THESIS

FACTORS INFLUENCING

THE

CAPILLARY WATER

IN SOIL

FOR DEGREE M. S.

H. F. TUTTLE

1912

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SOME FACTORS INFLUENCING

THE CAPILLARY WATER IN SOIL.

BY

HIRAM FOLEY TUTTLE

1912

THESIS FOR THE DEGREE, M. S.

HEAT AND ITS EFFECT ON CAPILLARITY.

The object of this experiment is to determine what effect the heating of certain soils has upon their relations to capillary water.

The soils under observation were heated to various temperatures, for different periods of time. And the heat used was generated in different ways.

In order that the samples should be treated more uniformly small lots were used. This also made it possible to secure samples of the same soils that were more nearly similar as to composition. The highest heat used was just sufficient to brown a match stick when thrust into the heating soil.

METHOD.

After heating, the soil was treated the same as the check lot and then tubed in glass tubes about ¼ in. inside diam. The soil was retained in the tubes by a cork, bored out to receive the tube snugly, and the end of the hole thus made covered with fine copper wire screen, or pinning to the cork.

The tubes were filled by pouring in the desired amount of soil and then dropped from a height of one inch, 20 times. In some cases, for comparison tubes were tapped lightly along their length till no further settling occurred.

In most cases 5 samples of each kind were run at the same time.

The tubes when filled were placed in a tap water bath, having a constant depth of about one inch.

As the water rose, its height was marked on the tube with a wax pencil at the end of 24-48-& 72 hrs., etc.

At the end of the desired period the tubes were taken down and the corks removed and the heights marked were measured and recorded.

In all cases where heat was applied by free flame the samples were allowed to cool in an open dish so that a vapor would not form and suck up the water.

★ The soils used were St. Peter's, Wis. quartz—also a chemically pure crushed quartz and Roscommon sub-soil, a sandy soil from northern Michigan. While the quartz is not a soil—for convenience it is termed as such.

HEAT AND EFFECT ON CAPILLARITY OF QUARTZ.

In this experiment St. Peter's, Wis. quartz was used. Its grains are practically spherical and can be readily screened to the desired mesh.

The screening was carefully conducted to remove all particles either larger or smaller than the grain size sought.

A chemically pure crushed quartz was also used, to notice whether the increased rise could be due to the driving of some substance other than water.

In all tubes except # 1 & 2 which contained #80 quartz heated for 2 min. a substantial gain was noted in favor of the heated quartz.

#40 mesh St. Peter's quartz was also heated and responded with decided gains in favor of heating.

★ St. Peter's Quartz is really a Broken Down or Crushed Sandstone

HEAT AND EFFECT ON CAPILLARY ATTRACTION OF QUARTZ.

						Time in [illegible]	[illegible]
1	Heat 2 min. over free flame.	#40 mesh G.P. Crushed Quartz				5	[illegible]
2	" 2 " " " "		Duplicate			8	
3	" 5 " " " "				"	13¾	[illegible]
4	" 5 " " " "				"	13	
5	" 10 " " " "				"	10¾	[illegible]
6	" 10 " " " "				"	[illegible]	
7	Untreated	no heat	original		"	4½	[illegible]
8	"	"	"		"	4¾	

1	Heat 2 min.	#30 mesh St. Peter's, Ill. quartz			7¾	7¾
2	" " "	"	"		7¾	
3	" 5 "	"	"		9¾	[illegible]
4	" 5 "	"	"		14½	
5	" 10 "	"	"		18	[illegible]
6	" 10 "	"	"		18	
7	Unheated	original "	"		8½	[illegible]
8	"	"			8-3/8	

1	Heat 10 min.	#30 mesh St. Peter's, Ill. quartz	13½	13½
2	Untreated	"	10	10

It was thought that the grains of quartz were broken down by the heating and thus produced a more compact soil, and smaller capillary tubes.

Examination under the compound microscope failed to show a difference. In fact it was impossible to distinguish one lot from another.

Also to further demonstrate the above point, heated sands with unheated lots of same size were run for effective diam. on Kings Aspirator, with the following results.

EFFECTIVE DIAM.

	Heated	Not Heated	Diff.	DIAM. IS LARGER IN
#40 mesh St.Peter's quartz	.0339	.03358	.00032	HEATED
#100 " " " "	.011098	.01134	-.000242	UNHEATED

It is seen that in case of #40 mesh the heated quartz has a trace larger diam., while in the #100 the unheated is larger, but in both the above the heated quartz gave the greater capillary rise. It is also noted that the theoretical capillary tubes formed are practically the same diam.

In regard to heating, Briggs in U. S. Bulletin #24, on mechanical analysis, says, "Heating at 100° C does not affect the mechanical analysis of a soil."

HEAT AND ITS EFFECT ON CAPILLARY ATTRACTION, P.C. SUB-SOIL.

Poscommon sub-soil was next treated in the same manner as the quartz samples.

However, another method was adopted to control the intensity of the heat. This was accomplished by placing wire gauze under the dishes of part of the samples. In all cases the same flame was used, but in some cases a screen was interposed. Each sample of each lot was heated separately.

Again the rise was increased by heating the soil, except when heated less than 10 min.

In this experiment two lots were saved after completion of experiment, dried in open dish at room temp., and tested again for capillarity. These samples thus had all the hygroscopic moisture possible at room temp. These results are noted in the last column and show that the change produced in the soil was permanent.

HEAT-INTENSITY & DURATION-ON CAPILLARITY P.C. SUB-SOIL.

	In Rise 4 D	5	6	7	8	Avg.	Compare with Original Loss	Gain	Soils Dried & Used ov[illegible]
Heat 2 min. over screened flame.	10					10.2			
	10½								
Heat 2 min. over same flame not screened	12½					11.6			
	10¾								
Heat 5 min. over free flame not screened	13½								18-[illegible]/8
	14					13.7			17-7/8
	13¾								18-[illegible]/4
	13-5/8								Avg.18 [illegible]
	13-5/8								
10 min. free flame	21	22½	24-1/8	25-1/8	25½				20½
"	21-1/8	23¼	24¼	25¼	25½	24.1			22-1/8
"	19¾	21	21¾	22	22-1/8				20¾
"	–	–	–	–	23½				Avg.21 [illegible]
10 min. over same flame-but screened	14¼	14½	14-5/8	14¾	14¾				
	17¼	18¾	19	19-1/8	19-1/8	16.5			
	15-1/8	15-3/8	15½	15¾	16¾				
Original soil unheated.	12½	13½	16½	17	17½				
	15½	16½	16-5/8	16-7/8	17	17.5			
	15-5/8	16¾	17½	18	18				
	15¾	16-5/8	17¼	17-5/8	17¾				

The results obtained in the last column tend to prove that the increased rise cannot be due to loss of hygroscopic moisture, as these samples were soaked and then air dried.

In heating the samples over the gas flame, they were discolored, turning brownish. It was first thought this was due to the charring of organic matter, but when the same results were obtained on a chemically pure quartz this idea, while probable in T. C. Sub-soil, could not account for the increased capillary rise in quartz.

It was thought that if there had been a deposit left on the soil from the gas or a loss of some substance other than moisture, it might be noted by observing the results obtained by applying different kinds of heat.

Accordingly heat was applied to [illegible] Sub-soil by means of a steam bath, and electric constant temp. oven, steam radiator and the sun.

CAPILLARY TEST [illegible] HEAT [illegible]. [illegible]. [illegible] SOIL.

