A MANUAL OF SOIL PHYSICS

BARKER AND YOUNG

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A MANUAL OF SOIL PHYSICS

BY

PERCY B. BARKER, M.A.

PROFESSOR OF AGRONOMY IN THE UNIVERSITY OF NEBRASKA

AND

HORACE J. YOUNG, B.Sc.

ASSISTANT PROFESSOR OF AGRONOMY IN THE UNIVERSITY OF NEBRASKA

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PREFACE

The exercises described on the following pages are intended to give the student an understanding of the origin, composition, and physical properties of soils and to show the relations of these properties to methods of soil management. The work outlined in the manual is sufficient for two semesters, but may be completed in less time if more than two laboratory periods are held per week.

While these exercises are the outcome of ten years' experience in teaching the important physical properties of soils, they are not all original with the authors. Material has been drawn from many sources and arranged to give the best applications to important principles of soil management.

In connection with each exercise, references have been given and questions asked. It is hoped that this method of study will enable the student to obtain a great amount of information relative to the application of each exercise.

THE AUTHORS

University of Nebraska, College of Agriculture
Lincoln, Nebraska

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MANUAL OF SOIL PHYSICS

INTRODUCTION

SOIL SAMPLING

In collecting samples of soil for study in the laboratory, great care should be taken to obtain samples that are representative of the soils in the area from which they are taken. Avoid taking samples in places where conditions are unusual, such as gopher mounds, squirrel holes, footpaths, cattle trails, old roadways, depressions, and other places showing abnormal plant growth.

After selecting a place which represents the soil and field conditions, scrape away from the surface all foreign matter and plant remains. The underground parts of plants, as well as insects and other animal life in the soil, are considered as a part of it.

The tools commonly used in taking samples are augers and soil tubes (Fig. 14). In sampling by the auger method, two augers, one 3 and one 6 feet long, are usually employed. By using a smaller bit on the 6-foot auger, samples may be procured which are less contaminated with soil from the upper three feet. Marks are made upon the shanks of the augers so that the depth from which the sample is being taken may be easily ascertained. The soil obtained from each foot is placed in a separate bag or container and labeled accurately as to the location and depth. After the sample from one foot has been obtained, work the auger up and down in the hole several times and discard the soil which sticks to the bit. This helps to keep the soil from the next foot from being contaminated with that above. In this manner continue the sampling to the desired depth.

The soil tube has a cutting edge somewhat smaller than the bore. It is simply driven into the soil to the depth of one foot at a time, and a core of soil taken throughout the foot. For convenience, two or more tubes of different lengths are used.

If the samples are being taken for determining the total moisture in the field, precautions should be taken to prevent evaporation. For this purpose tight metal boxes or glass jars are usually employed.

The making of detailed studies of the soil sometimes calls for inch samples. A convenient method of procuring such samples is by means of the Nebraska Soil Auger (Fig. 13). This auger is also useful in obtaining a known volume of soil for determining the apparent specific gravity and porosity of field soil.

Since the composition and physical characters of soils of the same type (especially soils of glacial origin) vary somewhat, it is the practice to take what is known as a composite sample. This means the taking of several samples in the same type and uniting them. The larger the number of places from which soil is taken, the more representative the sample. A composite sample made up of soils from three different locations will usually be fairly representative of areas of less than ten acres.

EXERCISE I

A STUDY OF SOILS IN THE FIELD

Object. The object of the exercise is to make a thorough study of soils under field conditions.

Materials needed. Four-foot auger; 6-foot auger; drawing paper; notebook.

Procedure. Examine several types of soil to the depth of 6 feet, with special reference to the following points:

1. Depth of the surface soil at different locations.
2. Texture and structure at different depths.
3. Amount and distribution of the organic matter at various depths and locations.
4. Variations in color.

The soil types should be selected so as to give a variation in the depth of the surface soil and in the topography. In each type ascertain accurately the depth of the surface soil.

Describe each of the soil types examined, giving due emphasis to depth of surface soil, distribution and amount of organic matter, texture, structure, color, and topographic effects. Draw a section of each type examined, using a scale of 1 inch to the foot, showing the depth of the surface soil, the location of lime concretions, etc. In drawing the sections, use the following legend:

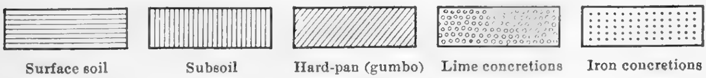


FIG. 1. Legend used in drawing sections

References:

Widtsoe: Dry-Farming, pp. 59–73.
Wiley: Principles and Practices of Agricultural Analysis, Vol. I, pp. 59–60.
Hilgard: Soils, pp. 120–187.
Lyon and Fippin: Soils, pp. 68–69.

Questions:

1. State briefly what is understood by the following terms: (*a*) surface soil; (*b*) subsoil.
2. Explain briefly (*a*) the difference between the surface soil in arid and in humid regions; (*b*) the difference between the subsoil in arid and in humid regions.
3. Account in as many ways as possible for the even distribution of the organic matter in the surface soil.

EXERCISE II

SOIL REGIONS AND PRECIPITATION

Object. The object of the exercise is to make a study of the soil regions of the state or county, together with the distribution of rainfall.

Materials needed. Ruler; hard pencil; base map of state or county; guide map.

Procedure. Draw upon the base map all the regions of main types of soil indicated on the guide map, and the lines representing the annual precipitation. Use the same legend as has been used on the guide map; also place this legend at the bottom of the map.

References:

Condra: Geography of Nebraska, pp. 72–113.

Annual Report of the Nebraska State Board of Agriculture (1909), pp. 271–311

In other states the experiment station bulletins and the surveys of the United States Bureau of Soils will give valuable information.

Questions:

1. How many square miles are there in each region?
2. What is the origin of the soil in each region: (*a*) residual? (*b*) glacial? (*c*) loess? (*d*) alluvial?
3. What is the average annual precipitation in the state or county?
4. In which soil region is your home farm located?
5. What is the annual precipitation on your home farm?
6. Name two crops that are profitably raised in each soil region.

EXERCISE III

GEOLOGICAL MAP AND VERTICAL SECTION OF STATE

Object. The object of the exercise is to make a study of the important geologic formations of the state, with reference to their part in soil making.

Materials needed. Ruler; hard pencil; base map of state or county; drawing paper; guide maps.

Procedure. Draw a map of the state or county, showing the geologic formations as they are exposed on the surface. Use the same legend as is used on the guide map; also place the legend in the margin of the map. Draw, according to scale, a vertical-section profile map, showing the underlying formations of the state or county. Label each formation carefully.

References:

Annual Report of the Nebraska State Board of Agriculture (1906–1907), pp. 325–344.

The bulletins of the State Agricultural Experiment Station or of the State Geological Survey will give valuable information for this exercise.

Questions:

1. Name in order, commencing with the oldest exposed, all the underlying formations in the state or county.
2. What is the surface geologic formation of your home farm?
3. How many formations underlie your home farm or place? Name them.
4. Which formations give rise to good productive soils?
5. Which formations furnish a good water supply? Which a poor water supply?

EXERCISE IV

SOIL CLASSIFICATION

Object. The object of the exercise is to become familiar, first, with the different soil types, and, second, with the scheme of soil classification.

Materials needed. Three-foot auger; notebook.

Procedure:

CLASSIFICATION AS TO ORIGIN

1. Sedentary
   - *a.* Residual
   - *b.* Cumulose
2. Transported
   - *a.* Colluvial
   - *b.* Water
     - (1) Marine
     - (2) Lacustrine
     - (3) Alluvial
3. Glacial
4. Æolian

PHYSICAL CLASSIFICATION

<table>
<tr><td>1. Texture . . . . .</td><td>Class</td><td rowspan="10">Type</td></tr>
<tr><td>2. Structure</td><td rowspan="9">Series</td></tr>
<tr><td>3. Organic matter</td></tr>
<tr><td>4. Origin</td></tr>
<tr><td>5. Color</td></tr>
<tr><td>6. Depth</td></tr>
<tr><td>7. Drainage</td></tr>
<tr><td>8. Topography</td></tr>
<tr><td>9. Native vegetation</td></tr>
<tr><td>10. Natural productiveness</td></tr>
</table>

The field selected for study should contain as many different soil types as can be found together. In this exercise the following points must be kept in mind: texture, structure, organic matter, origin, color, depth, drainage, topography, native vegetation, and natural productiveness. Also the meaning of the following terms should be well understood: *soil province*, *soil series*, *soil class*, and *soil type*.

Write a full description of each soil type that you have studied, giving due emphasis to the ten points mentioned above.

