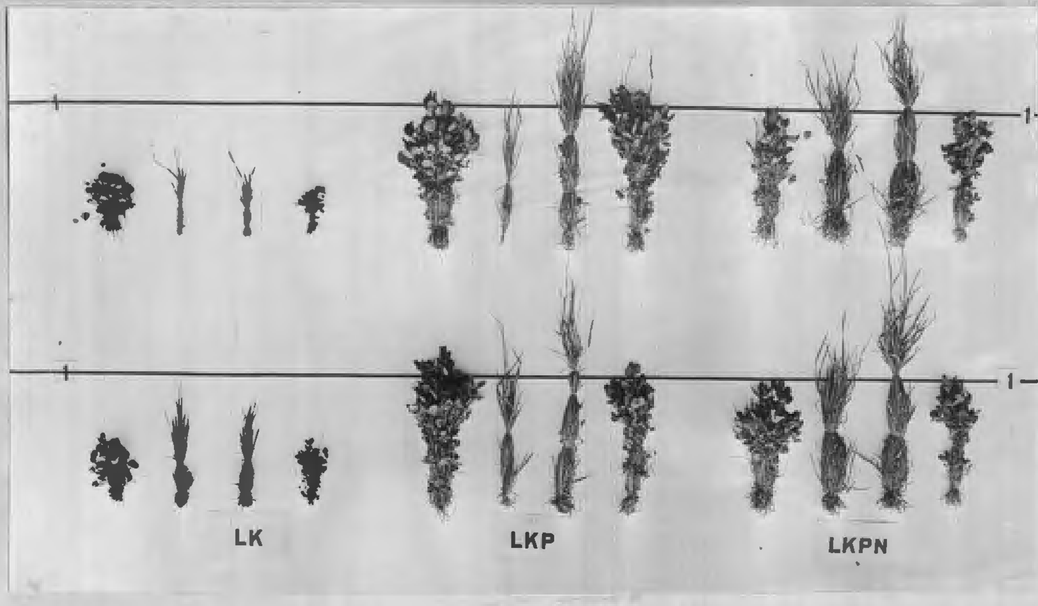
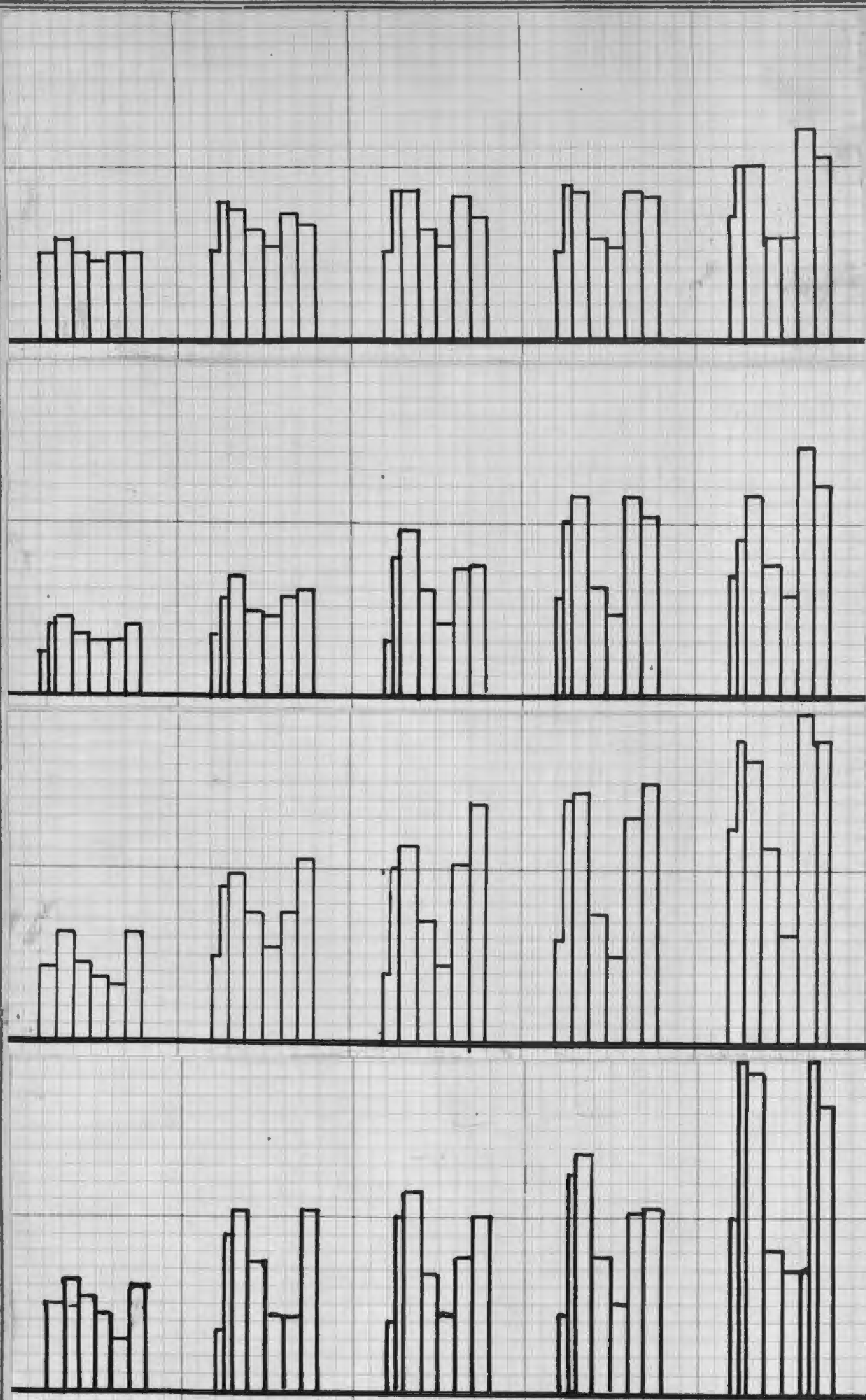


Plate 21 Experimental Tract grasses and clovers.