TREATMENT	24 hrs.	72 hrs.	12[illegible] hrs.	Avg.	Gain
1 Heated at	1[illegible]-5/8	13	13½		
2 100 C temp. oven 5 days	13-5/8	14¼	14-5/8	13.8	.8
3 cool 15 m. in	12¼	12½	13¾		
4 Dessicator	12¼	12½	13-7/8		
5	12-7/8	13	13-3/8		
6 Heat on steam bath 5 days &	12	12-1/8	12½		
7 cool in dessi-cator 15 min.	13-3/8	13¾	13-3/8	13.7	0.7
8	14-1/8	14-5/8	15-1/8		
9 In dessicator 5 days, no	12¼	12½	13-1/8	13.1	.1
10 heating	9¾	10	10¼		
11 Plain soil, no heat or dessica-	12-3/8	12½	13	13	-
12 tion, air dried only	11¾	12	12½		

Again the effect of heat gave a decided increase in the capillary rise.

Chemically pure crushed quartz #40 mesh gave similar results.

The plain sample gave a rise of 4¼ in.

" sample heated in electric oven & dessicated-4½

" " not heated but dessicated-4-5/8

The above oven [illegible] in constant use and was frequently filled with moisture determination samples, which may have had an effect on results.

The effect of the sun was obtained by hanging the tubes of soil in a window where they received sunlight for part of each day, 6-8 hrs. Part of the tubes were inside an asbestos trap, one side of which was open to the window. This trap was simply a piece of asbestos forming a half cylinder and merely acted as protection from air currents from behind. The top was not closed. Its efficiency is doubtful, as the results show little difference between the tubes in the trap and those hanging free.

During the period required for the above experiment the weather was cloudy. It required practically two weeks to secure 72 hrs. of sunshine.

In the experiment conducted on the radiator the heat was turned off during the day and was thus intermittent, the period occupied by this trial lasting two weeks.

In every instance a gain resulted, except in the case of the quartz tube which was on radiator and sealed. Here a slight loss resulted.

	Inches 24 hrs.	48 hrs.	72 hrs.	Avg. rise 72 hr.	Cal.
Plain R. C. Sub-soil	12¼	13-1/8	13-3/8	13.7	
"	13-1/8	13-5/8	14-1/8		
Roscommon Sub-soil on radiator 2 wks. heat intermittent Temp. 70 C	16¼	17¼	17¾		
	12-7/8	13¼	13-3/8		[illegible]
	14-3/8	14-5/8	14-7/8	15	1.3
	13¾	-	14½		
	14½	-	16		
R. C. Sub-soil in sun trap. 72 hr. sunshine in 2 wks.	11-7/8	12	12¼		
	13-3/8	13¾	14-1/8	14.3	[illegible]
	14-5/8	15-1/8	15-3/8		
R. C. Sub-soil in sun but not protected by trap. Otherwise same as above.	12¾	13	13¼		
	16½	17-3/8	18¼	16.6	[illegible]
			16		
"30 mesh St. Peters quartz, plain	9-5/8		10		
*"30 mesh St. Peters in sun 3 days			13-1/8		3.[illegible]
*"30 mesh St. Peters tube open on radiator	10¼		10½		[illegible]
*"30 mesh St. Peters tube corked & on radiator	9		9-3/8		[illegible]

*These results were not in duplicate.

The following pure quartz samples were tested in gas oven at 70-100 C, at irregular intervals during a period of 2 wks. Moisture samples were run during the time test was being applied and the open dishes containing the quartz sat on the [illegible] shelf of the oven.

	Time			
	72 hrs.	Avg.	Gain	Loss
#40 quartz not heated	7¼	7.2	[illegible].0	
" " "	7¼			
#40 quartz heated in gas oven intermittently	3¾			
"	3¾	3.[illegible]		[illegible]
"	[illegible]			
"	2-5/8			
#80 quartz not heated	9½	9	5.[illegible]	
	9½			
#80 quartz heated in oven	3-7/8	3.8		5.[illegible]
"	4			
"	3			
"	3¾			
"	7-7/8			
#100 quartz not heated	16-7/8	17	5.7	
	17-1/8			
#100 quartz heated	11½			
	11-7/8	11.[illegible]		
	11¾			5.[illegible]
	12¼			
	11¾			

In this experiment the [illegible] samples were screened [illegible], to make sure of the fact that compound grains had not resulted from the moisture and heating.

However, the results show conclusively that for some cause this intermittent heating caused a decrease in the capillary rise.

The finer the grains, the greater the decrease.

As before with the electric oven moisture samples were dried in the same oven, but it is impossible to say that this caused a decrease in the capillary rise.

HEAT BY BOILING

This time heat was applied by boiling in water for 10 min.

In one case the water was drained off and the wet mass [illegible] like that of the original soil, [illegible] to dry on soil.

In the second case, to note whether this boiling would make a difference in capillary rise by removing some substance from the soil, a quantity was simply boiled 10 min. and the [illegible] solution allowed to dry on.

After the various samples were dried in the room they were screened and rolled [illegible] with the fine particles [illegible] from compound grains.

The figures show that where heat was applied a gain resulted.

Also that the addition of the boiling [illegible]

[illegible]

[illegible] sifted through [illegible] mesh [illegible] 200 mesh.

[illegible] Quartz	Time 72 hrs.	[illegible] Avg.	[illegible]	Boiling [illegible] Loss
A				
Boiled only-[illegible] [illegible] Temp. [illegible] dripping [illegible] times [illegible].	8½ 8½ 8¾	8.6	0.9	
Temp. [illegible] the [illegible] boiling [illegible]	8¾ 9-1/8	9.2		
[illegible]				
Boil-wash-& drain, temp. by dropping	9-7/8 8¾ 8½	8.7	0.0	
Temp. by [illegible] boiling [illegible]	9 9½	9.2		
[illegible]				
Original quartz [illegible] dropping	7-7/8 7-7/8 7-7/8	7.8	.1	
Original quartz [illegible]	8-3/8 8½	[illegible].5		

TABLE CONT. NEXT PAGE

[illegible] Quartz			[illegible] 72 Hrs.	[illegible] Avg.	[illegible]	[illegible]
D Original quartz		dropped	$7\frac{3}{4}$	7.7		
"	"	"	$7\frac{3}{4}$			
"	"	[illegible]	7-7/8	7.8		

A & B were both boiled, but "B" was drained. Compari[illegible] shows that both gave the same rise.

C & D were both of original sample, but "C" had [illegible] from B added to it. No difference resulted. Hence [illegible] that "heat" only produced the change-unless some volatile substance has been removed which is not likely in quartz.

The previous experiment was repeated, using [illegible] [illegible] Soil. As with the quartz, heat appears to be the controlling factor. However, a decrease is noted in the [illegible] to which washings were added, apparently showing that something was removed from the washed soil.

[illegible] Soil	72 Hrs. Avg.		Rise over [illegible] Soil	Boiling. [illegible]
Soil in [illegible]-drain & rinse Tamp by dropping 30 times " "	17-3/8 18 17-1/2 18	17.1	7.4	
Tamp by tamping " " " [illegible] settled " " " " "	18 18-1/2 18½	17.[illegible]		

TABLE CONT. R.S.

to min. [illegible], [illegible].

the soil, after cooling, was cooled [illegible] in the open, [illegible] the hygroscopic moisture possible. The heated samples [illegible] treated differently. The heated samples still gave an increased rise over the unheated. From this [illegible] is [illegible] that loss of hygroscopic moisture [illegible] of [illegible] due to heat or the change of the grain [illegible] [illegible] account for the increased rise.

Further, the effective diam. were unchanged, and the microscope showed no differences in structure.

[illegible], in an electric [illegible], [illegible] 100 degrees C on a radiator at 70 degrees C [illegible] water, the heat produced [illegible] causing a condition in the soil [illegible] capillary rise, except as noted on P. 11, or intermittent heating caused a decrease.

The sunlight also produced the same effect.

As to why this effect is produced, it is not possible to say, [illegible] physical [illegible] change, [illegible].

THEORY OF CAPILLARITY.

Capillary rise of liquids is due to surface tension. Any factor which affects the tension of the surface film will cause a decrease or increase in the capillary rise. Heat will reduce the tension and cause a decrease, [illegible] most soil solutions cause a decrease. Most mineral fertilizers cause a rise. Lyon-Fippin, P.[illegible].