References:

Lyon and Fippin: Soils, pp. 69–80.
Hopkins: Soil Fertility and Permanent Agriculture, pp. 114–136.
"Soils of the United States," in *Bulletin No. 96* of the United States Department of Agriculture, Bureau of Soils, pp. 109–165, 303–381, 465–495.

Questions:

1. What is understood by a soil province, soil series, soil class, and soil type? Give one example of each.
2. Describe the following classes of soils as used by the United States Bureau of Soils: (*a*) fine sandy loam; (*b*) silt loam; (*c*) loam; (*d*) clay loam; (*e*) clay.
3. How deep are soils sampled in establishing soil types?

EXERCISE V

EXAMINATION OF SOIL PARTICLES

Object. The object of the exercise is to study soil particles, with and without the microscope, in order to become familiar with the general composition of soils.

Materials needed. Microscope; sand; surface soil; subsoil; clay; drawing paper; pen or hard pencil.

Procedure. Examine, without the aid of the microscope, a small amount of sand, noting the color and adhesion of the particles. Examine a small amount of sand with the microscope, noting the color, shape of the particles, and any cohesion. While the mount of sand is under the microscope, make a drawing of several particles to show their comparative sizes and shapes.

In the same manner examine some of the surface soil, the subsoil, and the clay, placing the drawings on the same piece of paper with the drawings of the sand particles. In studying the surface soil, note the structure of the crumbs, comparing it with the same structure in the subsoil and in the clay.

References:

Snyder: Soils and Fertilizers, pp. 11–20, 326.

Lyon and Fippin: Soils, pp. 69–79.

Wiley: Principles and Practices of Agricultural Analysis, Vol. I, pp. 282–290.

"The Mineral Composition of Soil Particles," in *Bulletin No. 54* of the United States Department of Agriculture, Bureau of Soils.

Questions:

1. What are the colors of the particles that compose the sand?
2. What is the difference in the color of the particles that compose the sand, the surface soil, the subsoil, and the clay? Why are soil particles so similar in their mineral content?
3. What is the range, in millimeters, in the size of sand particles? silt particles? clay particles?
4. What is the structure of the surface-soil particles? How do you account for such a structure?
5. By what means can you distinguish the organic matter in the different soils while under the microscope?
6. Define sand, silt, clay, and loam.

EXERCISE VI

SOIL-FORMING MINERALS

Object. The object of the exercise is to become familiar with the most important soil-forming minerals.

Materials needed. Specimens of quartz, feldspar, mica, talc, hornblende, calcite, gypsum, dolomite, iron ores, serpentine; gravel; microscope; mortar and pestle; hydrochloric acid.

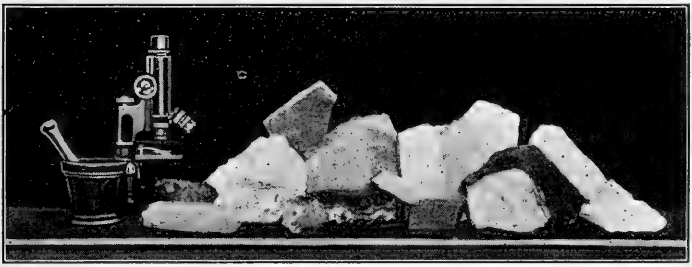


FIG. 2. Common soil-forming minerals

Procedure. Study the above-named minerals, describing each according to the following outline:

1. Name.
2. Crystalline or amorphous.
3. Cleavage (number of planes).
4. Fracture (conchoidal or irregular).
5. Colors.
6. Luster.
7. Hardness.
8. Effect of hydrochloric acid.

9. Composition.
10. Kind of soil formed.
11. Per cent in earth's crust.
12. Miscellaneous.

After describing each mineral select about half a dozen pebbles of the mineral from the gravel. Place them in the mortar and pulverize them, examining the broken pieces from time to time, noting the constancy of the cleavage and fracture characteristics. After they are pulverized examine some of the particles with the microscope, noting the same characteristics.

References:

Lyon and Fippin: Soils, pp. 4–9.
Snyder: Soils and Fertilizers, pp. 64–67.
Crosby: Common Minerals and Rocks, pp. 35–122.

Questions:

1. Write out the scale of hardness you have used in determining the hardness of the different minerals.
2. What is a plane of cleavage?
3. Does the number of cleavage planes influence the weathering qualities of a mineral?
4. Which minerals are found most abundantly in sand? in clay?
5. Define a mineral.
6. Why is mica the most difficult to pulverize?
7. Do the number of cleavage planes and the fractures remain true in the pulverized material?

EXERCISE VII

SOIL-FORMING ROCKS

Object. The object of the exercise is to become familiar with the most important soil-forming rocks.

Materials needed. Specimens of granite, limestone, quartzite, shale, gravel, phosphate rock, sandstone; microscope; mortar and pestle; hydrochloric acid.

Procedure. Study the above-named rocks, describing each according to the following outline:

1. Name.
2. Kind (igneous, sedimentary, or metamorphic).
3. Crystalline or amorphous.
4. Cleavage (number of planes).
5. Fracture (conchoidal or irregular).
6. Colors.
7. Luster.
8. Hardness.
9. Effect of hydrochloric acid.
10. Composition.
11. Kind of soil formed.
12. Miscellaneous.

After describing each rock pulverize a small amount in the mortar, noting the manner in which it breaks down. After it is pulverized examine it under the microscope, noting the cleavage planes and other characteristics due to the mineral composition.

References:

Lyon and Fippin: Soils, pp. 9–15.
Crosby: Common Minerals and Rocks, pp. 35–122.
Merrill: Rocks, Rock Weathering, and Soils, pp. 150–195.

Questions:

1. What is a rock?
2. What minerals are the most abundant in granite?
3. When a rock or a mineral effervesces with hydrochloric acid, what does this denote as to its composition?
4. Define igneous, sedimentary, and metamorphic rocks.
5. Name one igneous, one sedimentary, and one metamorphic rock found in the state or county.

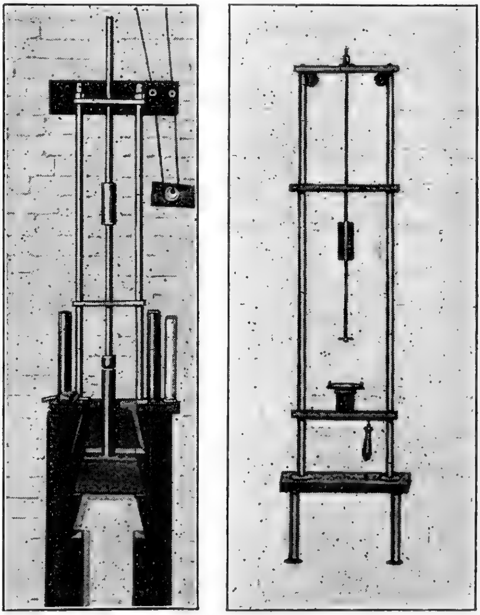
EXERCISE VIII

VOLUME DENSITY AND POROSITY

Object. The object of the exercise is to determine the volume weight, apparent specific gravity, and pore space of soils.

Materials needed. Three tubes; soils; balance; graduate.

Procedure. After weighing the tubes, fill one with sand, another with surface soil, and the third with subsoil, to within 1 inch of the top of the tube. Use compacting machine No. 1 in filling the tubes, allowing the weight to fall eight times from the 12-inch mark for each small measure of soil added to the tube. Determine the volume space occupied by each soil by measurements or by filling the tube to the same height with water and measuring the number of cubic centimeters. If the



No. 1 No. 2

FIG. 3. The two designs of compacting machines used in these exercises

hygroscopic moisture content is not known, it must be determined with a separate sample (see Exercise XII).

Calculation. To obtain the apparent specific gravity of the soil, divide the weight of the water-free soil by the weight of the same volume of distilled water.

$$\text{Per cent pore space} = 100 - \frac{\text{Apparent specific gravity}}{\text{Absolute specific gravity}} \times 100.$$

Tabulate the results in a form similar to the following:

Soil	Weight of Empty Tube	Weight of Filled Tube	Weight of Soil	Weight of Hygroscopic Water	Weight of Water-free Soil in Tube
	Grams	*Grams*	*Grams*	*Grams*	*Grams*
Sand					
Surface soil					
Subsoil					

Soil	Volume of Cylinder	Weight of 1 cc. Water-free Soil	Apparent Specific Gravity	Absolute Specific Gravity[1]	Per Cent Soil Space	Per Cent Pore Space
	CC.	*Grams*				
Sand						
Surface soil						
Subsoil						

From results obtained in this exercise, compute in pounds the weight per cubic foot and weight per acre foot of each soil.