Crops harvested from grass and clover pot experiments. Crops are from left to right - red clover, red top, timothy and alsike clover.

late 22



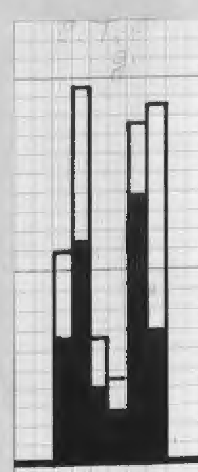


Plate 22 Experimental Tract Grasses and Clovers.

Figure 1 - Comparative heights of red clover at bi-weekly intervals.

Figure 2 - Comparative heights of alsike clover at bi-weekly intervals.

Figure 3 - Comparative heights of timothy at bi-weekly intervals.

Figure 4 - Comparative heights of red top at bi-weekly intervals.

Figure 5 - Comparative yields. Black indicates relative yields of clovers to total.

Plate 23

Fig. 1

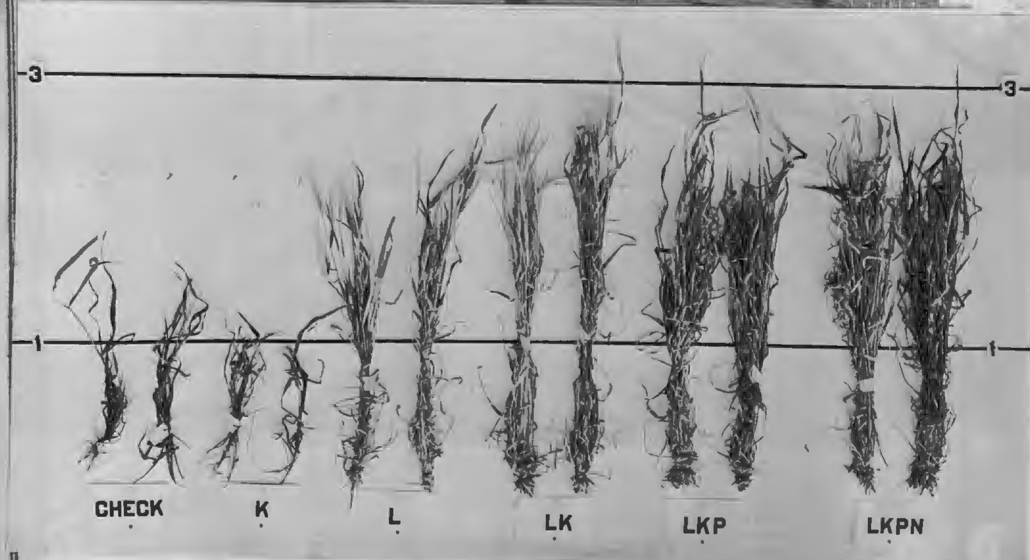


Fig. 2

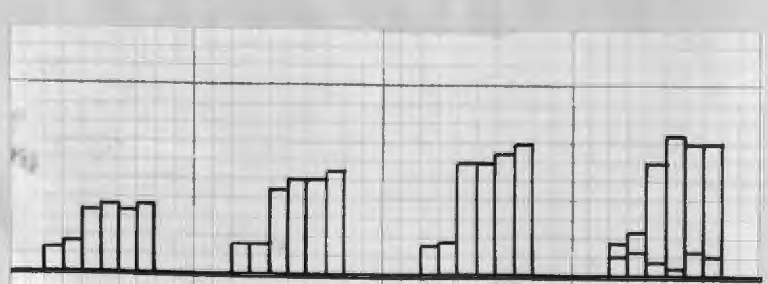


Fig. 3

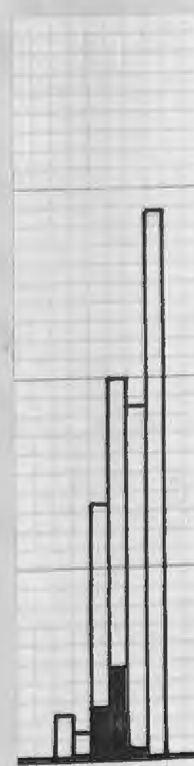


Fig. 4

Plate 23 Grand Rapids Barley.

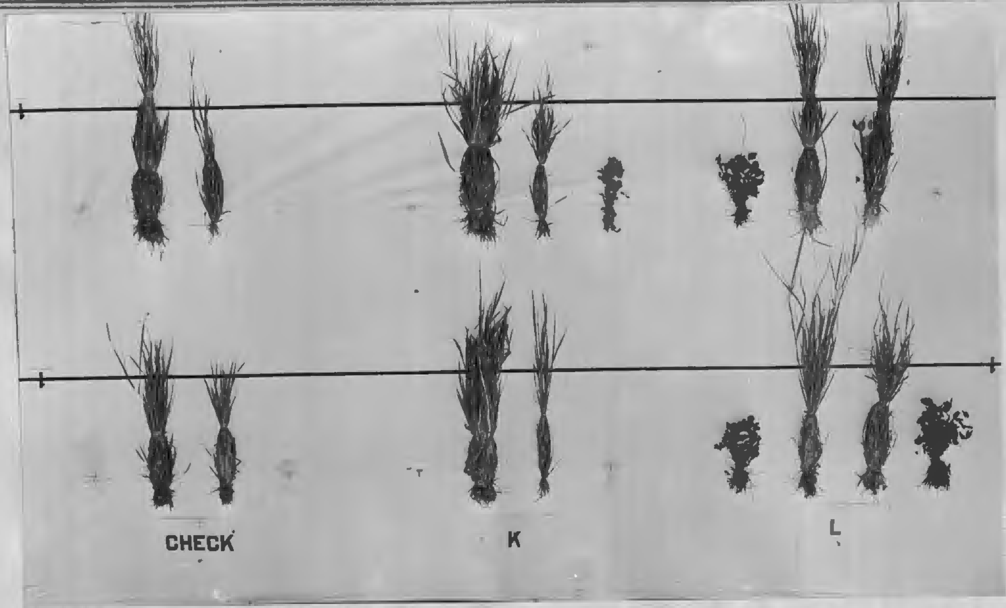
Fig. 1 - Pot experiments.