Bacteria thrive on soil solutions, [illegible] on mineral fertilizers, especially if organic matter is present.

According to Lyon & Fippin, p. 1[illegible]0, [illegible] surface tension. If gypsum is placed in a soil under favorable moisture conditions, it is broken up [illegible] it is given off [illegible]. Also denitrifying organisms may cause nitrites to disappear from a soil. [illegible] others fix nitrogen in the soil. There are [illegible] changes which take place in a soil and their [illegible] influences the soil solution as shown by chemical analysis. Stevens & Withers, Lipman, also [illegible], Marshall's "Microbiology", Chap. II, III, IV.

With the above facts in view an attempt [illegible] demonstrate that on various nutrient solutions, [illegible] would produce appreciable changes in the surface tension of these solutions,—this change to be noted by the [illegible] height to which [illegible]

[illegible] in [illegible].

[illegible], [illegible] of capillary here was not [illegible] appreciable differences. [illegible].

While the [illegible] be desired, they seem to show that changes [illegible] surface tension [illegible].

The [illegible] these [illegible], have been planned which it is believed will [illegible] differences more clearly.

CAPILLARITY AS INFLUENCED BY BACTERIA.

In the following work the bases of the [illegible] soil solutions made by soaking a soil in an equal weight [illegible] water and filtering the resulting solution [illegible].

To the above was added various salts [illegible]. In choosing these an attempt was made [illegible] which would influence the greatest change.

When filling the flasks the solution in each [illegible] practically the same depth.

The soils used to indicate the height [illegible] solutions rose were placed in the [illegible] capillary experiments, [illegible] tamping, [illegible] solutions [illegible].

The [illegible] readings were obtained [illegible] in [illegible].

[illegible], [illegible] [illegible].

Soil infusion [illegible] 1:4, [illegible] soil, [illegible] [illegible] of the [illegible].

The [illegible] as follows:

Soil infusion [illegible] 2,

" " [illegible] 10,

" " [illegible] 1, [illegible] 2,

" " [illegible] 1, [illegible] 2, [illegible]

Sterilize the above.

Inoculate each flask with 1 c.c. soil suspension, made by shaking some of the above soil in tap water and allowing coarser particles to settle.

The [illegible].

In the column of averages it is seen that [illegible] inoculation is [illegible] in solutions [illegible], [illegible] A [illegible]. The [illegible].

Another trial [illegible] on the same flasks, [illegible].

These results are recorded in the last column.

These [illegible] hrs.

		[illegible] Avg. [illegible] [illegible].	[illegible] soil. Avg 34 [illegible].
	Soil-leaching-sugar-peptone inoc. grown at 22 C	7.3 IN.	9.7 IN.
	" " " " " 37 C	7.3	11.[illegible]
A	" sterile " 22 C	8.[illegible]	11.[illegible]
	Soil-leaching & peptone inoc. 22 C	9.1	11.3
	" " " " 37 C	9.	9.7
B	" sterile 22 C	8.7	11.
	" & manure leachings, inoc. 22 C	9.3	11.3
	" " 37 C	8.8	11.3
C	sterile 22 C	8.1	11.3
	"sugar-peptone-manure inoc. 22 C	7.4	8.9
	" 37 C	[illegible].3	11.2
D	sterile 22 C	9.4	11.2

In the first column the growths as indicated [illegible] in series A & D the bacteria reduced the surface tension, [illegible] in B & C they increased it.

A difference is also noted between the growth at 22 degrees and 37. In B the culture at 37 degrees decreased the rise in [illegible]. A different organism [illegible] at this temp., as noticed by the odor of the cultures.

While the general conclusion above stated may be drawn from the results given in the 2nd column under "[illegible] soil, variations have crept in. It will be remembered that the inoculation [illegible], [illegible] mixed culture, [illegible] the results [illegible] obtained after the growth [illegible] in the same flasks.

The difference shown above may be taken only to indicate that bacteria may produce changes in a soil solution that will affect its surface tension and capillary rise.

This is a repetition of the former, using a [illegible] loam to produce the soil leachings.

A. Soil solution plus 10% manure leachings
B. " " 1% peptone
C. " " 5% " 5% manure, 1% [illegible]
D. " " 5% lime, 1% [illegible] [illegible], .1% [illegible]
E. " " .2% " , 1% [illegible], .1% [illegible]

Used 100 mesh P.C. [illegible] soil to measure the capillary rise.

Soils			Avg. rise 72 hrs.	[illegible] of 10
A.	sterile		[illegible].5	
	inoculated grow @ 22 C		9.7	[illegible]
	" " @ 37 C		9.[illegible]	[illegible]
B.	sterile		9.5	
	inoc.	@ 22 C	9.5	–
	"	@ 37 C	9.[illegible]	–
C.	sterile		10	
	inoc.	@ 22 C	9.1	–
	"	@ 37 C	9.3	–
D.	sterile		9.[illegible]	
	inoc.	@ 22 C	9.1	–
	"	@ 37 C	9.3	[illegible]
E.	sterile		9.[illegible]	
	inoc.	@ 22 C	[illegible]	–
	"	@ 37 C	9.7	[illegible]

[illegible] WATERPROOFING [illegible].

[illegible] (Pa. Sta. R. [illegible]) "various solvents such as alcohol, chloroform, ether, etc. remove from the soil a wax for which the name "agricere" is proposed. The removal of this wax or waterproofing renders the material far more available."

Briggs, in U. S. Bul. Soil # 10, states that oils resulting from the decay of organic matter occur in the soil and thus arrest the capillary rise.

If such substances were removed would they tend to increase the rise of capillary moisture?

The method of procedure was as follows: After thoroughly mixing a sample by rolling on an oilcloth, it was divided into equal lots, and treated as below:

A. One lot left untreated as a check.

B. " " washed in ether & ether washed out with alcohol and after draining the washings were added to another lot—C, and left to dry on C.

D. Another lot washed in ether but washings not removed and left to dry on soil.

After A, B, C, D had dried in air until air-dry—about less than 24 hrs.—they were placed in the glass tubes used in the last experiments.

The various lots were then carefully [illegible] by the fine sediment, and rolled again.

These tubes were tamped by dropping them from a height of one inch 20 times. These were a few tubes which were tamped by tapping lightly until no further settling occurred.

The tubes were then placed in a water bath having a constant depth of one inch.

Marks were made on the tubes at the end of each 24 hrs. for 3 days.

At the end of this period the heights reached were measured and recorded.

In the following table it will be noticed that washing the soils with ether caused a decrease in the capillary rise, except in the case of chemically pure quartz.

The addition of ether washings to the plain soil decreased the rise in every case.

While the washed soils approach their respective untreated checks, when their respective washings are added to check soils something has been introduced or a change produced that causes a great decrease in the capillary rise.

A. [illegible] soil treated 15 min. [illegible]
B. " " " " 24 hrs.
C. St. Peter's quartz 60 mesh treated 24 hrs.
D. Chemically pure crushed quartz 60 mesh treated 24 hrs.
The heights here indicated are the avg. rise for 72 hrs.

	A	B	C	D
Plain soil, no treatment	12.7"	13.7"	10"	4.7"
Wash in ether & alcohol & drain	9 "	11.8"	9.5"	3.7"
Plain soil & washings	8.7"	9.8"	8.5	[illegible].2"
Wash in ether & alcohol & not drain		10.4		

[illegible] MANURE, PEAT AND CLAY.

The object of this experiment was to determine the relative efficiency of peat, manure, and clay in increasing the amount of water held in ten foot columns of soil and the location of the increase.

The experiment was conducted in ten foot columns, each composed of 15 eight inch sections of brass tubing, about 1-3/8 diam., joined together by screwing into brass sleeves.

The bottoms of the columns were formed by soldering wire screens to several of the brass sleeves and screwing them to the bottom sections.