Soil	Weight per Cubic Foot in Pounds	Pounds per Acre Foot
Sand		
Surface soil		
Subsoil		

[1] The average absolute specific gravity of most soils is 2.65.

VOLUME DENSITY AND POROSITY

References:

King: Physics of Agriculture, pp. 108–117.
Lyon and Fippin: Soils, pp. 88–97.
Wiley: Principles and Practices of Agricultural Analysis, Vol. I, pp. 95–99.
Hall: The Soil, pp. 60–67.

Questions:

1. Explain the difference between absolute specific gravity and apparent specific gravity.
2. Given a soil having an apparent specific gravity of 1.1 and a pore space of 58.5 per cent, what is the absolute specific gravity?
3. Given three soils, having pore spaces of 65, 55, and 45 per cent respectively and an absolute specific gravity of 2.65 each, what is the apparent specific gravity of each soil?
4. The apparent specific gravity of soils in the field may be taken as an approximate indication of the tilth of the soil. Explain.
5. What factors influence the apparent specific gravity of soils?

EXERCISE IX

NUMBER AND SURFACE AREA OF SOIL PARTICLES

Object. The object of the exercise is to ascertain the number and surface area of the particles in a given volume of different soil separates.

Procedure. Considering the particles in each separate to be perfect spheres and arranged in a simple columnar structure, find the average number and surface area of the particles in a cubic foot of each of the soil separates, from coarse sand to clay inclusive. In obtaining the average diameter of a separate, use the average of the largest and smallest diameters. Indicate the method used in making the computation and tabulate your results in a form similar to the following:

Soil Separate	Number of Particles per Cubic Foot, in Millions	Surface Area per Cubic Foot, in Acres
Coarse sand		
Medium sand		
Fine sand		
Very fine sand		
Silt		
Clay		

References:

Lyon and Fippin: Soils, pp. 80–84.
King: Physics of Agriculture, pp. 109, 117–122.
King: Soil Management, pp. 161–187.
Widtsoe: Principles of Irrigation Practice, pp. 8–13.

Questions:

1. What are the difficulties in determining the surface area of soil particles accurately?
2. Would the number of soil particles per cubic foot be increased or decreased if the soil had a single, or composite, structure? Explain.
3. What relation exists between the number of soil particles and the total surface area of all soil particles in equal volumes of different soil classes?
4. Is there any relation between the total surface area of all soil particles per volume of soil and the water-retaining capacity? Explain.
5. Is there any relation between the total surface area of all soil particles per volume of soil and the rate of chemical solution by which the plant-food constituents contained in the mineral particles become available for plant use? Explain.
6. What influence does the total surface area of all soil particles per volume of soil have upon the quantity of food materials retained therein in a semiavailable form? Explain.

EXERCISE X

FLOW OF AIR THROUGH SOILS

Object. The object of the exercise is to study the flow of air through different classes of soil.

Materials needed. Three percolation tubes; aspirator; large bottle; graduate; sand; surface soil; subsoil.

Procedure. Fill the three percolation tubes, one with each class of soil, using the compacting machine in filling the tube, allowing the weight to fall three times from the 12-inch mark for each small measure of soil that is added to the tube.

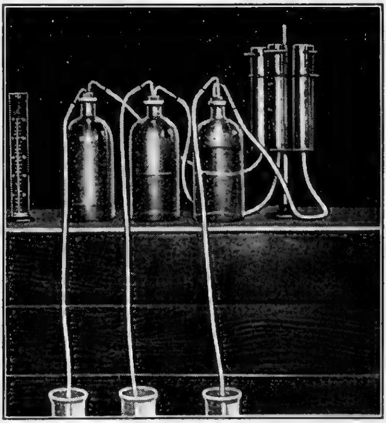


Fig. 4. Bottle aspirators, and apparatus for studying flow of air through soils

After filling the bottle of the aspirator with water, attach the tube that ends near the top of the bottle to the tube containing the sand. By means of the other tube, siphon the water from the aspirator into the large bottle, which should be placed on the floor. Record the number of cubic centimeters of air that will flow through the sand in a given time. The amount of water, in cubic centimeters, that flows from the bottle is equal to the amount of air that is drawn through the soil.

In a similar manner, determine how many cubic centimeters of air will flow through the surface soil and through the subsoil in the same length of time.

Record your results in a form similar to the following:

SOIL	CUBIC CENTIMETERS OF AIR IN 10 MINUTES
Sand	
Surface soil	
Subsoil	

References:

Lyon and Fippin: Soils, pp. 432–447.
King: The Soil, pp. 229–232.
King: Physics of Agriculture, pp. 125–137.

Questions:

1. How do you account for the air flowing through the sand so much faster than through the subsoil?
2. What kinds of soils are naturally well aërated?
3. What kinds of soils are naturally poorly aërated?
4. Name several methods by which aëration of soils that are naturally well aërated may be reduced.
5. Name several methods of increasing aëration in compact, fine-textured soils.
6. What relation does aëration have to growth of organisms in the soil?

EXERCISE XI

PERCOLATION OF WATER

Part I

Object. The object of the exercise is to note the rate of flow of water through different classes of soil.

Materials needed. Three percolation tubes; three beakers; graduate; rubber tubing; sand; surface soil; subsoil.

Procedure. Fill the percolation tubes to within 3 inches of the top, one with each class of soil. In filling the tubes, use compacting machine No. 1, allowing the weight to fall three times from the 8-inch mark for each small measure of soil added to the tube. Place about an inch of gravel on the top of each soil, to prevent puddling. Connect the tubes by means of short pieces of rubber tubing, and, by means of a longer piece, connect to the water cock. Arrange the tubes so that the water will flow over the top of the soil in each tube, the surplus being conveyed into the drain. Before taking the readings, allow the water to percolate through each soil a week.

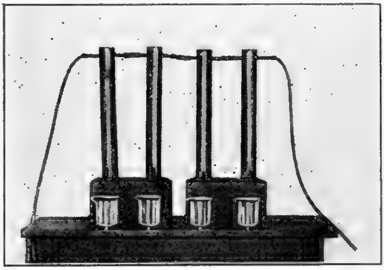


Fig. 5. Apparatus for studying percolation of water through soils

Determine the number of cubic centimeters of water that will flow through each soil in one half hour.

Reduce the results of Exercise X to a ratio and compare with the ratio of water movement.

Tabulate your results in a form similar to the following:

Kind of Soil	Cubic Centimeters in 30 Minutes	Relative Ratio of Water Movement	Relative Ratio of Air Movement
Sand			
Surface soil			
Subsoil			

Part II

Materials needed. Three 8-foot percolation tubes; plotting paper; loam; silt loam; clay. (The tubes should be prepared by the laboratory assistant.)

Procedure. Take readings, every period, of the rate of percolation in each tube, recording your results in a convenient form. After the water has percolated through the entire column, take readings on the amount of water that percolates through each soil in twenty-four hours.

After all the data have been collected, plot curves showing the rate of water movement through each soil.

References:

Hilgard: Soils, pp. 221–228.
Widtsoe: Dry Farming, pp. 111–116.
Hall: The Soil, pp. 75–79.
King: The Soil, pp. 170–173.

Questions:

1. What factors influence the flow of water through soils?
2. What objections to a sandy subsoil does this exercise show?
3. In what practical way may a clay subsoil be improved?
4. Will water percolate most rapidly through a dry, a moist, or a wet soil? Explain your answer in full.

EXERCISE XII

DETERMINATION OF HYGROSCOPIC MOISTURE

Object. The object of the exercise is to make a determination of the amount of hygroscopic moisture in air-dry soil.

Materials needed. Three tin boxes; balance; drying oven; sand; surface soil; subsoil.

Procedure. Put a 20- or 30-gram sample of each air-dry soil into a weighed tin box, and heat in a drying oven at 110° C. until a constant weight is reached. (Constant weight is usually reached, with most air-dry soils, in two and one-half hours.) The loss in weight is due to the loss of hygroscopic water.

Determine the per cent of hygroscopic moisture in each sample of soil, using *water-free soil* as the basis of calculation.

Tabulate the results in a form similar to the following:

Soil	Weight of Can	Weight of Can and Soil		Weight of Hygroscopic Water	Weight of Water-free Soil	Per Cent of Hygroscopic Water
		Before heating	After heating			
	Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
Sand						
Surface soil						
Subsoil						

References:

Hall: The Soil, pp. 84–88.
Hilgard: Soils, pp. 195–201.
Lyon and Fippin: Soils, pp. 143–145.

Questions:

1. Define hygroscopic water.
2. Name the soil and climatic factors that influence the hygroscopic capacity of soils.
3. What influence does the porous condition of the various soil materials have upon the amount of hygroscopic water in a soil?
4. Is hygroscopic moisture of utility to plant growth? Discuss at length.