Fig. 2 - Crops harvested from pot experiments.

Fig. 3 - Comparative heights at bi-weekly intervals.

Fig. 4 - Comparative yields of barley. Black indicates comparative grain yields.

Plate 24



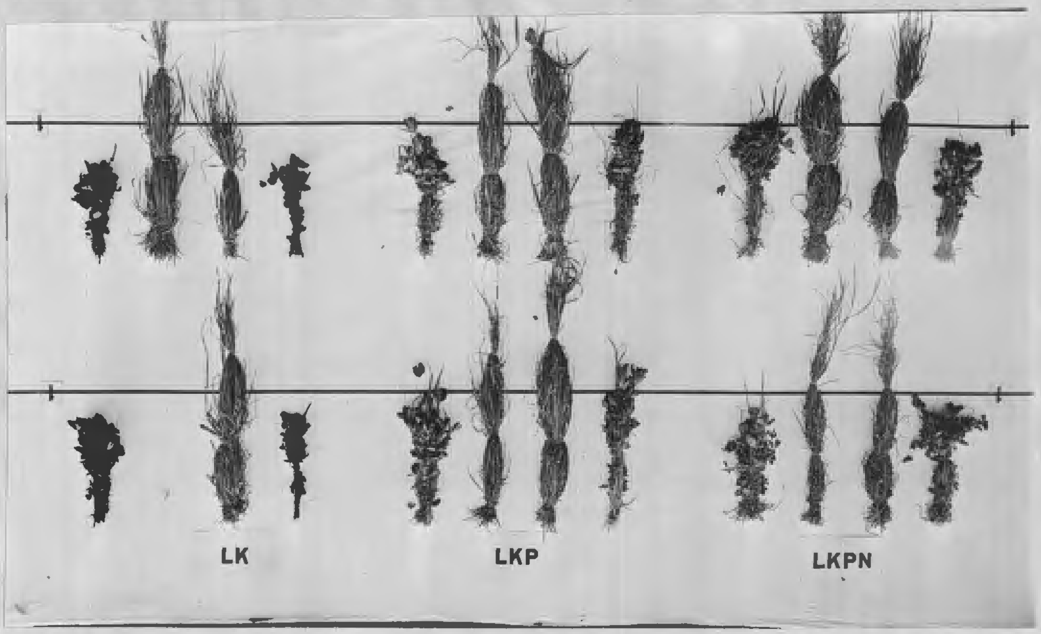


Plate 24 Grand Rapids Grasses

Crops harvested from fertilizer experiments. Crops in order, left to right, are red clover, red top, timothy and alsike clover.