Water was admitted at the top through a feed length made by cutting an 8" section in half and closing one end of each half. A hole was then bored on the side near the closed end and a small brass tube screwed in and soldered in place.

The supply tank for the water was just a few inches above the upper end of the column, so as to give a minimum pressure.

The threads of each section were greased to make the column water tight.

The soil under observation was screened through a 20 mesh screen to remove coarse particles, and then thoroughly mixed by rolling on an oilcloth. In introducing it into a column, the column was first placed perpendicular and a [illegible] funnel placed on top. The soil was then poured [illegible] rapidly and uniformly. When filled the soil was packed by lightly tapping each section, once, beginning with the bottom section, then adding soil to make up the deficit. This was repeated five times. That is, each section was struck 5 times, once in each rotation. This left in each section approximately 700 gms. of soil. Naturally those sections containing manure and peat held less soil. After levelling the column with soil the last time, a feed length was screwed in place, and tap water admitted. After a few hours the water would begin to drip from the bottom. The water was now shut off and the tube on the feed length lightly plugged with cotton to prevent evaporation.

The column was now allowed to drain 72 hrs., which time was found to be sufficient for the water in the soil to adjust itself and practically stop dripping from the bottom.

At the end of 72 hrs. the column was taken down, each section being placed in a separate container and weighed at once.

They were then introduced into a gas oven at about 110°C, dried for 24 hrs., or until they had reached a constant weight. In order to facilitate this drying the soil was removed from the tubes by tapping. Each section was then weighed again, and also the amount of dried soil each contained was noted. From this data the percent of moisture held was obtained. Also, the volume of each section being known, the percent pore space could be determined.

As the temperature influenced the amounts of water retained, and was run in triplicate, or duplicate at other times varied.

When manure, peat or clay was added, the amount of soil required to fill the section was measured out and the material to be used added and mixed with the soil by rolling on an oil-cloth.

The manure used was dried horse manure, sifted through a 40 mesh screen.

The peat was sifted through same screen.

The clay was blue clay, ground very fine.

Under agricultural conditions the amount of water a soil will hold when saturated is of small practical importance, as this condition occurs only when the water table of a soil is near the surface or after long, heavy rains. Warington.— Phys. Prop. Soil, p. 74.

When the above condition occurs an attempt is made to overcome it by drainage systems. And it is the amount of water that the soil retains after fully drained that is one of the important factors in crop production.

Mayer, Agr. Chem. Vol. II, p. 143, terms the proportion of water retained by a soil when fully drained, its "Absolute Water Capacity."

He further states that when the columns of soil are so short that the gravitational forces are reduced to a minimum, accurate deductions of this "water capacity" are impossible. By experiments with different soils, mineral and peat...

be practically the same size, he concludes that the "Water capacity" varies with the structure increasing in fixed r[illegible] with the porosity.

Meyer's method consisted of using a column composed of 2 sections, the bottom 75 cm. and the top 25 cm., the de-ductions being based on the upper section.

Hilgard, King, Wolloy, Haberlen and others have performed numerous experiments that tend to prove if a plant were dependent on only such waters as are raised by capillary action from the soil water it would soon die. However, the frequent additions of rain to a soil and its capacity to retain a portion of this from being drained away, controls the [illegible] [illegible]ibution.

Hilgard mentions that the extreme height under favorable conditions to which water rose in a soil was 36 inches and this only after several months. Cal. Exp. Sta. Rep. 1892-1894, p. 100.

King, "Physics Agr.", p. 172, states that manure may cause an increased rise of capillary water at the expense of the soil moisture from below. Watson, p. 106, V. 13, Iowa Academy Sci., states this result is probably due to retarded evaporation.

Instead of using a three foot column, as recommended by Meyer, the ten foot columns were used, so that drainage would be as perfect as possible. That this method produced better drainage than a three foot column can be seen by comparing

No. of Feet	1½	.3	.6	12	3	6	12
1	4.4	3.4	[illegible]	[illegible]	[illegible].1	7.8	9.9
2	[illegible]	4.5	4.7	4.1	5.3	[illegible]	7.[illegible]
3	[illegible]	4.3	3.0	4.1	4.2	[illegible]	[illegible]
4	4.3	3.0	3.0	4.2	4.3	4.7	3.0
5	4.7	3.1	3.6	4.3	4.5	4.2	3.3
6	4.5	5.5	3.9	4.9	4.3	5.6	3.5
7	[illegible].7	5.7	3.6	5.6	3.6	5.7	5.6
8	3.3	[illegible]	3.9	5.1	5.7	6.4	5.7
9	[illegible]	[illegible].7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	3.9	3.1	[illegible]	[illegible]	3.7	[illegible]
11	3.5	8.1	3.2	[illegible]	5.7	[illegible]	[illegible]
12	[illegible]	7.0	[illegible].4	[illegible].1	5.5	[illegible].1	[illegible]
13	[illegible].7	7.0	8.[illegible]	7.1	[illegible]	7.4	3.1
14	13.1	14.7	[illegible]	10.3	15.[illegible]	13.7	13.7
15	25.1	21.6	22.7	23.3	22.3	26.2	13.7

Table [illegible] % H₂O [illegible] on Total Wts. Soil [illegible]

Soil wt.	[illegible]	[illegible]	4367	4220	4458	4000	4476
H₂O	307.1	329.4	[illegible]	302.4	313.1	321	324
% H₂O	6.95	7.16	7.04	7.0	7.1	7.3	7.3

Table [illegible] — % Pore Space in 1st [illegible]

1	15	41	11.3	10.5	41.5	10.[illegible]	19.6
2	37.4	35	36.3	35.7	12.1	13	41.7

sections #10 to #15, which would equal a 3 foot column to the upper sections of the same columns.

Table A shows the percentage of water based on the dry weight of soil, as found in each section after the column had drained 72 hrs.

Table B shows the total dry weight of soil, the total weight of water, and the percent of water found in each column.

Table C shows the percent pore space in the 1st & 2nd sections.

Figure 1 presents the comparison of the percentages of water found in the first and second sections of each column.

Those sections containing clay, peat or manure, held an increased amount of water when fully drained for 72 hrs.

In order of amount of water held, the manure stands first and the clay last.

Comparing volumes of manure, peat and clay per gram of dry weight, the manure has the greatest volume and the clay least. However, 8 gm. of manure has a smaller volume than 12 gms. of peat, but held a greater amount of water.

The manure columns also show that an increase was made in the amount of water retained in the second sections. To an extent this was also true of the peat, when added to the first 8 inches only, but in this case the largest amount of peat, while producing the greatest increase in the first section, contained less water in the second section than was contained in the same section of the other columns of the same series.

However, in the series to which 1.5 gms peat were added to the 2nd sections, gains are noted in the second sections which are greater than can be accounted for by the addition of 1.5 gms. of peat, especially in those columns which received 6 and 12 gms of peat in the 1st sect. The comparison is as follows. 1½ gms. peat produced a gain over the 2nd section of the plain soil column of .6 gm.

Grams peat in 1st section	3	6	12
2nd sects. containing 1½ gm. peat	5.3	6.2	7.5
2nd sect. columns peat 1st 8" only	4.8	4.7	4.1
Increase	.5	1.5	3.4
Increase due to 1½ gm.	.6	.6	.6
Gain unaccounted for	-.1	.9	2.8

In comparing the pore spaces of "Table C" with the amounts of water in the first two sections of "Table A", it will be seen that with but one exception- when 3 gms. peat was added to 1st 8"-the greater percentage of water retained, the larger the percentage of pore space.

While in general this is true, it would not be safe to state that a certain pore space would retain a certain percentage of water. For on examining the percentage of water and the pore spaces of the second sections of the manure and clay columns, it will be noticed that though the pore spaces are nearly alike, the amounts of water vary greatly, giving the impression that the manure has some other effect on the soil that influences its water capacity, besides a mere physical effect.

