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COMPARATIVE STUDY OF SOILS.

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#1.

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The comparative study of soils herein given is a physical study of five types of soil in their relation to Agriculture. This study has to do only with the relation of moisture and air to the soil. The comparisons given are found in experiments carefully preformed in the soil physics laboratory. Although field conditions were not obtained in the laboratory, we found no conditions or results than which could not be applied directly to some phase of Agriculture.

The moisture problem is one of great importance to farmers in the Middle West, and only by careful study of the physical conditions of the soil can the problem be solved. We must learn the conditions which aid in conserving soil moisture, and those which cause a loss, and practice farming methods which conserve the soil moisture. If certain conditions in the laboratory are influential in conserving moisture, like conditions in the field will produce similar effects. Eight experiments have been performed in the laboratory to demonstrate the difference in the relation of the five types of soil to soil moisture and air. In performing these experiments care was given to each soil. Also each soil had received the same treatment previous to experimenting. Each soil was air dried, and sifted so that of each type only the fine soil was used.

Experiment No. 1.

Determination of the specific gravity of soils.

This shows the weight of soils as compared with wqual volumes of water. There are two different kinds of specific gravity; real, and apparent. This is the real.

Apparatus used in experiment:- A 100 c.c. flask with ground glass stopper, drawn out to an open capillary tube; another flask with distilled water; five samples of soil which had been dried at 110° C for 24 hours.

Method of performing esperiment:- The flask with stopper was weighed dry, and then filled with water and wiped dry and weighed again. The soil was then put into flask and flask filled with water and both boiled in water for two minutes, then cooled to temperature of flask before, and weighed again.

Calculation:- Add weight of soil used to weight of flask filled with water and deduct therfrom weight of flask filled with water and soil. The difference expresses the weight of a volume of water equal to the quantity of soil used. The specific gravity is found by dividing the weight of the sokl taken by the weight of the water it has displaced. The following table gives the data taken and the results obtained from the experiment:

Kind of Soil	Wt. of fl. and Water.	Wtl of Soil used.	Wt. of Soil & Water in Flask.	Wt. of water displaced by Soil.	Specific Gravity.
Sand	136.05 gms.	10 gms.	142.3 g.	3.75 g.	2.66
Sandy Loam	" "	" "	142.2 "	3.85 "	2.59
Loam	" "	" "	142.15"	3.90 "	2.56
Humus	" "	" "	142.5 "	4.00 "	2.5
Clay	" "	" "	142.27"	3.78 "	2.64

The specific gravity of the soil is soil calculated free of air spaces, and is found to be from 2.5 to 2.66 times as heavy as water. The specific gravity of the soil has no partivular effect on moisture or air content. It shows more the chemical nature, or the amount of organic matter the sokl contains. The specific gravity decreases as the amount of organic matter contained in the soil increases.

The common minerals and elements found in the soil have a specific gravith of from 2.5 to 3., therefore the soils having the highest specific gravity are the ones which are conposed of compounds of the heavier elements, while those whose specific gravity is as low as 2.5 or perhaps less, are made up largely of the lighter elements, or contain a considerable amount of organic matter.

Experiment No. 2.

Determination of Hygroscopic water in the soil.

The hygroscopic water is the water which is held by the soil, and is not affected by capillarity or evaporated away at air temperatures. It may be called the water held by a soil which is air dried.

Method of performing experiment:- A given amount of soil by weight was placed in a tin receptacle and heated to 110°C for 24 hours. The soil was then weighed again. The loss in weight is the amount of hygroscopic water. The following table gives the weights before and after drying and the per cent of hygroscopic water in each type of soil:

Soils	Wt. before drying.	Wt. after drying.	%Hygroscopic Water
Sand	25 grams.	23.8 grams	4.8%
Sandy Loam	" "	23.15 "	7.4%
Loam	" "	23.1 "	7.6%
Humus	" "	22.3 "	10.8%
n Clay	" "	22.5 "	10.0%

The hygroscopic water is water that cannot be drawn upon by plants. Its only effect is in case of drouth. If a soil becomes very dry and exposed to hot winds, and sun it becomes heated to such a degree as to injure it. The evaporation of hygroscopic water may cool the soil. Then the less hygroscopic water in a soil, the warmer it becomes when dry.

Experiment No. 3.

Determination of apparent specific gravity pore space, and volume weight of soils.

Apparatus used:- A tube closed at one end, and about 13 inches long. The soil compacting machine, and scales.