EXERCISE XIII

CAPILLARY RISE OF WATER IN SOILS

Object. The object of the exercise is to make a detailed study of the upward movement of the water in different classes of soil when in different conditions.

Part I

Capillary Rise of Water in Loose Soils

Materials needed. Three 6-foot sections of 2-inch tubing; sand; surface soil; subsoil; ruler; muslin; plotting paper.

Procedure. Fill three tubes, one with each class of soil, exercising care to compact the soils as little as possible. After placing the tubes in the tube rack and adding water, take readings every half hour during the period. Also take readings every day for a week and then once a week until the end of the exercise.

Part II

Capillary Rise of Water in Compact Soils

Materials needed. Three 6-foot sections of 2-inch tubing; sand; surface soil; subsoil; ruler; muslin; plotting paper.

Procedure. Fill three tubes, one with each soil. Compact the tubes by tapping the sides of the tube six times after each measure of soil has been added. The water should be added to these tubes at the same time it is added to the tubes in Part I. Take all readings as directed in Part I.

Part III

Determination of the per cent of Capillary Water

Materials needed. Soil containers; balance; drying oven.

Procedure. When the capillary water has risen as high as it will by capillarity or has reached the top of the tube, obtain samples from each tube representative of each six inches from the top of the water table to the top of the moist column. Determine the per cent of moisture in all six tubes for every 6-inch section.

Part IV

Capillary Rise of Water in Loam, Silt Loam, and Clay

Materials needed. Three 8-foot tubes; loam; silt loam; clay; plotting paper. (The tubes should be prepared by the laboratory assistant.)

Procedure. Take readings, every period, of the rate at which the water rises in the three classes of soil, recording your results in a convenient form.

After all the data for Parts I, II, and IV have been collected and tabulated in a convenient form, plot curves showing the capillary movement of the water as observed in each part.

References:

Hilgard: Soils, pp. 201–215.
Widtsoe: Dry-Farming, pp. 106–111.
Hall: The Soil, pp. 97–102.
Lyon and Fippin: Soils, pp. 169–189.

Questions:

1. In which soil was the water rising most rapidly at the end of the first hour? the 48th hour? the 112th hour? Explain.
2. What effect does compacting a soil have upon the capillary movement of the water?

3. What factors influence the amount of water drawn up in soils?
4. What factors influence the rise of capillary water in soils?
5. What is the effect on capillarity if wet from the top as in rains? Explain in full.
6. Is the quantity of water in the moist column uniformly distributed? Explain in full.
7. Why is the daily rise of water not uniform?

EXERCISE XIV

EFFECT OF ORGANIC MATTER AND DRY CLODS UPON CAPILLARITY

Object. The object of the exercise is to note the effect of organic matter and dry clods upon the capillary rise of water in soils.

Materials needed. Stand with three glass tubes; three beakers; ruler; muslin; surface soil; clods; compost; sawdust.

Procedure. Tie a piece of muslin over the bottom of each tube and fill each with 12 inches of surface soil. Place a 1-inch layer of clods in one tube, a 1-inch layer of compost in another, and a 1-inch layer of sawdust in the third; then fill the remainder of each tube with surface soil. Place the tubes in the stand and fill the beakers about half full with water. Every thirty minutes for the remainder of the period take accurate readings of the rate at which the water rises in each tube.

Tabulate your results in a form similar to the following:

Soils	Hours					
	½	1	1½	2	24	48
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
Surface soil and clods						
Surface soil and compost . . .						
Surface soil and sawdust . . .						

References:

Fletcher: Soils, pp. 89–96.
Lyon and Fippin: Soils, pp. 144–160.

Questions:

1. What effect does a layer of coarse organic matter have upon the capillary rise of water?
2. What may be the effect of plowing under coarse organic matter just prior to planting corn?
3. What may be the effects upon capillarity if land which is to be planted to corn is plowed the previous fall?
4. Is there any reason suggested in the exercise for plowing the wheat land several weeks before sowing the seed? Explain.

EXERCISE XV

POWER OF SOILS TO RETAIN WATER AGAINST PERCOLATION

Object. The object of the exercise is to study the water-retaining power of soils in different degrees of compactness and containing various amounts of organic matter.

Materials needed. Two stands of six tubes each; sand; surface soil; subsoil; compost or sawdust; 4-gallon jar; scales.

Part I

Power of Loose Soils to retain Water against Percolation

Procedure. Weigh three tubes and record the weights in the proper blanks. Fill the tubes to within two inches of the top, one with each class of soil, exercising care not to compact the soil more than is necessary. Weigh and label the filled tubes. (A very convenient method of labeling is to place a small piece of paper on the top of the soil in the tube.)

Determine the per cent of hygroscopic moisture in each sample, and the apparent specific gravity.

Part II

Power of Compact Soils to retain Water against Percolation

Procedure. Weigh three other tubes as indicated in Part I. Fill one tube with each class of soil. Compact the soil with compactor No. 2 if possible; otherwise use machine No. 1, allowing the weight to fall four times from the 12-inch mark for each measure of soil that is added. Weigh and label as directed in Part I. Also make all determinations as in Part I.

Part III

Power of Organic Matter to retain Water against Percolation

Procedure. Repeat Parts I and II, using the remaining six tubes. The soil, however, should be mixed with one fourth its volume of compost.

Procedure in general. After filling and weighing all the tubes, place them in the jar and fill it with water, so that the water level is a little above the level of the soil in the tubes. Allow them to remain in the water until the soil is thoroughly saturated. After saturation remove them and weigh as soon as possible; then place them in the stands and allow to drain for two weeks. Place two inches of cotton in the tops of the tubes to reduce evaporation. Weigh the tubes every period during the two weeks and note the rate of loss in each.

It is difficult to determine the time when the soils are thoroughly saturated if the water is allowed to run into the tubes from the top. By submerging the tubes below the level of the soil and allowing the water to flow up from the bottom the time of complete saturation will be indicated when the water appears on top of the soil.

Calculate the weight of water, the per cent of water, the pounds per cubic foot, and the inches of water retained against percolation in each soil. In making these calculations the student will find it necessary to know the apparent specific gravities of the samples. It is not required that a special determination be made at this point, provided the student has already obtained the figures from a previous exercise.

POWER TO RETAIN WATER AGAINST PERCOLATION

Tabulate your results in a form similar to the following:

POWER OF____________TO RETAIN WATER AGAINST PERCOLATION

KIND OF SOIL	WEIGHT OF TUBE	WEIGHT OF TUBE AND SOIL	WEIGHT OF AIR-DRY SOIL	WEIGHT OF WATER-FREE SOIL	APPARENT SPECIFIC GRAVITY
	Grams	*Grams*	*Grams*	*Grams*	
Sand					
Surface soil . . .					
Subsoil					

KIND OF SOIL	WEIGHTS OF TUBES AND SOILS AFTER SATURATION				
	Date	Date	Date	Date	Date
	Grams	*Grams*	*Grams*	*Grams*	*Grams*
Sand					
Surface soil					
Subsoil					

KIND OF SOIL	MAXIMUM WEIGHT OF WATER RETAINED AGAINST PERCOLATION	WATER RETAINED AGAINST PERCOLATION	WATER RETAINED PER CUBIC FOOT	
	Grams	*Per cent*	*Pounds*	*Inches*
Sand				
Surface soil . .				
Subsoil				

References:

King: Physics of Agriculture, pp. 131–141.
Hilgard: Soils, pp. 207–214.

Questions:

1. Why is it important to know the water-retaining power of soils? Explain.
2. Explain why the compact surface soil and subsoil will not hold as much water against percolation as they do when loose.
3. Why does the addition of organic matter increase the water-holding capacity?

EXERCISE XVI

THE EFFECTIVENESS OF MULCHES

Object. The object of the exercise is to study the effect of mulches to retard evaporation of moisture from the soil.

Materials needed. Eight evaporimeters; scales; surface soil; mulching materials. It is advisable that the instructor start this exercise, so that the student may begin at once to make weighings of the evaporimeters.

Procedure. Fill the evaporimeters to within three inches of the top with surface soil. Over the surface of the soil in each evaporimeter place a 3-inch mulch in the following order:

1. No mulch; soil compact.
2. No mulch; soil compact (check).
3. Soil mulch, cultivated three inches deep.
4. Soil mulch, cultivated three inches deep (check).
5. Gravel mulch.
6. Sand mulch.
7. Sawdust mulch.
8. Cut-straw mulch.

Weigh the evaporimeters every period for two or three weeks, and at the end of that time determine the amount of water that has evaporated from each evaporimeter.

Calculate in terms of tons per acre and in inches of rainfall the amount of water that has been evaporated from each evaporimeter.