Turning to "Table [illegible]" and comparing the percentages of water retained in the entire columns, it is seen that the total percentage of moisture in each is practically equal to every other column, regardless of amount or of kind of material in the first and second sections.

King, Wis. Rept., V. 8, p. 113, finds that to a depth of six feet manured and unmanured ground contain practically the same amounts of water, but the manured ground contains more in the first three feet.

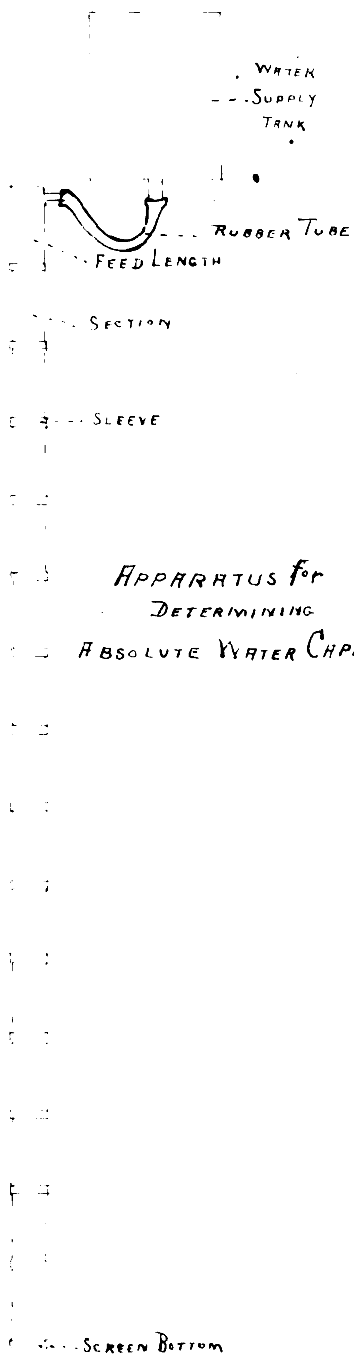
As to the influence of manure, peat and clay on the entire column, the above general statement holds true, but on examination of the curves representing the various columns it will be noticed that in general as the amount of organic matter increases in the first section, this increase is also made apparent by a slight increase in the balance of the column down to a height to which capillary forces may lift water in the soil under observation, when wet. i.e. Down to Sect #13
However when compared to the plain soil this increase may not equal increases in Plain Soil "See Curves."

In this soil capillary attraction may cause a rise of 18 inches in the dry soil. As in certain cases the second sections of the columns being considered were influenced [illegible], in this consideration the first two and last [illegible] sections will be omitted. The average percents are [illegible] follows:

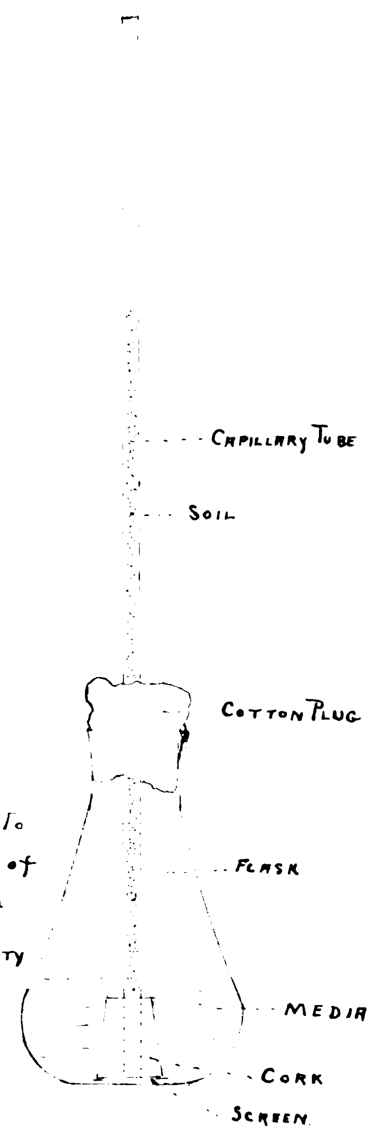
Average Sections #3-#12.

	Peat 1st Feet.	Peat 1st Feet. & 2nd Feet.	Manure 1st Sect.	Clay 1st Feet.	Surface soil 1st Feet.	Plain sub soil
12 in.	4.9				*	*
6 "	5.3	4.9	5.4	5.6	5.5	4.2
3 "	5.[illegible]	5.3	5.5	5.8		
18 "	5.5	5.5		5.6		

*[illegible] section filled [illegible] these soils.



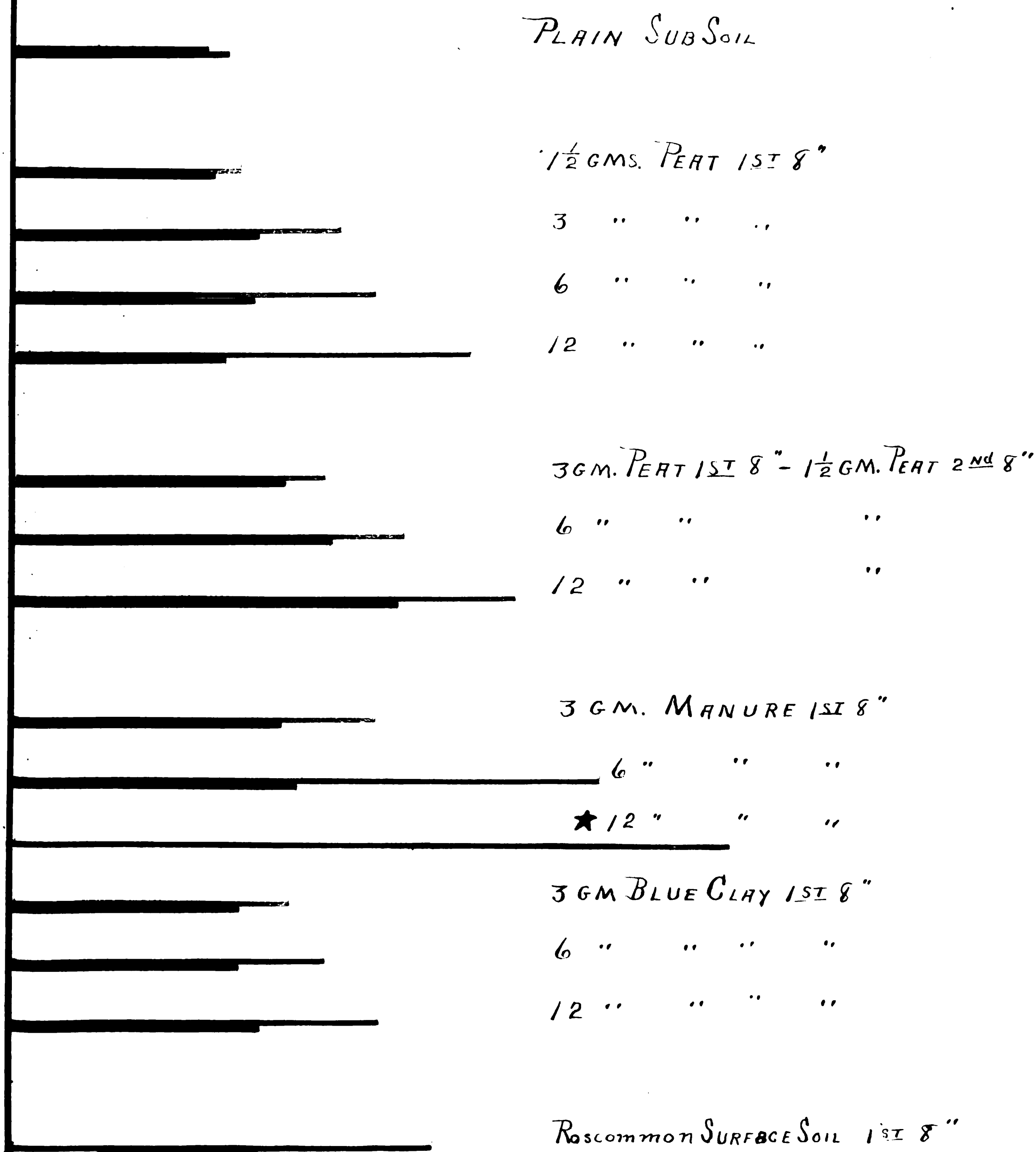
Apparatus for Determining Absolute Water Capacity