Plate 26

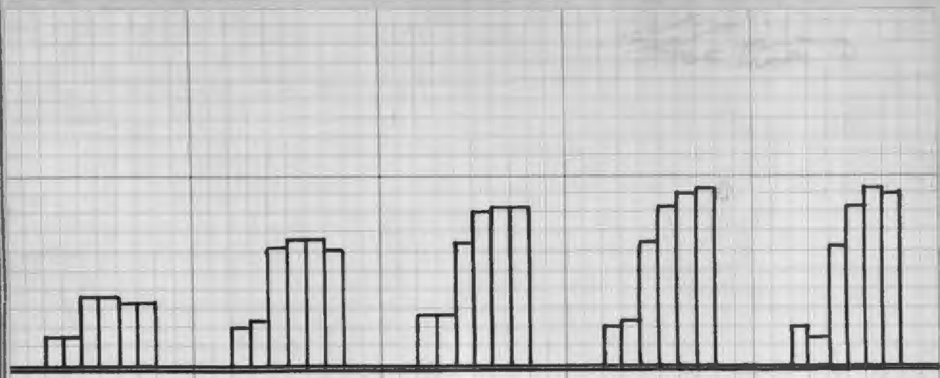


Fig. 1

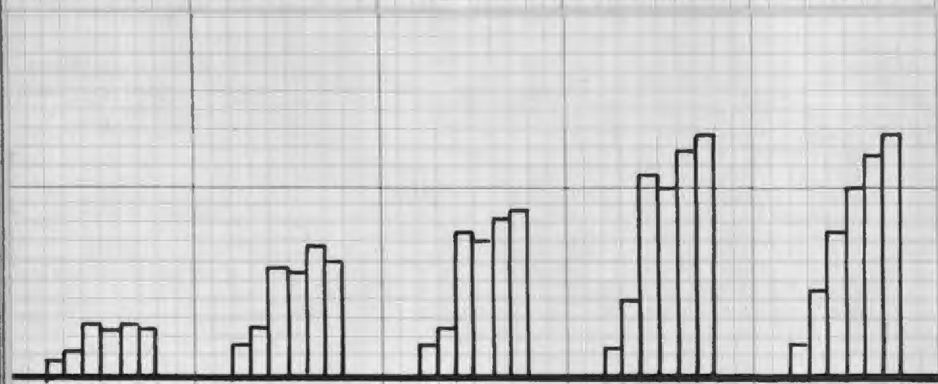


Fig. 2

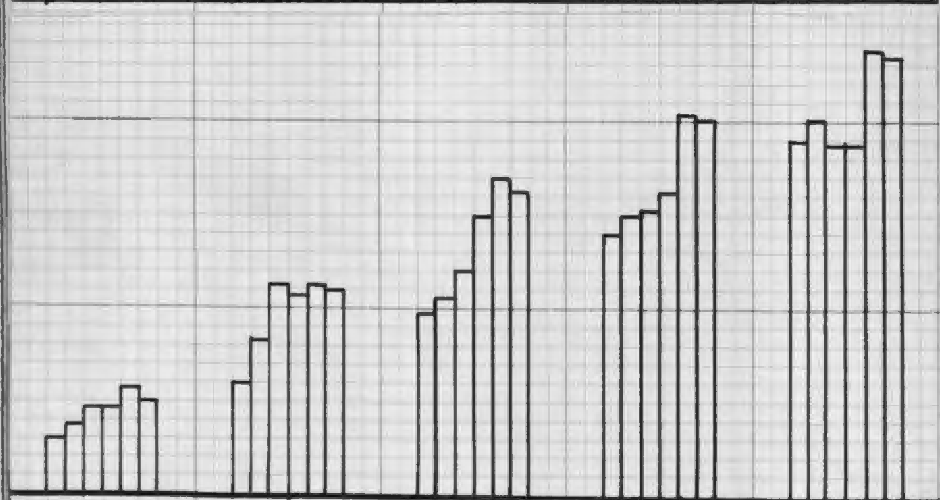


Fig. 3

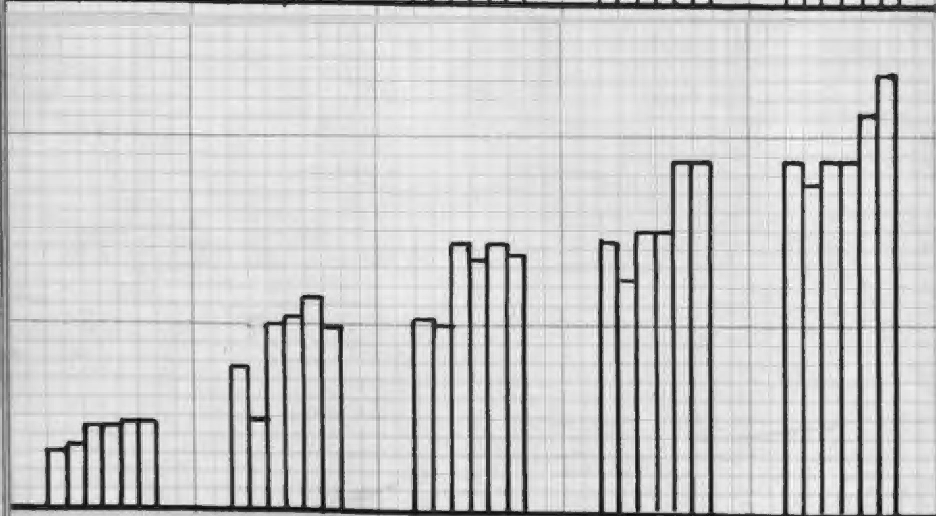


Fig. 4

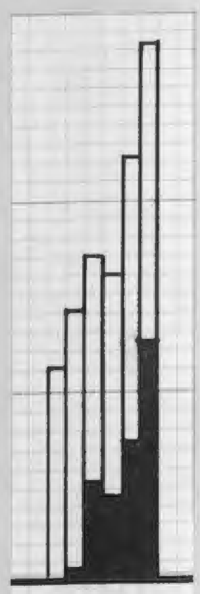


Fig. 5

Plate 25 Grand Rapids Grasses and Clovers.

Figure 1 - Comparative heights of red clover at bi-weekly intervals.

Figure 2 - Comparative heights of alsike clover at bi-weekly intervals.

Figure 3 - Comparative height of timothy at bi-weekly intervals.

Figure 4 - Comparative height of red top at bi-weekly intervals.

Figure 5 - Comparative yields of grasses and clovers. Clovers are indicated by black.

Plate 26

Fig. 1

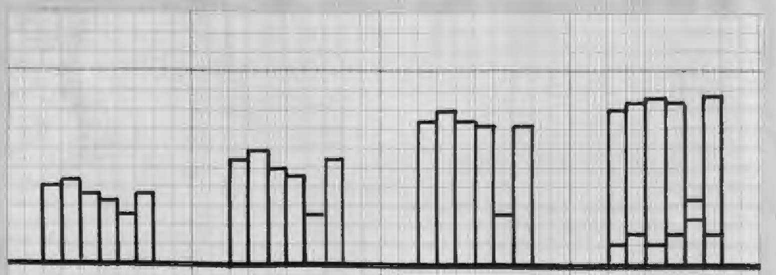


Fig. 2

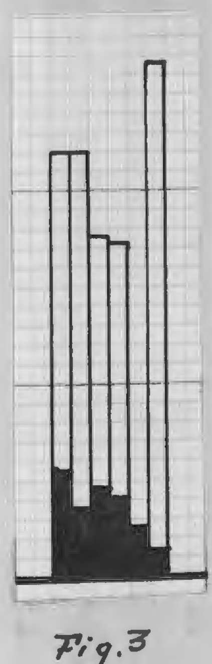


Fig. 3

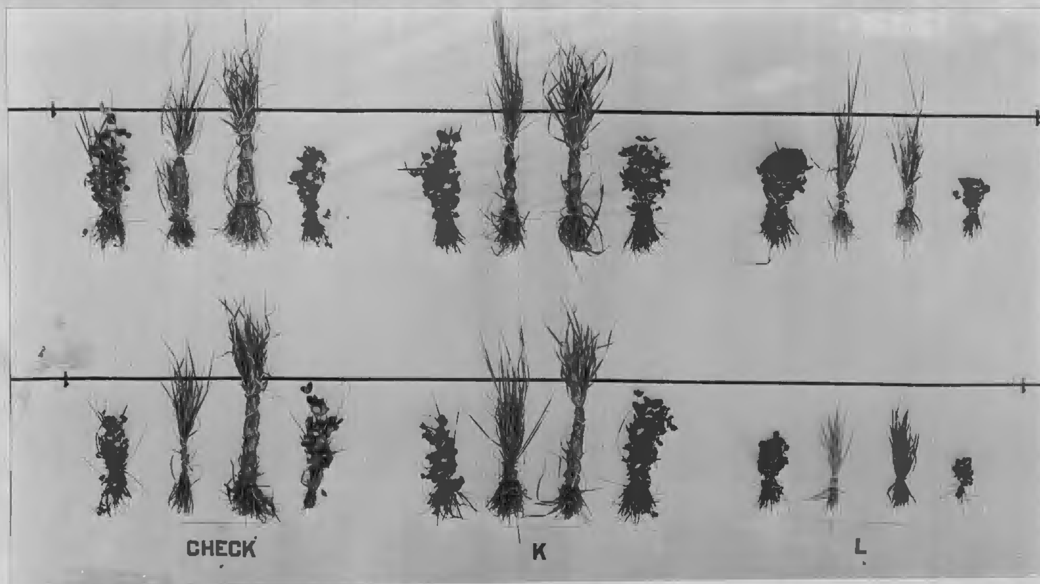
Plate 26 High Timber Barley.