Tabulate your results in a form similar to the following:

Tube No.	Date	Date	Date	Date	Date	Date	Date	Total Evaporation
	Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
1								
2								
3								
4								
5								
6								
7								
8								

Tube No.	Average Amount of Water evaporated in One Day	Water evaporated in One Day per Acre	Water evaporated in One Day	Time required to evaporate One Inch
	Grams	*Tons*	*Inches*	*Days*
1				
2				
3				
4				
5				
6				
7				
8				

References:

King: Physics of Agriculture, pp. 185–195.

Lyon and Fippin: Soils, pp. 199–210.

"Soil Mulch" in *Twenty-fifth Annual Report of Nebraska Agricultural Experiment Station*, pp. 124–128.

Widtsoe: Dry-Farming, pp. 152–156.

Questions:

1. What climatic factors influence the evaporation of moisture from the soil?
2. What constitutes a mulch?

3. Under what conditions may a hard, dry layer of soil be as effective as a loose, dry layer of soil in retarding the evaporation of moisture? Explain.
4. Why is sand, gravel, or straw more effective as a mulch than the loose soil?
5. When is it practical to use the following materials as mulches: gravel? sand? straw?

EXERCISE XVII

EFFECT OF WATER UPON SOIL VOLUME

Object. The object of the exercise is to determine the per cent of expansion and the per cent volume shrinkage of soils.

Materials needed. Four cans; ruler; sand; surface soil; subsoil; clay.

Procedure. Place exactly three centimeters of soil in each can, using one can for each class of soil. Slowly add water to each can until the soil is thoroughly saturated; then measure the number of centimeters of expansion. Place the cans in a warm place and allow them to dry. When dry, take measurements of the volume occupied by each soil.

Calculate the number of cubic centimeters of expansion and shrinkage, and the per cent of expansion and volume shrinkage based upon the original volume of the soil.

Tabulate the results in a form similar to the following:

Soil	Cubic Centimeters		Expansion on Basis of Original Volume	Shrinkage on Basis of Original Volume
	Expansion	Shrinkage		
	cc.	*cc.*	*Per cent*	*Per cent*
Sand				
Surface soil				
Subsoil				
Clay				

References:

Warrington: Physical Properties of the Soil, pp. 35–42.
Hall: The Soil, pp. 34–35.
Lyon and Fippin: Soils, pp. 97–99.

Questions:

1. What is the per cent of linear shrinkage of clay? the per cent of volume shrinkage?
2. Name the factors that influence the degree of shrinkage in soils.
3. Explain the effect of shrinkage on crop growth.
4. Give three good methods of retarding the checking of clay soils.

EXERCISE XVIII

LOSS ON IGNITION

Object. The object of the exercise is to determine the amount of organic matter in the soil when the total volatile matter is considered as organic matter.

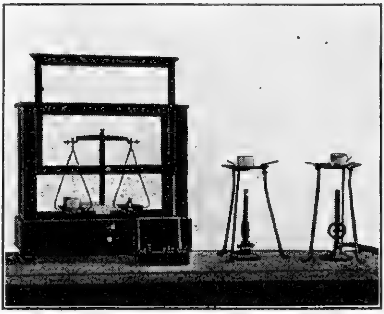


Fig. 6. Apparatus for determining the loss on ignition

Materials needed. Three crucibles; three burners; three tripods; soils; desiccators; balance.

Procedure. Put about 10 grams of each soil in separately weighed crucibles and ignite at a slow red heat. Stir the soil from time to time, noting the change in color. The stirring of a hot soil should never be attempted with a glass rod, as it is apt to chip off and cause trouble. After complete ignition place the crucible containing the soil in a desiccator to cool, and then weigh.

Note 1. A very convenient method of working the exercise is to use the water-free soil. If air-dry soil is used, the hygroscopic moisture content must be determined with a separate sample.

Note 2. It will be frequently noticed during the process of ignition that the soil surface becomes darker in color. In some instances this is partially due to the water movement from the soil, but usually it is caused by the breaking up of carbon compounds and the temporary deposit of carbon on the surface of the soil. This temporary deposit is soon oxidized and lost as a gas.

Tabulate your results in a form similar to the following:

Soil	Weight of Crucibles	Weight of Crucible and Soil		Loss by Ignition	Weight of Water-free Soil	Loss in Organic Matter	Organic Matter Calculated in		
		Before ignition	After ignition				Per cent	Pounds per cubic foot	Tons per acre foot
	Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*			
Sand									
Surface soil									
Subsoil									

References:

Lyon and Fippin: Soils, pp. 124–127.
Hall: The Soil, pp. 42–47.
"Changes in the Composition of the Loess Soil," in *Bulletin No. 111* of the Nebraska Agricultural Experiment Station.

Questions:

1. Why do soils change color upon ignition?
2. What is organic matter?
3. Distinguish between organic matter and humus.
4. What essential plant-food elements are removed from the soil by ignition?

EXERCISE XIX

SOIL ACIDITY AND BASICITY

Object. The object of the exercise is to study the method of determining whether a soil is acid or basic.

Materials needed. Blue and red litmus paper; two evaporating dishes; distilled water; soils.

Procedure. In testing a soil with litmus paper the greatest care must be exercised. All apparatus must be clean, and the paper must not be handled with sweaty fingers.

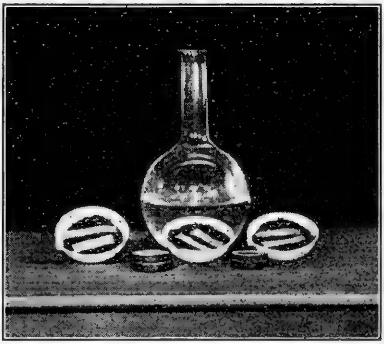


Fig. 7. Testing soils with litmus paper for acidity

Fill one of the evaporating dishes nearly full with soil and moisten with distilled water. Place a piece of the red litmus paper on the soil; press it down with a clean knife blade, so that it is well in contact with the soil. In a similar manner place a piece of blue litmus paper on the same soil on the opposite side of the dish from the red paper; allow it to stand for ten minutes, and then observe results. Care must be taken not to confuse the two pieces of paper.

After making one determination procure unknown samples from the instructor, and determine whether they are acid or basic. Report your results to the instructor.

References:

"Acid Soils," in *Bulletin No. 90* of the Oregon Agricultural Experiment Station.

Fletcher: Soils, p. 401.

Van Slyke: Fertilizers and Crops, pp. 140–144.

"Soil Acidity and Liming," in *Bulletin No. 230* of the Wisconsin Agricultural Experiment Station.

EXERCISE XX

DETERMINATION OF HUMUS

Object. The object of the exercise is to determine the amount of humus in soils.

Materials needed. Two 250-cc. Erlenmeyer flasks; balance; distilled water; hydrochloric acid (4 per cent solution); ammonium hydroxide (5 per cent solution); two glass funnels; filter paper; two beakers; graduate; burner; tripod; two evaporating dishes; water bath; water-free surface soil.

Procedure.

1. Weigh two samples of from 10 to 15 grams of water-free surface soil and place in separate flasks.
2. Add to each flask 100 cc. of 4 per cent hydrochloric acid and allow to digest for at least twenty-four hours.
3. Transfer the soil to a filter in a funnel, and filter off all the acid, discarding the filtrate. Wash the soil thoroughly with distilled water.
4. After the soil has been thoroughly washed, pass 5 per cent ammonium hydroxide through the soil until the filtrate is entirely clear or does not give a precipitate when treated with hydrochloric acid.
5. Transfer the filtrate to an evaporating dish and evaporate to dryness; then dry for one hour at 100° C.
6. When dry, weigh and ignite at a red heat; then reweigh. The loss in weight is humus.
7. Calculate the per cent of humus in the sample and in terms of pounds per acre foot.

Record your results in a form similar to the following:

	Weight of Evaporating Dish and Residue		Weight of Humus	Per Cent of Humus	Pounds per Acre Foot
	Before ignition	After ignition			
	Grams	*Grams*	*Grams*		
First sample					
Second sample					

References:

Hilgard: Soils, p. 132.
Wiley: Principles and Practices of Agricultural Analysis, pp. 357–366.
Widtsoe: Dry-Farming, pp. 58–59.
Snyder: Soils and Fertilizers, pp. 103–116.

Questions:

1. What is the material left in the evaporating dish after the humus has been driven off by ignition?
2. What are some of the defects of the Grandeau method of humus determination?
3. Describe the formation of humus in the soil.
4. Discuss the relative plant-food values of humus found in humid and in arid regions.

EXERCISE XXI

LEACHING OF SOILS

Object. The object of the exercise is to study the leaching of soils.