Used To Note Affect of Bacteria on Capillarity

Absolute Water Capacity of Roscommon Sub Soil

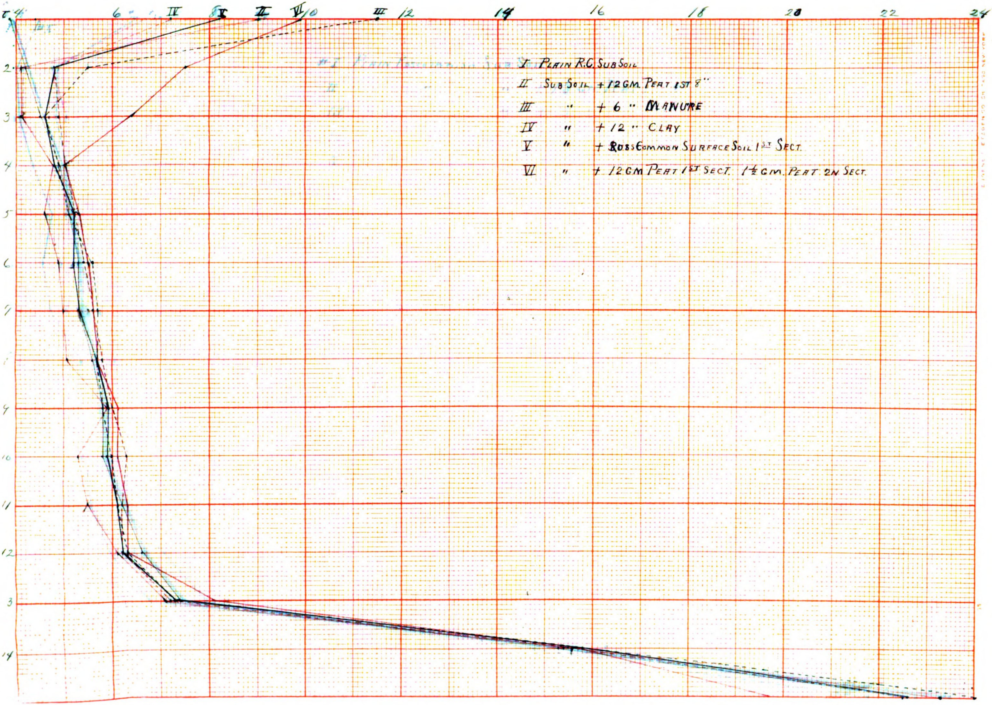
FIG. 1

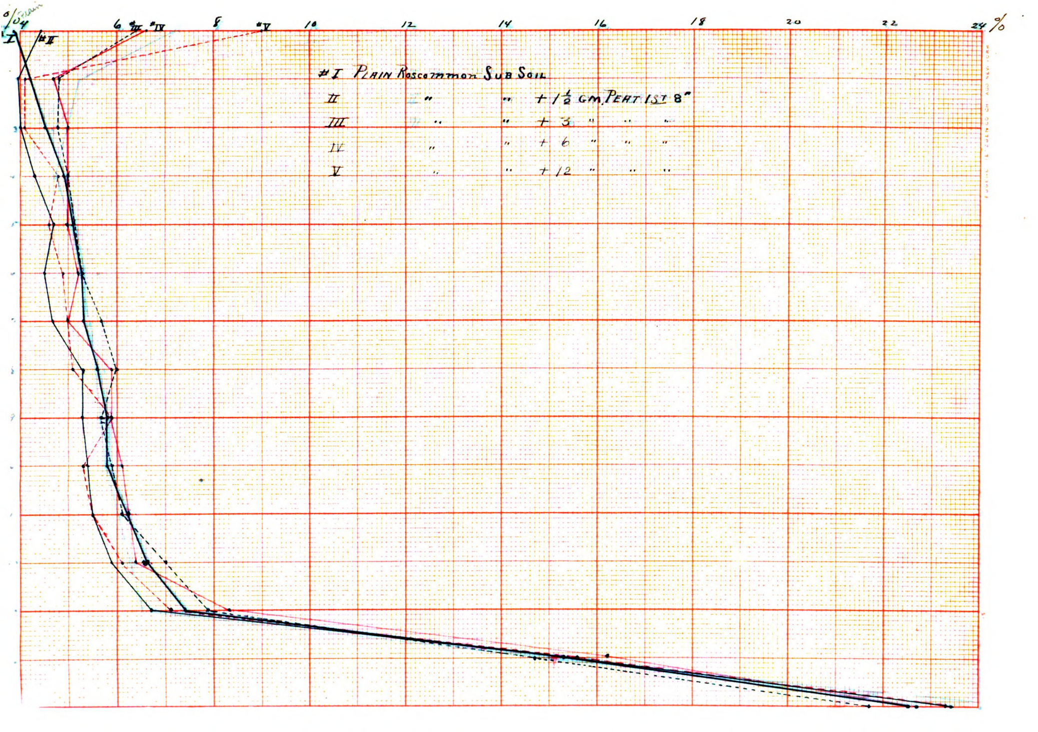


RED = 1ST 8"

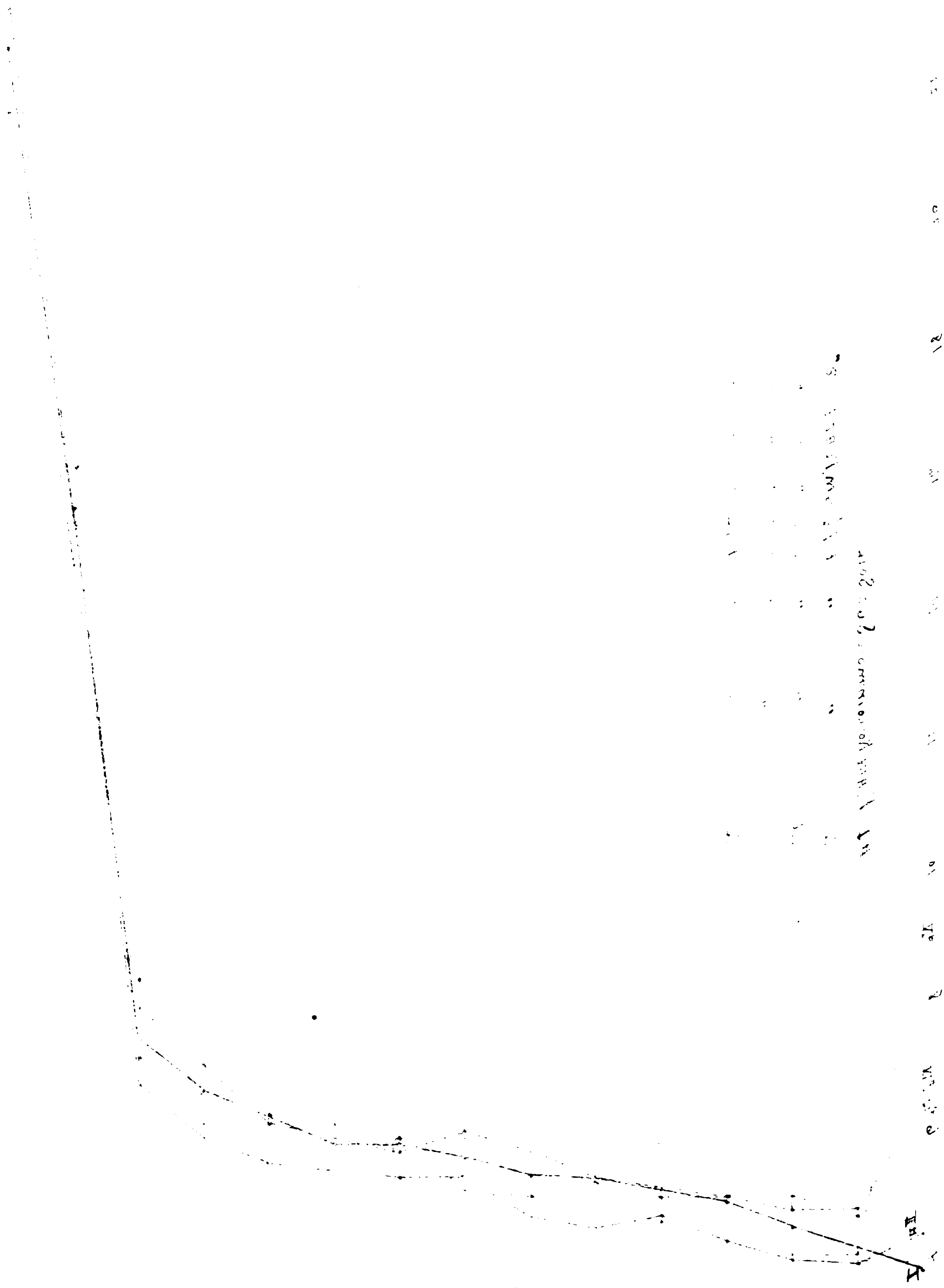
BLACK = 2Nd 8"