Figure 1 - Pot Experiments.

Figure 2 - Comparative heights at bi-weekly intervals. Clover heights represented in last graph only.

Figure 3 - Comparative yields. Weight of grain expressed in black.

Plate 27



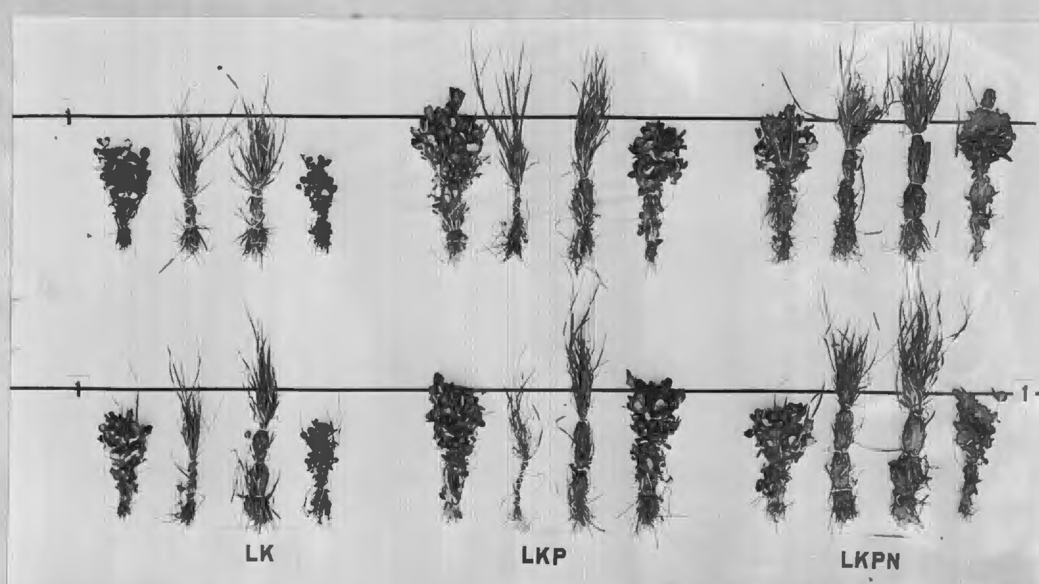


Plate 27 High Timber Grass

Crops from fertilizer pot experiments. Order of plants is as follows - red clover, red top, timothy and alsike clover.