Method of performing the experiment.- A measure of soil was poured into the tube, and then it is placed in the compacting machine and the weight allowed to fall six times from the 12 inch mark. This is repeated until tube is filled to near the top. Then determine the number of cubic inches occupied by the soil.

Calculation:- Subtract the weight of the empty tube plus the weight of hygroscopic water in the soil used from the weight of the filled tube. This will be the weight of the given volume of soil. By dividing the volume weight of soil by the weight of the sum volume of water the apparent specific gravity is obtained. By dividing this apparent specific gravity by the real specific gravity obtained in experiment No. 1, and subtracting from 100, the remainder expresses the per cent of porosity of the soil, the space which in the dry soil, is occupied by the air. The volume weight and the apparent specific gravity increases with the amount of packing given to the soil, while the pore space decreases.

The following table gives the data taken and the results obtained from the experiment:

Kind of Soil	Vol. of Soil used.	Weight of Soil and Tube	Weight of Soil less tube and Hyg. Water.	Apparent sp. gravity.	Pore Space.
Sand	36.7cu."	3.53#	1.76#	1.33	50%
Sandy Loam	37.48 "	3.28#	1.5#	1.1	57%
Loam	36.05 "	3.11#	1.224#	.94	63.3%
Humus	37.48 "	2.99#	1.16#	.86	65.6%
Clay	36.7 "	3.4#	1.58#	1.2	55.0%

The soil used in this experiment was directly from the bin. It contained more moisture and humus, and more air space than the finely prepared, and oven dried soils. The apparent specific gravity of the soil has no bearing on the subject, except that is shows that a large part of the soil is occupied by air space. It also shows a loose mellow texture of the soil, such as is obtained by deep, and thorough cultivation.

The porosity of soils is an important question in the agricultural world. Soils need air, and the bacteria of the soil reauire air to insure a working condition. The pore spaces allow air to circulate about the roots of the plants, which is necessary to the health of the plant. The pore space also influences the amount of water a soil will hold, and also the rate of capillary action. The capillary action is greater for compact soils.

Experiment No. 4.

The power of loose soils to retain moisture.

Apparatus used:- Tubes with perforated end. Galvanized iron tank, and drainage rack.

Method of performing experiment.- The five different types of soil were poured loosely into the tubes without compacting. A blotter was used to keep soil from passing through the holes in the tube. The tubes were placed in the tank and the tank filled with water to near the top. When the tubes of soil had become thoroughly saturated by capillary water, they were removed and weighed, and pur in the rack to drain by percolation. They were weighed from day to day till percolation ceased entirely. Then the final weight was determined.

Calculation.- The difference in weight between the tubes filled with wet and with dry soil will be the water retained by the loose soil.

Then by determining how much is held by this volume we can determine how much is retained per cubic foot and also the number of surface inches of water it represents. The following table gives the data taken and the amount of moisture held by loose soils:

Kind of Soil.	Wet. Wt.	Dry Wt.	Water held	Wt. of Water per cu. ft.	Inches of water held per cu. ft.
Sand	2.88#	2.59#	.29	22.94#	4.4 inches.
Sandy lm.	2.68#	2.32#	.36	28.5#	5.4 "
Loam	2.33#	1.96#	.37	29.17#	5.52 "
Humus	2.54#	2.06#	.48	37.97#	7.19 "
Clay	2.43#	2.06#	.37	29.17#	5.52 "

Experiment No. 5.

The power of compact soils to retain moisture.

This experiment was performed thesame as the preceding one except that after each measure of soil was poured into the tube it was placed in a compacting machine and the weight allowed to fall six times from the 12 inch mark. The following table gives the data taken and the amount of moisture held by compact soil:

Kind of Soil	Wet. Wt.	Dry Wt.	Water held	Wt. per cu. ft. of Water	Inches of water held per cu. ft.
		66666			
Sand	2.96#	2.68#	.28#	22.15#	4.2 inches.
Sandy Loam	2.60#	2.23#	.37#	29/27#	5.54 "
Loam	2.52#	2.13#	.39#	30.85#	5.84 "
Humus	2.33#	1.97#	.36#	_____	_____
Clay	2.68#	2.30#	,38#	30.1#	5.67 "

No data was determined for the humus soil as it compacted so hard that when placed in water the capillary action could not bring the water to the surface of the tube.