Materials needed. Three glass tubes in stand; muslin; three beakers; distilled water; graduate; sand; surface soil; subsoil.

Procedure. Tie a piece of muslin over the small end of the tubes and place 6 inches of sand in one tube, 6 inches of surface soil in a second, and 6 inches of subsoil in the third. Place the filled tubes in the stand and pour 50 cc. of distilled water into each. Allow the water to percolate into the beakers, which are placed under the tubes.

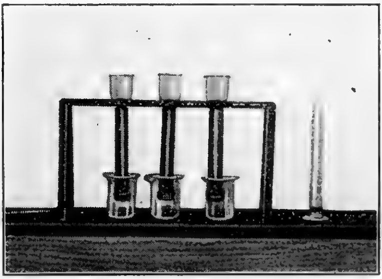


FIG. 8. Apparatus for studying leaching of soils

Observe the color of the water after it has percolated through each soil. The first two or three drops should be compared with the last few drops as to their color. Write a brief summary of your observations and conclusions.

References:

Hilgard: Soils, pp. 22–28.
Widtsoe: Dry-Farming, pp. 65–66.
Hopkins: Soil Fertility and Permanent Agriculture, pp. 556–561.
King: Physics of Agriculture, pp. 77–79.

Questions:

1. Why does the water become colored in passing through the soil?
2. What undesirable effects of heavy rains are suggested in this exercise? Explain.
3. Can leaching be retarded? Explain the methods.
4. What salts are least liable to be leached from the soil?
5. The humid soils contain 15 per cent less soluble material than arid soils and, as compared with the semiarid region, 9 per cent less soluble material.[1] Is this condition due to the power of the soil to retard leaching or to climatic factors? Explain.

[1] Lyon and Fippin: Soils, p. 66.

EXERCISE XXII

POWER OF SOILS TO ABSORB SALTS

Object. The object of the exercise is to study the absorptive power of different classes of soil.

Materials needed. Three glass tubes in stand; three beakers; muslin; graduate; eosin solution; sand; surface soil; subsoil.

Procedure. Tie a piece of muslin over the small end of each tube and place 6 inches of sand in one tube, 6 inches of surface soil in another, and 6 inches of subsoil in a third. Place the filled tubes in the stand and pour two inches of the solution over each soil. Place beakers under the tubes to catch the solution that percolates through the soil.

Note carefully the color of the first two or three drops that percolate through each soil, and compare it with the last drops that percolate through. Write a brief summary of your observations and conclusions.

References:

Snyder: Soils and Fertilizers, pp. 191–197.
Hopkins: Soil Fertility and Permanent Agriculture, pp. 562–564.
Hall: The Soil, pp. 211–232.
Fraps: Principles of Agricultural Chemistry, pp. 234–243.

Questions:

1. Do all soils have some power to absorb salts?
2. Make a comparison of the color of the solutions that drip from each class of soil.
3. What salts do not undergo fixation?
4. Why is it important that soils have the power of absorption?
5. What factors influence the power of absorption?

EXERCISE XXIII

ABSORPTION OF GASES BY SOILS

Object. The object of the exercise is to study the power of soils to absorb gases.

Materials needed. Four air-tight containers; four watch glasses; sand; surface soil; subsoil; ammonia water.

Procedure. In one of the containers place about 50 grams of sand; in the second, 50 grams of surface soil; and in the third, 50 grams of subsoil. No soil is placed in the fourth container. Pour a few drops of ammonia water on each of the watch glasses and place one in each container. Cover the container so that none of the ammonia gas can escape. Put the containers away until the next period. At the next laboratory period open and try to detect the odor of ammonia in each container.

References:

Hall: The Soil, pp. 214–216.
Hilgard: Soils, pp. 272–276.
"Absorption of Vapor and Gases by Soils," in *Bulletin No. 51* of the United States Department of Agriculture, Bureau of Soils.

Questions:

1. What differences can you notice in the odor of the four containers after letting them stand from one period to the next? Name the soils in the order of their greatest apparent absorptive power.
2. Is absorption a physical or a chemical process?
3. What is absorption?
4. How is this exercise related to the application of organic matter?

EXERCISE XXIV

ABSORPTION OF MOISTURE BY SOILS

Object. The object of the exercise is to study the power of soils to absorb moisture when placed in a saturated atmosphere.

Materials needed. Six tin boxes; plotting paper; thermometer; water-free soils; compost; balance; moist-air chamber.

Procedure. Weigh 20 grams of water-free sand, surface soil, subsoil, clay, and compost in separately weighed boxes. Place them, with the covers removed, in the moist-air chamber. Place the empty can in the moist-air chamber, to determine the amount of moisture that collects on it. Ascertain the weight of each can at the end of 24, 48, 72, and 96 hours, recording each time the temperature of the air in the chamber.

NOTE. In making the weighings do not leave the lid of the moist-air chamber open any longer than necessary, as it causes a change in the humidity of the atmosphere. Make all weighings as rapidly as possible, in order that the loss by evaporation may be reduced to a minimum.

Tabulate your results in a form similar to the following:

SOIL	TEMPERATURE	WATER ABSORBED DURING				
		1st 24 hrs.	2d 24 hrs.	3d 24 hrs.	4th 24 hrs.	Total
	Degrees	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Sand . . .						
Surface soil .						
Subsoil . .						
Clay. . . .						
Compost . .						

Plot curves showing the amount of absorption by each soil as indicated by the data.

References:

Hilgard: Soils, pp. 196–200.
Hall: The Soil, pp. 84–89.
"The Wilting Coefficient for Different Plants and its Indirect Determination," in *Bulletin No. 230* of the United States Department of Agriculture, Bureau of Plant Industry.

Questions:

1. What is meant by the maximum hygroscopic coefficient of soil?
2. What relation exists between the maximum hygroscopic coefficient and the wilting coefficient of soils?
3. What practical applications may be made of the determinations for the maximum hygroscopic coefficient of soils?
4. What factors influence the absorption of moisture from the air?
5. Why should the temperature be kept as nearly constant as possible?

EXERCISE XXV

FLOCCULATION OF CLAY

Object. The object of the exercise is to study the flocculating effect of various materials on clay particles in suspension.

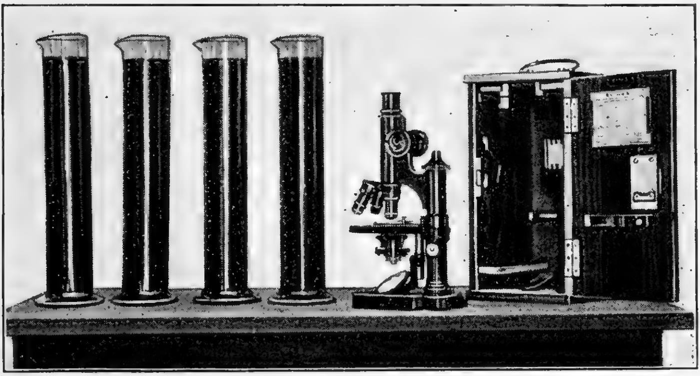


FIG. 9. Apparatus for studying flocculation

Materials needed. Four glass cylinders; clay; distilled water; 1 per cent ammonia solution; alum; limewater; pipette; microscope.

Procedure. Place 20 grams of clay in one of the cylinders and fill with distilled water. Stir thoroughly the contents of the cylinder, and after five minutes of sedimentation decant the turbid liquid into a second cylinder, rejecting all the sediment. Divide the turbid liquid into four equal portions. To one of the cylinders add 20 cc. of limewater; to the second, 10 cc. of ammonia water; and to the third, 0.1 grams of alum. Fill all four cylinders with distilled water, stir, and set aside, observing the results. After twenty-four to forty-eight hours examine, with the aid of a microscope, some of the particles in each cylinder. Procure a sample for the mount from the bottom of the cylinder by the use of the pipette. Care should be taken not to destroy the structure of the floccules.

Take careful notes on the rate of flocculation in the four cylinders, as well as the time required for the water to become comparatively clear. Write a brief summary of your observations.

References:

Hall: The Soil, pp. 38–41.

Van Slyke: Fertilizers and Crops, pp. 103–104.

"The Effect of Soluble Salts on the Physical Properties of Soil," in *Bulletin No. 82* of the United States Department of Agriculture, Bureau of Soils.

Questions:

1. In which cylinder does the turbid water first become clear?
2. What is the physical effect of liming clay soils? Explain.
3. Define flocculation.
4. What materials will cause flocculation?
5. What materials will cause deflocculation?

EXERCISE XXVI

EFFECT OF LIME ON SOIL STRUCTURE

Object. The object of the exercise is to study the crumbling or granulating effect of lime on clay soils.