Plate 28

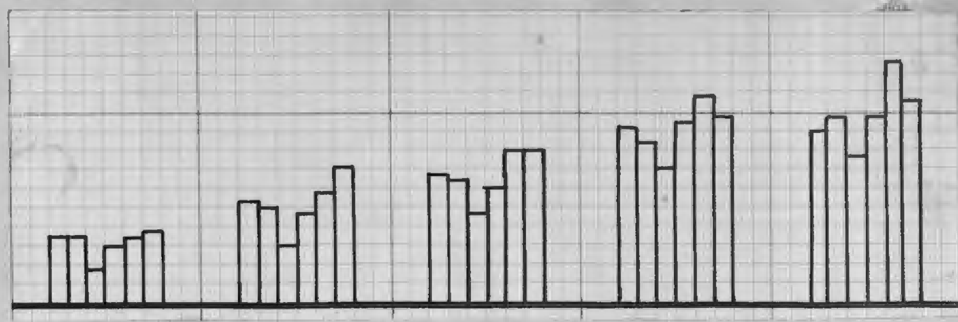


Fig. 1

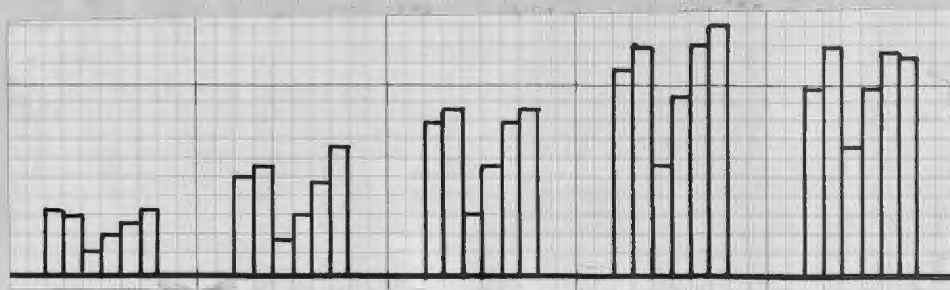


Fig. 2

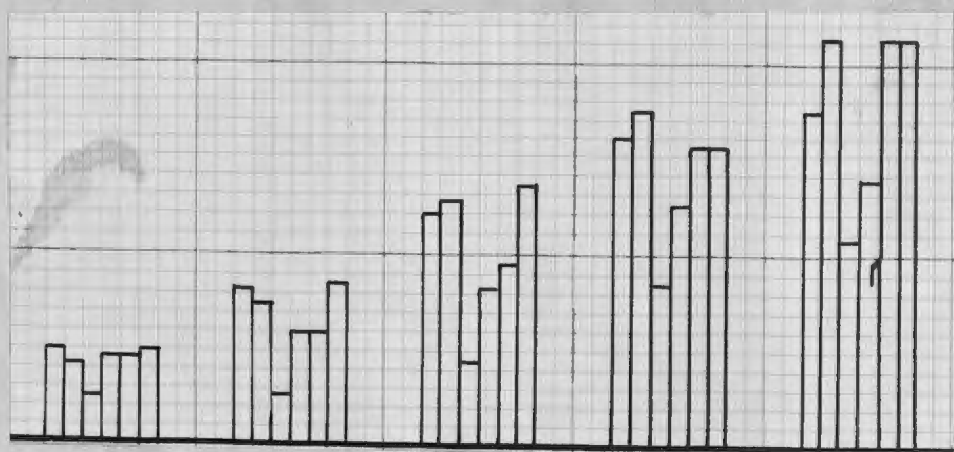


Fig. 3

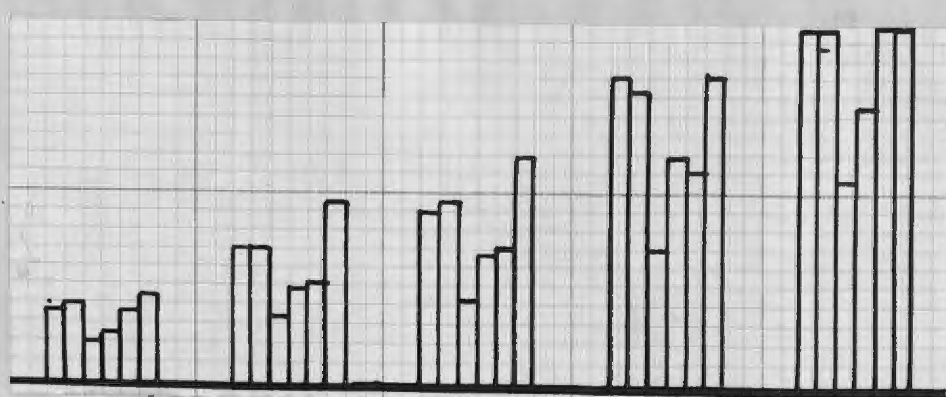


Fig. 4

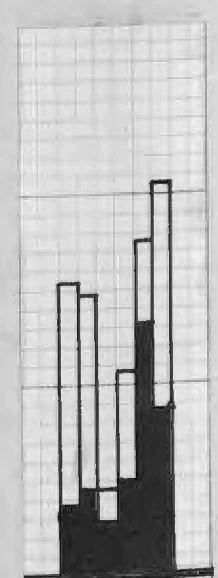


Fig. 5

Plate 28 High Timber Grass and Clovers.

Figure 1 - Comparative heights of red clover at bi-weekly intervals.

Figure 2 - Comparative heights of alsike clover at bi-weekly intervals.

Figure 3 - Comparative heights of timothy at bi-weekly intervals.

Figure 4 - Comparative heights of red top at bi-weekly intervals.

Figure 5 - Comparative yields of grasses and clovers combined. Black indicates clovers.

Plate 29.

Fig. 1

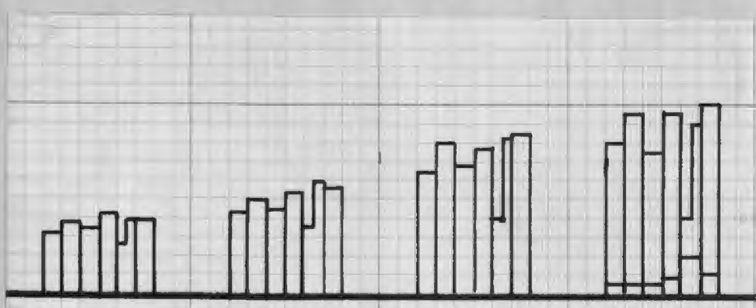


Fig. 2

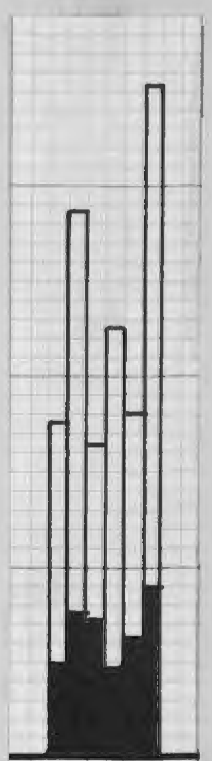


Fig. 3

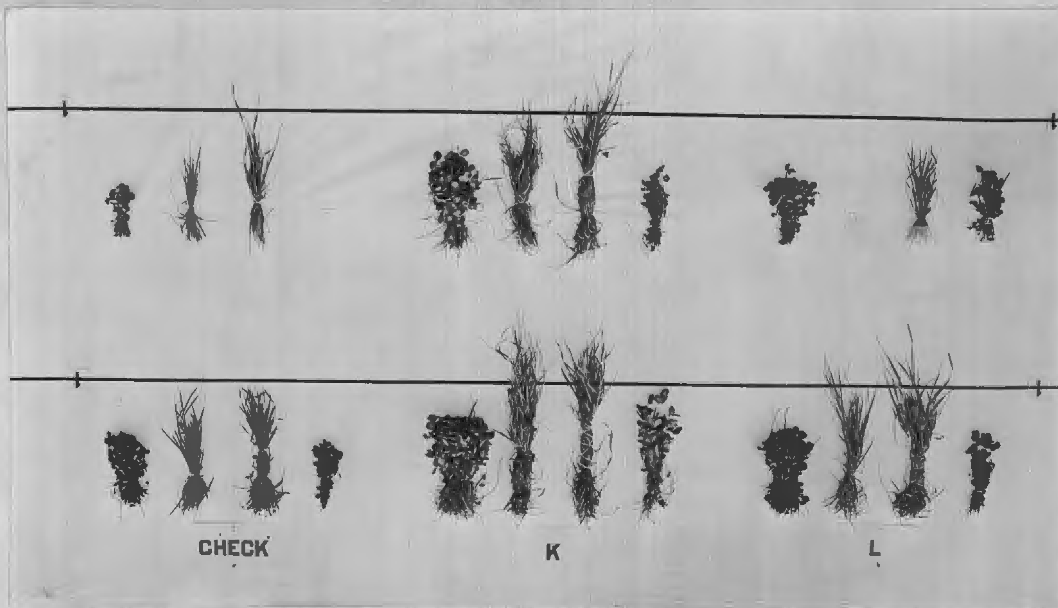
Plate 29 Pennington Barley

Figure 1 - Pot experiments.