Experiments Nos. 4 and 5 show some very interesting results. By preventing any evaporation from the surface a great amount of water was retained in the soil. With the exception of sand, the compacting slightly increases the water holding capacity of each soil. This goes to show that capillary action is stronger in compact soil than in loose soils, as was stated under experiment No. 3. The conditions obtained in this experiment are such as may be had in any field. With the exception of sand, soil there are more surface inches of water in compact than in loose soils. The next question is: What condition must we have to retain the most water in the soil. The answer is the results obtained in the following experiment:

Experiment No. 6.

Effect of soil mulches on evaporation of water from soils.

Apparatus used.- Compacting machine , and galvanized iron tubes, 18 inches deep by 4 inches in diameter, with a water reservoir around bottom of tube.

Method of performing experiment.- One pint of soil was emptied into tube and tube placed in compacting machine and weight allowed to fall five times from the 12 inch mark. This was repeated until the tubes were of the required depth. The soil used was from the same bin and of the same degree of fineness. Tube No. 0 was compacted till full; No.1 had one inch of loose soil on surface; No. 2 had two inches of loose soil on surface; No. 3 had three inches of loose soil on surface; No. 4 had four inches of loose soil on surface. Then the reservoir was filled with water and each day water was added. The soil was air dry when placed in tube so that it required a great deal of water to moisten it to the degree of saturation when evaporation would begin. The following table gives the amount of water used in each tube:

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Inches of Mulch.	Water used in each tube.	Rate of evaporation per sq. ft.	
0 in.	1555 c.c.	8.71#	in 18 days.
1 "	1520 " "	8.52#	" "
2 "	1455 " "	8.17#	" "
3 "	1407 " "	8.01#	" "
4 "	1380 " "	7.9#	"

This experiment shows well the value of a soil mulch in the field. The tubes were in the laboratory and left uncovered for the entire term allowing constant loss of water by evaporation. The windows and doors were open for a good part of the day, giving a change of air frequently. We find in the experiment that the most water was lost from the can which was compacted to the top with no soil muchlch. It was noticed that the increase of mulch caused a decurease of evaporation but not a constant proportion. The greatest difference in evaporation was observed between the one with 1 inch mulch and the 2 inch mulch. The decrease was not so rapid per inch after the second inch, though the four inch mulch conserved more moisture than the lighter mulches.

Experiment No. 7.

The rate of flow of air through soils.

Apparatus used.- Tubes 2 inches in diameter, closed at one end, with a tube to connect rubber hose with. The aspirator used was made of two tin vessels about eight inches in diameter by eighteen inches deep, one fitting in the other. The larger one has a small tube down through center and passing through the bottom and returns up along the side of vessel to a point higher where there is a stop cock attached to the tube. This can is filled with water and the other can inverted into it, forcing out the air through the tube.

Then a rubber tube is attached to the stop cock and from there to the small tube on the tube of soil, making air tight connections. There was a frame work over the aspirator with two pulley wheels in line, one directly over the center of the smaller vessel. A string was attached to top of the small vessel and passes over these pulleys and is attached to a weight. The second pulley has an arrow which turns before a plate graduated to degrees. The weight on the string raises the vessel, forming a vacuum which can be filled with air only by the air passing through the soil in the tubes. Therefore each degree pointed off by the arrow means a definite amount of air passed through the soil. The following table gives the amount of air passing through each soil in ten minutes:

Kind of Soil	No. of degrees passed over.
Sand	375°
Sandy Loam	295°
Loam	165°
Humus	105°
Clay	22°

This shows a great difference in the amount of air passing through different soils of the same compactness and of the same air pressure. There is seventeen times as much air passes through the same volume of sane as through the clay. The Sandy Loam is next and is about half way between Loam and Sand, showing that the result is similar to what would be expected from a mixture of the two. The Humus is somewhat less than the Loam, but considerable more than the clay. This is accounted for by the way Humus compacts. It has been noticed that when the different soils are given the samd amount of compacting the Humus appears more compact than other soil. This is due to the amount of organic matter present. The amount of air that passes into the soil is of great importance in crop production. Air not only affects the amount of water present in the soil but also the value of the water to the plant. Soils without air passing through become rancid and valueless to plant life.

Experiment No. 8.

Rate of percolation of water through soils.

Apparatus used.° The only apparatus used was a set of tubes 2 inches in diameter, which have a spout at bottom end for water to pass out at, and one extending out at each side at the top for hose connection to allow water to pass over the top of the soil from one tube to another. The tubes are placed so that water will stand to the same level in each tube. Adrain pan is placed under the tubes and when all the tubes are running the test bigins.