Materials needed. Three pans; air-slaked lime; clay.

Procedure. Place about half an inch of clay in each of the three pans. Add to one of the pans one eighth as much air-slaked lime as there is soil in the pan; to a second pan add one fourth as much lime as there is soil; leave the third pure clay. Mix the lime thoroughly with the soil in the two pans, taking care that no lumps remain. Add to each pan enough water to saturate it; then place all three pans where they will dry. Do *not* stir the soil after adding the water.

As soon as the soils are dry, make drawings of each soil, showing the cracks that have been formed. Afterwards examine each soil carefully, noting the physical condition and comparative hardness.

References:

Lyon and Fippin: Soils, pp. 116–118.
Hall: Fertilizers and Manures, pp. 253–257.
Hopkins: Soil Fertility and Permanent Agriculture, pp. 160–182.

Questions:

1. What is the effect of lime on the cohesiveness of the soil particles?
2. In what form and in what amounts should lime be applied to a clay soil to change the structure?
3. In which pan is the soil the hardest? the softest? Why?

EXERCISE XXVII

EFFECT OF SAND AND ORGANIC MATTER ON SOIL STRUCTURE

Object. The object of the exercise is to study the effect of sand and organic matter upon the texture and structure of soils.

Materials needed. Three pans; sand; sawdust; clay.

Procedure. Place one half inch of clay in one of the pans and add to it one eighth as much sand, mixing it thoroughly. In a similar manner, place as much clay in another pan and add one eighth as much sawdust, mixing it well with the soil. Fill the third pan with an equal amount of clay, then add sufficient water to make the contents of each pan in a slushy condition, and put them away to dry.

When dry, make drawings of the soils, showing the cracks. Work over the material in each pan, noting carefully the structure and hardness of each soil.

References:

Lyon and Fippin: Soils, pp. 113–116.
Van Slyke: Fertilizers and Crops, pp. 134–140.

Questions:

1. In which pan is the soil the hardest? the softest? Why?
2. From the results of the exercise, is it advisable to add organic matter to the fine-textured soils to alter their physical condition?
3. When is it practical to add sand to a soil in order to change the texture and the structure?
4. What are the most important physical properties of soils that are modified by the addition of sand or organic matter?

EXERCISE XXVIII

EFFECT OF ALTERNATE WETTING AND DRYING ON SOIL STRUCTURE

Object. The object of the exercise is to study the effect of alternate wetting and drying on the structure of soils.

Materials needed. Six pans; spatula; surface soil; clay.

Procedure. Place 150 grams of surface soil in each of three pans and mix to a pasty mass. Use the spatula in mixing the soil, destroying any crumb structure that may exist. Put the pans in a warm place and allow the soils to dry. When dry, add a sufficient amount of water to two of the pans to saturate the soil, but *do not stir* it. Allow them to dry, and again wet one of the pans and again allow it to dry. In each of the other three pans mix 150 grams of subsoil to a pasty mass and treat in the same manner as the surface soil.

After the soils are thoroughly dried, make a comparative study of the soils in each pan, noting the compactness and friability. Crumble a little of the soil from each pan between the thumb and finger, noting its relative hardness. Write a brief discussion of your observations, accounting for the differences in the soils.

References:

Lyon and Fippin: Soils, pp. 105–108.

"Moisture Content and Physical Condition of Soils," in *Bulletin No. 50* of the United States Department of Agriculture, Bureau of Soils.

Questions:

1. Why does alternate wetting and drying change the structure of soils?
2. From the results of this exercise, may there be any benefit derived from plowing clayey soils before the fall rains?
3. Why are soils that have been wetted more than once, more granular in structure than soils that have been wetted only once?
4. Would a sandy soil (75 per cent sand) show the same effect of wetting and drying?

EXERCISE XXIX

EFFECT OF ALTERNATE FREEZING AND THAWING ON SOIL STRUCTURE

Object. The object of the exercise is to study the effect of alternate freezing and thawing on soil structure.

Materials needed. Four pans; surface soil; clay.

Procedure. Mix to a pasty mass 150 grams of surface soil in each of two pans and 150 grams of clay in each of the other two pans. Place one of the surface-soil pans and one of the subsoil pans where they will freeze, and the other pan of each soil where they will dry out slowly. After the soils in the two pans are frozen, put them in a warm place until they thaw out, and again allow them to freeze. Repeat this process of freezing and thawing twice; then dry the soils out slowly.

When the soils are dry, determine the relative hardness of each, noting any differences that may exist in the structure of the soils.

References:

Lyon and Fippin: Soils, pp. 108–111.
Hilgard: Soils, pp. 118–119.
"Physical Improvement of Soils," in *Circular No. 82* of the Illinois Experiment Station.

Questions:

1. From the results of the exercise, would it be advisable to hold water in the surface soil in the fall of the year, so that the soil would be subject to a greater freezing and thawing?

2. Which is the most effective in producing a desirable structure, alternate freezing and thawing or alternate wetting and drying?
3. Why does the alternate freezing and thawing change the structure of the soil?
4. Why are the clay soils of some Southern states in poorer tilth in the spring than similar soils in the Northern states?
5. Give illustrations showing the same effects of freezing and thawing on materials other than soil.

EXERCISE XXX

EFFECT OF COLOR ON SOIL TEMPERATURE

Object. The object of the exercise is to study the effect of color on soil temperature.

Materials needed. Two thermometers; black and white cloths; five flower pots, three white and two black; sand; surface soil; subsoil.

Procedure. Fill one of the black pots with surface soil, and fill one of the white pots with sand and one with subsoil. After taking temperature readings in all of the pots at depths of 1, 2, and 3 inches, place them in the full sunlight.

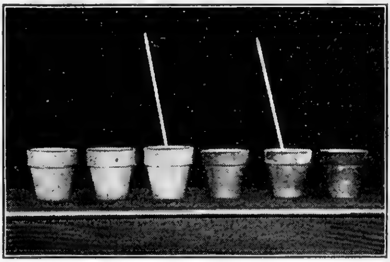


FIG. 10. Method of studying soil temperature

Fill the other black pot with surface soil, covering the top with $\frac{1}{8}$ inch of charcoal. Fill the remaining white pot with surface soil and cover with $\frac{1}{8}$ inch of lime. After taking readings at depths of 1, 2, and 3 inches, place them in the full sunlight.

Hang the two colored cloths in the full sunlight and at the end of fifteen minutes take temperature readings 1 inch from the back of the cloths. If the thermometer is held against the cloth or too far back from it, the reading taken will be useless for this exercise.

Take readings every half hour during the period, recording the results in a form similar to the following:

Depth	Sand				Surface Soil				Subsoil			
	Original	Hours			Original	Hours			Original	Hours		
		½	1	1½		½	1	1½		½	1	1½
1 inch . . .												
2 inches . .												
3 inches . .												

Depth	Light Covering				Dark Covering			
	Original	Hours			Original	Hours		
		½	1	1½		½	1	1½
1 inch								
2 inches								
3 inches								

White cloth............... Black cloth...............

References:

Hall: The Soil, pp. 126–128.
King: Physics of Agriculture, p. 217.

Questions:

1. How does color affect the temperature of the soil?
2. How does the color of a soil affect its heat-retaining power?
3. Mention the soil factors to be taken into account in considering the effect of color on the temperature of field soils.
4. How much difference is there in the temperature of the three classes of soils at the end of the period?

EXERCISE XXXI

EFFECT OF WATER ON SOIL TEMPERATURE

Object. The object of the exercise is to study the effect of water on soil temperature.

Materials needed. Six flower pots; two thermometers; sand; surface soil; subsoil.

Procedure. Prepare wet and dry samples of each class of soil in the flower pots. Take accurate temperature readings at the immediate surface, 1 inch deep, and 2 inches deep; then place them in the full sunlight. Take temperature readings every half hour during the period.

Record the results of each class of soil in a form similar to the following:

Time	Temperature of Dry Sand			Temperature of Wet Sand		
	Surface	1 in.	2 in.	Surface	1 in.	2 in.
Original						
½ hour						
1 hour						
1½ hours						
2 hours						

References:

Snyder: Soils and Fertilizers, pp. 46–47.
King: The Soil, pp. 225–228.
"An Investigation of Soil Temperature and Some of the Most Important Factors Influencing It," in *Michigan Technical Bulletin No. 17*, 1913.

Questions:

1. How does evaporation affect the temperature of the soil?
2. Why is a drained soil warmer than an undrained soil?
3. What are the chief causes which make undrained clayey soils cooler than well-drained sandy soils?
4. At what time of the year is there the greatest difference between the temperature of the drained soil and that of the undrained soil? the least? Why?
5. The temperature of the air 9 inches above the drained soil is higher than the temperature 9 inches above the undrained soil. Why?
6. What is the specific heat of soil as compared with the specific heat of water?