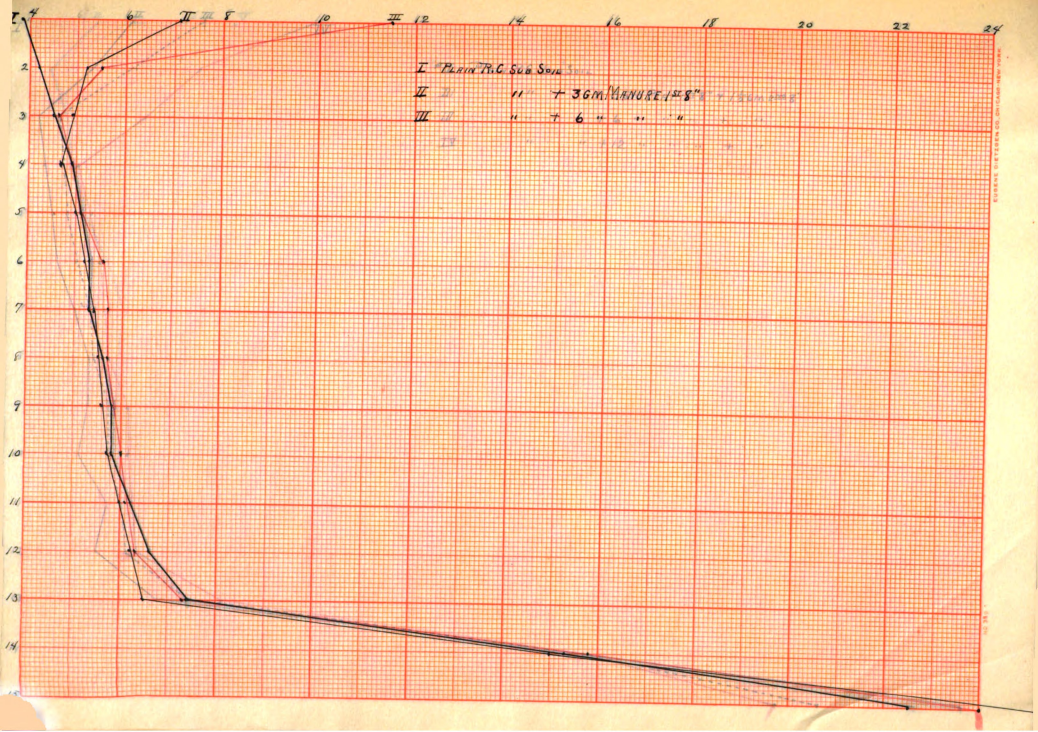
★ Results of 2nd 8" not shown as the bottom 14 sections were tamped until soil ceased to settle

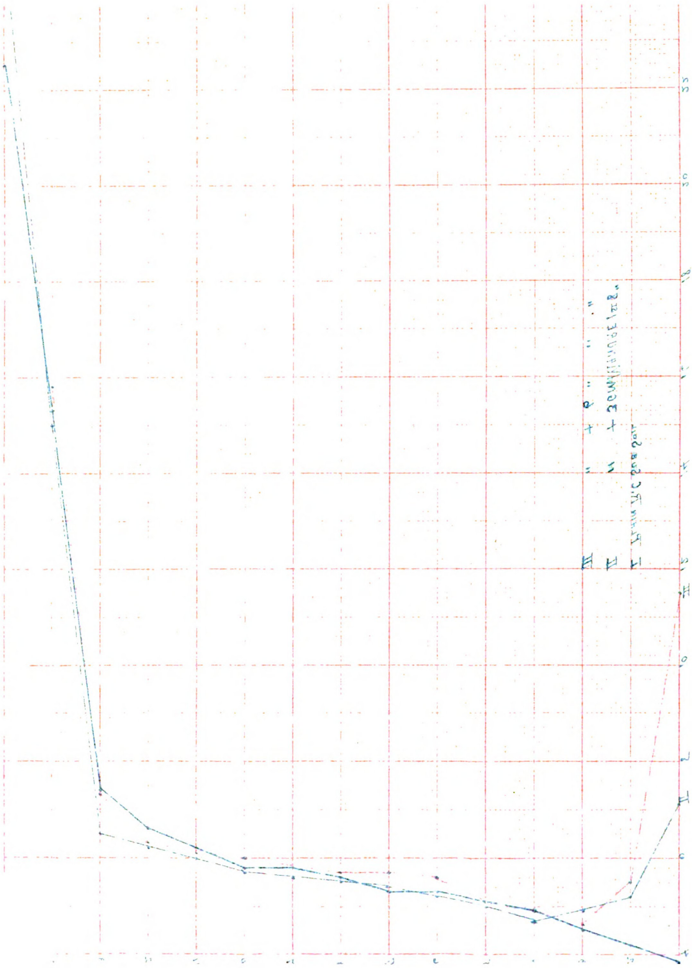

I Plain R.C. SubSoil
II SubSoil + 12 GM. Peat 1st 8"
III " + 6 " Manure
IV " + 12 " Clay
V " + Ross Common Surface Soil 1st Sect.
VI " + 12 GM Peat 1st Sect. 1½ GM. Peat 2n Sect.