Figure 2 - Comparative growths at bi-weekly intervals.

Figure 3 - Comparative yields. Black indicates the yield of grain.

Plate 50



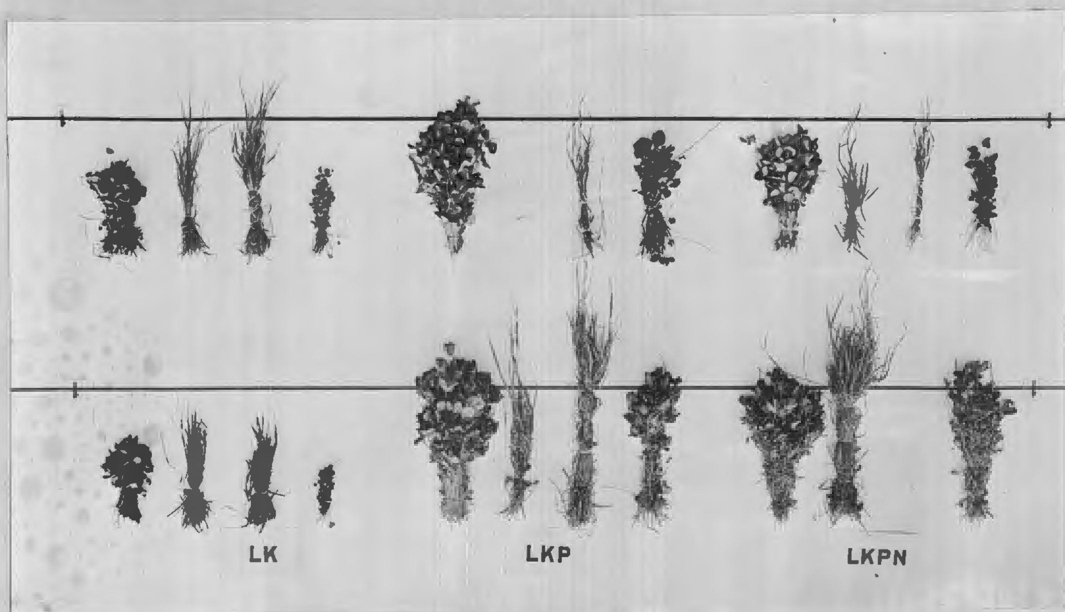


Plate 30 Pennington Peat Grasses and Clover

Crops harvested from fertilizer pot experiments. Order of crop from left to right is red clover, red top, timothy and alsike clover.