Calculation.- When all tubes are percolating we place a graduated beaker under each spout and allow them to flow for 30 minutes and remove and measure the water which has passed through. In the first trial the soil was compacted and two tubes would not percolate at all. This experiment was discarded and another tried with soil loosely poured into the tubes. This worked well with the exception of the Humus, which failed to work. The only reason I know for the failure of the Humus to work was that when the soil became wet from the top, it settled and compacted to such an extent that the water under such small pressure could not pass through. I think this is probable because in determining the power of compact soils to retain moisture we found that when Humus was compacted no water could pass through it by capillary action. The following table gives the amount of water passing through each soil:

Kind of Soil	Amt. of water percolating through in 30 min.
Sand	516.5 c. c.
Sandy Loam	16. " "
Loam	2.5 " "
Humus	None
Clay	2.5 " "

As the volume and surface area of the soils were the same, the figures show a proportion in the rate of percolation. We find that amount passing through sand was enormous whlie there was not very much difference in the rate of percolation with the other four samples, except in the Sandy Loam. This explains why water stands so long on some soils after a rain, while on sand it passes away as fast as it falls. It also shows why so many soils need underground drainage when nearly level. This account for so distince a water level in sandy soil.

After having given each experiment with the results, and the influences of the results obtained on farming in general, I think it would be well to take each soil separately and apply each experiment to it and the treatment each soil should receive.

Sand.

As sand has a high specific gravith it shows the absence of much organic matter. By adding this organic matter we add available plant food, besides changing the physical nature of the soil. It increases the air, and water holding capacity of sand by making more pore space, and checking the rate of percolation. Compacting makes very little difference with sand as to water holding capacity. It would tend to raise the moisture to the surface much faster, but I think it would not be advisable to compact sand, as it is of most too compact a nature under the best conditions obtainable.

Sandy Loam.

Sandy Loam has more Humus present and is a much better soil than sand in all respects. It has more pore space, it holds more water both when loose and when compact. It does not allow water to percolate away as fast but still it drains very well. Its per cent of hygroscopic water is nearly twice that of sand, which tends to prevent extreme heating in hot summer weather. While Sandy Loam does not allow so much air to pass through under the same conditions, it does allow plenty of change of air when in gooe texture.

Loam.

Loam has a great deal of Humus present , making the pore space large and the per cent of hygroscopic water large. Loam holds considerable water both when loose and compact. When compact the air space is greatly reduced and the soil is apt to become water logged and sour. To obtain the best results from Loam it should never be compacted, but left loose and kept well stirred.

Humus.

Humus soil needs more care than any other soil to derived the best results from it. There is apt to be so much organic matter present that it will be injurious. The more organic matter in a soil the more water it will retain, and the slower will be ther rate of change of water and air. Humus soil is generally level and not well drained. Water enters readily, filling the soil to its utmost capacity. The rate of percolation is so slow under normal conditions that without underground drainage the soil will become water-logged. The presence of the vast amount of decaying organic matter will soon cause the soil to becomr sour and unfit for the use of plants, and means death to the bacteria of the soil which assist in preparing the food for plants. The one important thing required in Humus soil then is a system of under drainage that will carry off the surplus water and keep the soil in a healthy condition.

Clay.

Clay soil contains but very little orgainc matter. Clay is of so fine a texture, and has such adhesive qualities that it is hard to get the best conditions for soil moisture, and soil air. While clay soil has a medium per cent of hygroscopic water it retains a large amount of moisture. Then clay gets very wet it sticks together so closely that water and air cannot penetrate through it. The treatment needed by clay soil is the addition of Humus, and good under-drainage. The Humus will tend to prevent the soil particles from adhering so closely, and by keeping the soil more open the water and air can pass through; resulting in a much better physical conditions of the soil. The soil mulch can and should be applied to all soils under cultivation. By having a layer of loose surface soil the capillary tubes, reaching down to the water level, are broken thereby preventing a great loss of water by surface evaporation.

The five types of soil discussed above practically include all soils, or at least the similarity between some one of these and any other soil that can be found is such that the results obtained here can be applied in some way to other soils. While laboratory conditions are not obtainable in the field, het there is a similarity between field, and laboratory conditions, making it possible to apply laboratory principles and results in general to the soil in the field. To learn these principles, and how they can be applied to field conditions, has been our intention, and we feel that we havebeen greatly successful in our work, and that the knowledge that we have derived of the difference between the various types of soil and the treatment that each requires will be a source of great benefit in our work in Agriculture.