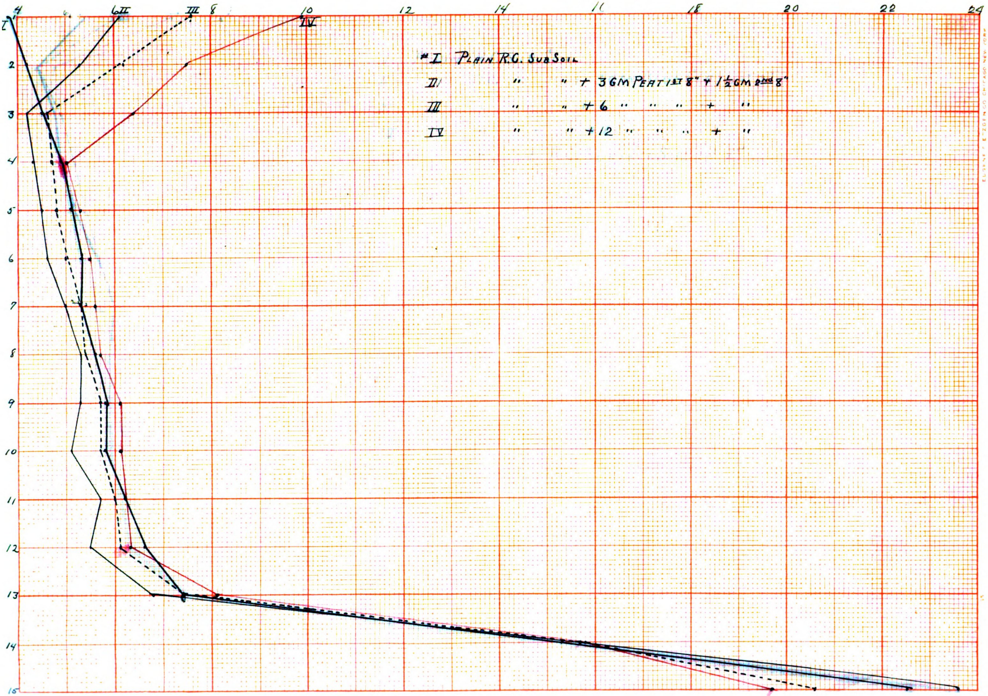


#I Plain Roscommon Sub Soil
II " " + 1½ Gm. Peat 1st 8"
III " " + 3 " " "
IV " " + 6 " " "
V " " + 12 " " "
0/0 4
6
8
10
12
14
16
18
20
22
24 %
#I
#II
#III
#IV
#V

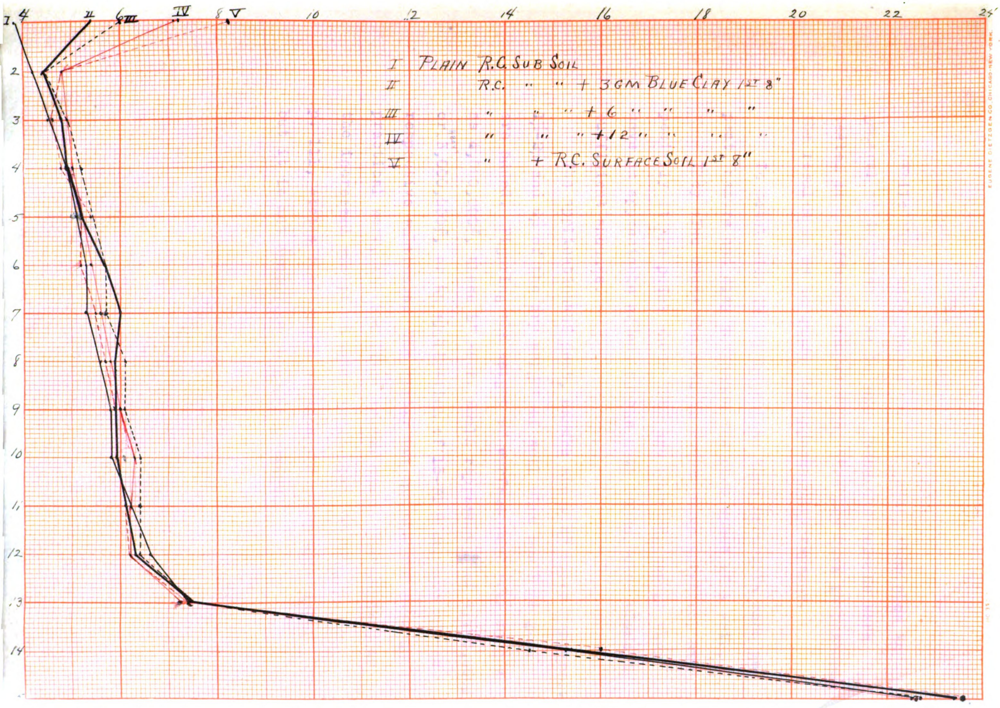


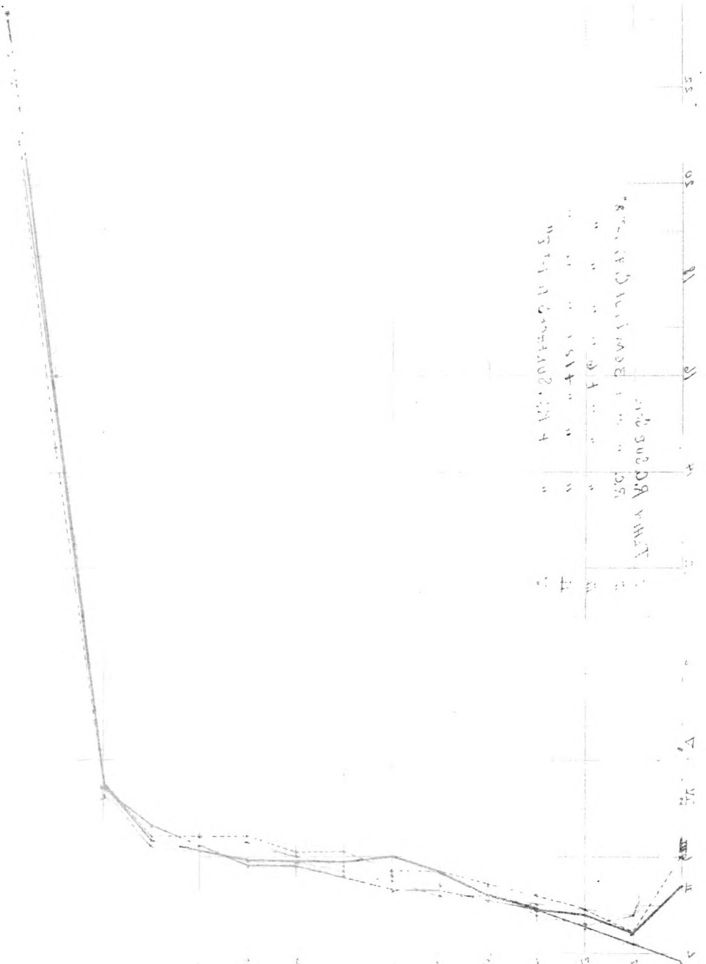

I PLAIN R.C SUB SOIL
II " + 3GM MANURE 1st 8"
III " + 6 " " "
4
6
8
10
12
14
16
18
20
22
24
2
3
4
5
6
7
8
9
10
11
12
13
14
EUGENE DIETZGEN CO. CHICAGO-NEW YORK





#I PLAIN R.C. SUBSOIL
II " " + 3 GM PEAT 1ST 8" + 1½ GM 2ND 8"
III " " + 6 " " " + "
IV " " + 12 " " " + "
4
6
8
10
12
14
16
18
20
22
24
6 II
III
IV
I
2
3
4
5
6
7
8
9
10
11
12
13
14
15


I PLAIN R.C. SUB SOIL
II R.C. " " + 3 GM BLUE CLAY 1ST 8"
III " " " + 6 " " " "
IV " " " + 12 " " " "
V " + R.C. SURFACE SOIL 1ST 8"
EUGENE DIETZGEN CO. CHICAGO-NEW YORK.
4
6
8
10
12
14
16
18
20
22
24
1
2
3
4
5
6
7
8
9
10
11
12
13
14



While these differences are not great, they are in general an increase. As in some cases the soil was tested at a different temperature, this may have influenced the results so as to cause the apparent discrepancy.

In conclusion it may be stated that materials such as peat, manure and clay influence the pore space of a soil.

They also cause the soil to retain more moisture, especially at the point where they are located, though they have an appreciable effect on the soil below, when added in sufficient amounts.

The applications of peat, manure and clay above represent 1%-2% and 4% of the dry weight of soil when 5-8 & 10 gms. are added. Figuring the weight of surface foot soil on 1 A as 4,000,000#, these 8" sect. would represent 2/3 of 4,000,000, or about 3,000,000#, or an application of 15-30 & 30 tons of the respective substance. The latter two amounts are rare in practical work, and the first seldom seen. Then, again, is the increased amount of water available? Watson, V. 13, p. 111, states that manure retains the water in the soil, but it is not available to growing crops.