Plate 51

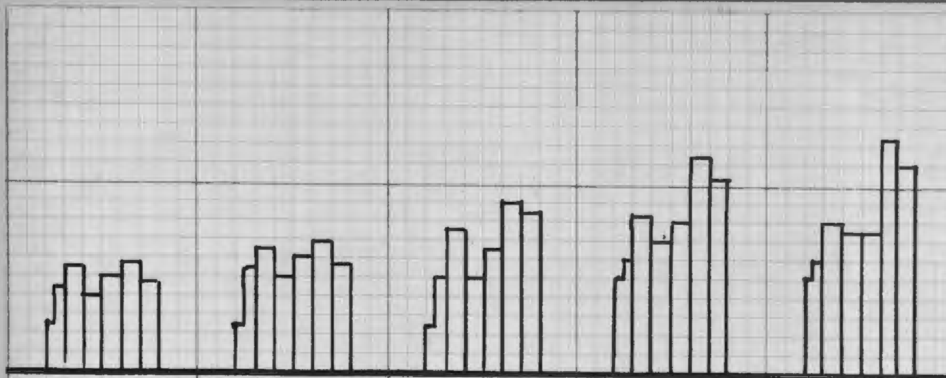


Fig. 1

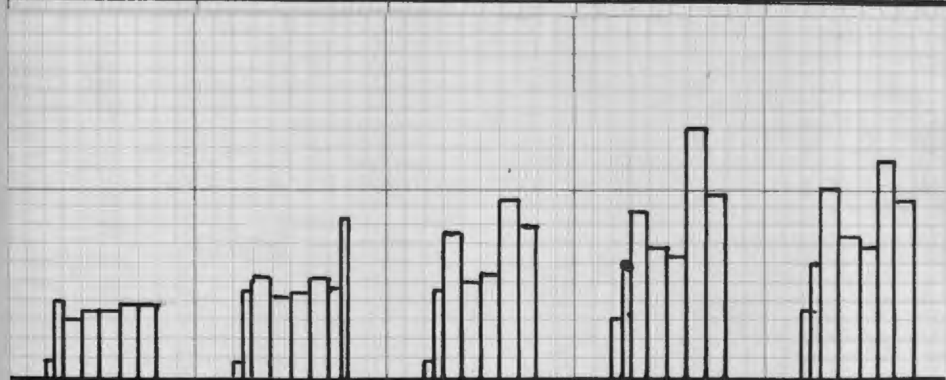


Fig. 2

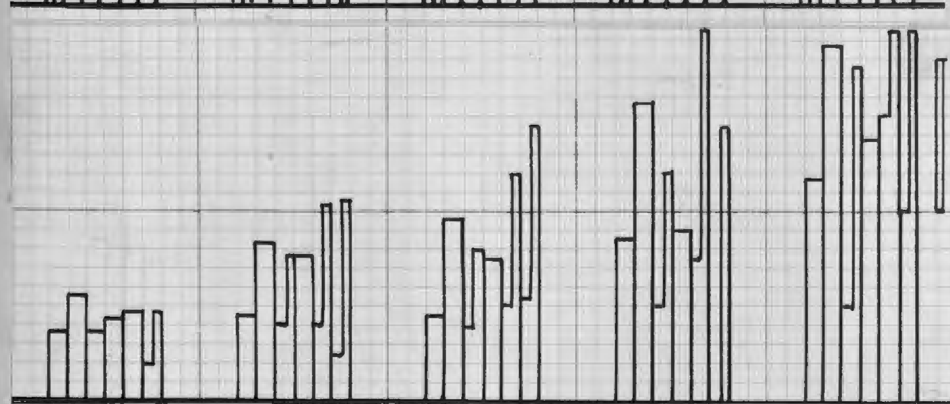


Fig. 3

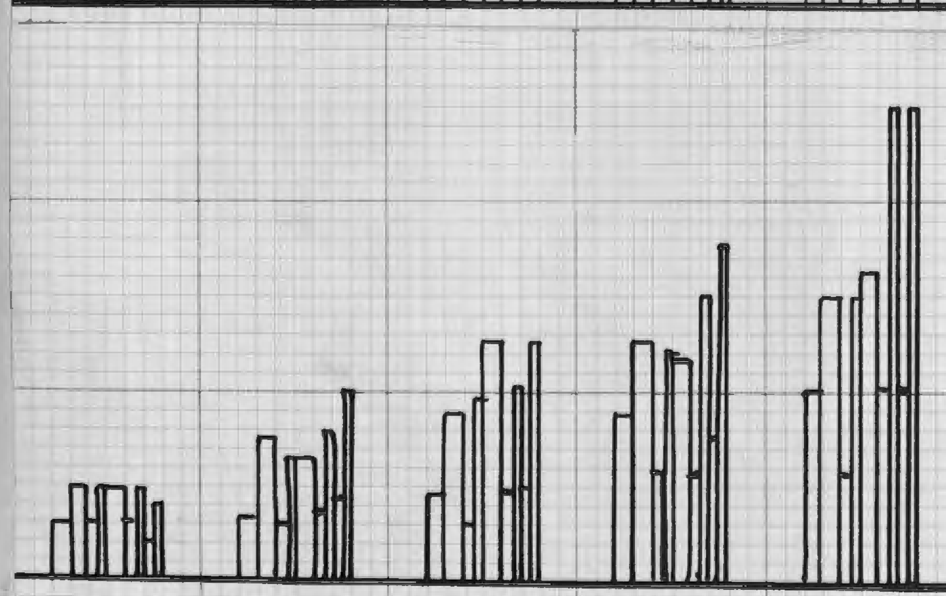


Fig. 4

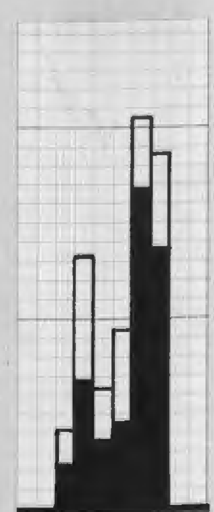


Fig. 5

Plate 31 Pennington peat grasses and clovers.

Figure 1 - Comparative heights of red clover at bi-weekly intervals.

Figure 2 - Comparative heights of alsike clover at bi-weekly intervals.

Figure 3 - Comparative heights of timothy at bi-weekly intervals.

Figure 4 - Comparative yields of grasses and clovers. Clovers are indicated by black.

SUMMARY AND CONCLUSIONS

1. In Pennington County, where less than 2 per cent of all the peat lands are under cultivation, the deep peat has shown very low productivity, while peat less than 12 inches in depth produces fair crops when other conditions are favorable.

2. In the Dibbell peat bog, with sphagnum moss and tamarack trees, the peat may be divided into two main types - the high timber and low timber types. The former is characterized by better drainage than the latter, by a comparatively high lime content, by an advanced stage of decomposition, and especially by tall, fast growing tamaracks. The low timber type is poorly drained, has a comparatively low lime content, is poorly decomposed and fibrous and supports a stunted low and sparse growth of tamarack trees. The peat on most of this bog is more than 5 feet in depth and much of it more than 8 feet. There is apparently no consistent relationship between the depth and any other property of the peat. The water movement through this peat is exceedingly slow, necessitating ditches at very frequent intervals in order to secure adequate drainage for any farm crops.

3. The most striking features in the chemical composition of the samples of peat soils from different parts of northern Minnesota are:

a. The uniformly low ash content of sphagnum moss bogs (7 to 12 per cent) and comparatively high ash content of grass bogs (12 to 24 per cent).

b. The high lime content of Pennington County bogs with very little or no acidity.

c. The very low lime content of Grand Rapids peat with intense acidity.

d. The consistent association on deep peat areas of the Dibbell tract of high lime content with high timber and of low lime content with low timber is very marked, both being characterized by very slight acidity.

e. The fact that in all cases a high percentage of solu-ble ash appears a very reliable indicator of high percentages of important constituents.

4. The yields in greenhouse tests, using only the first crop, appears to bear little relation to the chemical composition, provided the lime content is sufficiently high to eliminate any marked degree of acidity. The peat soils lowest in lime and nit-rogen show most strikingly the benefit from fertilizer treatment. With peat soils not distinctly acid an application of ground lime-stone appeared to exert a distinctly depressing effect. In all the experiments with clovers and grasses where the peat was at all acid the percentage of clovers in total yields was very materially increased by an application of ground limestone. On the untreated acid peats red top showed a markedly better growth than timothy. The same was true where potash only was applied. When lime was added this difference disappeared.

Acid phosphate, except with the Dibbell peats, gave with barley only a slight increase in crop. With clovers and grasses, however, the phosphate exerted a very favorable influence, in-creasing both the total yield and the proportion of clover in this yield. With the grasses the complete fertilizer gave no more marked benefit than the potash, phosphate and lime, while with the barley some of the peats gave a higher and others a lower yield than the unfertilized. As was to be expected a beneficial effect of potassium was almost universally observed.

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