EXERCISE XXXII

EFFECT OF VEGETATION AND TOPOGRAPHY ON SOIL TEMPERATURE

Object. The object of the exercise is to study the effect of vegetation and topography on soil temperature.

Materials needed. Three-foot auger; two thermometers.

Procedure. In taking soil temperatures the following points must be kept in mind:

1. The temperature of the atmosphere.
2. The direction and velocity of the wind.

By means of the auger make a hole 18 inches in depth and immediately place a thermometer in the bottom and press the bulb into the soil. At the same time insert the bulb of the second thermometer into the soil to a depth of 3 inches. Make all final temperature readings an average of three readings taken within a radius of 2 feet.

In this manner study the temperature of the soils on different slopes, comparing them also with the temperatures of level land. Make a study of the temperatures of soil covered with green vegetation, trees, and grass, comparing them with the temperatures of bare land.

Tabulate your results in a form similar to the following:

SUMMARY OF READINGS

Depth in Inches	Exposure of Slope			Kind of Vegetation		No Vegetation
	Level	South	North	Trees	Grass	
3						
18						

References :

Hall : The Soil, pp. 120–126 ; 133–135.
Lyon and Fippin : Soils, pp. 448–464.

Questions :

1. Which slope has the highest temperature? Why?
2. Why is the upper 3 inches of the soil warmer than the soil 18 inches down?
3. Why does growing vegetation keep the temperature of the soil more uniform?
4. Explain why the exposure of the slope affects the temperature of the soil.

EXERCISE XXXIII

EFFFCT OF CULTIVATION ON SOIL TEMPERATURE

Object. The object of the exercise is to study the effect of cultivation on soil temperatures.

Materials needed. Three-foot auger; two thermometers.

Procedure. By means of the auger make a hole 18 inches deep in a field that has been recently plowed. As soon as possible place a thermometer in the hole, pressing the bulb into the soil. At the same time insert the bulb of the second thermometer in the soil to a depth of 3 inches, and after it has become constant, record the temperature. Make all final temperature readings an average of three readings taken within a radius of 2 feet. In this manner study the temperatures of soils that have received no cultivation. Also take careful notes on the weather conditions, slope, and vegetation.

Tabulate your results in a form similar to the following:

SUMMARY OF READINGS

Depth in Inches	Cultivated	Uncultivated	Cultivated Vegetation	Uncultivated Vegetation
3				
18				

References:

Snyder: Soils and Fertilizers, pp. 46–51.
Hilgard: Soils, pp. 301–310.

Questions:

1. What effect does the loose structure have on the temperature of the soil?
2. How can a farmer aid in warming up the soil in the spring?
3. What factors influence the temperature of soils?
4. Why is the temperature of the upper three inches of the cultivated soil warmer than the upper three inches of the uncultivated soil?
5. From what sources does the soil receive its heat?

EXERCISE XXXIV

SOIL TENACITY

Object. The object of the exercise is to determine the tensile strength of different classes of soils.

Materials needed. Tenacity apparatus; pan; graduate; spatula; scales; surface soil; subsoil; clay.

Procedure. 1. Weigh 300 grams of soil and add water until you consider the greatest degree of stickiness reached, keeping a record of the amount of the water. Mix well.

2. Place the two parts of the soil container together on a level surface and lock firmly.

3. Fill the container level full with the moistened soil, leaving no air spaces along the sides.

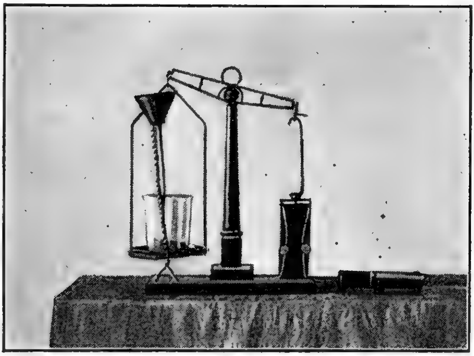


FIG. 11. Method of studying soil tenacity

4. Attach the filled container directly underneath the beam of the apparatus.

5. Unlock the container, exercising care not to jar or break the soil column.

6. Through a small funnel add sand to the other side of the beam until its weight is sufficient to break the soil column.

7. Weigh the sand.

8. Weigh the movable part of the container with the soil it contains.

9. Determine the tensile strength by subtracting the weight of the container, plus the soil it contains, from the weight of the sand.

10. To another 300-gram sample of the same soil add 15 cc. more water than was added to the first sample, and to a third 300-gram sample add 15 cc. less water than was added to the first sample, and in like manner determine their degree of tenacity.

Record results in a form similar to the following:

	Surface Soil			Subsoil			Clay		
	1st	2d	3d	1st	2d	3d	1st	2d	3d
Amount of water added .									
Weight required to break soil column									
Weight of soil and movable container									
Tenacity									

References:

Lyon and Fippin: Soils, pp. 97–99.
Warington: Physical Properties of the Soil, pp. 23–25.

Questions:

1. What is meant by tenacity of soils?
2. What factors determine the tenacity of soils?
3. About what per cent of water gives the greatest degree of tenacity in each soil?
4. Explain the relation between tenacity and the expansion and contraction of soils upon wetting and drying.
5. Give your opinion as to the desirability of the property of tenacity in field soils.

EXERCISE XXXV

TRANSFERENCE OF HEAT IN SOILS

Object. The object of the exercise is to study the heat-transferring power of soils.

Materials needed. Heat-transference apparatus; seven thermometers; flask; ruler; burner and tripod; asbestos gauze; distilled water; sand; surface soil; subsoil.

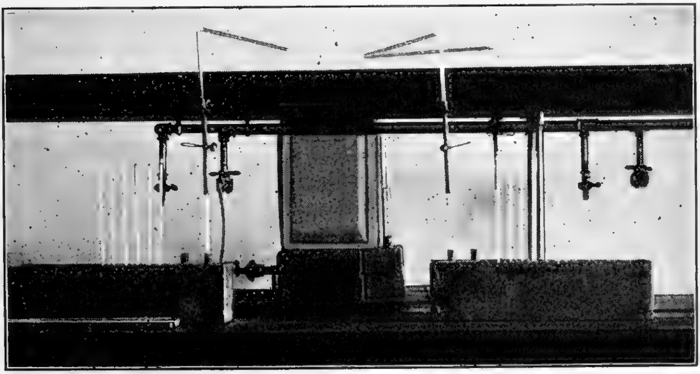


FIG. 12. Apparatus for studying transference of heat in soils

Procedure. 1. Place 950 cc. of distilled water in the flask and heat to boiling.

2. While the water is heating, fill the transference apparatus with sand, packing it as uniformly as possible. Place thermometers in the sand with the bulbs 2 inches below the surface at distances of 1, 2, 3, 4, 5, and 6 inches from the tank. As soon as they have become constant, record the temperature indicated by each.

3. On a piece of notebook paper rule a form similar to the one indicated below, in which to record your readings.

4. As soon as the water is boiling and the thermometers have reached a constant temperature, pour the boiling water into the tank, recording the exact time at which this is done. Immediately, by means of tubing, conduct a current of steam from the steam pipe into the water, in order to maintain a constant temperature.

5. Use the seventh thermometer to ascertain the temperature of the water. The cork may be removed from the opening from time to time in taking these readings.

6. Record the temperature indicated by each thermometer at the end of every 5-minute period for at least an hour and a half.

7. In the same manner determine the heat-transferring power of the surface soil and the subsoil.

After obtaining the results, plot curves showing the rate of heat-transference in each soil. (A convenient method of plotting the curves is to use one sheet for each soil.)

Tabulate the results in a form similar to the following:

Time	Temperature of Water	Distance from the Heat Source					
		1 in.	2 in.	3 in.	4 in.	5 in.	6 in.
Min.	*Degrees*	*Degrees*	*Degrees*	*Degrees*	*Degrees*	*Degrees*	*Degrees*

References:

"Heat Transference in Soils," in *Bulletin No. 59* of the United States Department of Agriculture, Bureau of Soils.

Technical Bulletin No. 17 of the Michigan Agricultural Experiment Station.

Questions:

1. What factors influence the heat transference of soils?
2. Summarize the conclusions as set forth in the first reference.

EXERCISE XXXVI

ABSOLUTE SPECIFIC GRAVITY OF SOIL

Object. The object of the exercise is to make determinations of the absolute specific gravity of soils.

Materials needed. Pycnometer; balance; distilled water; thermometer; water bath; water-free soil.

Procedure. 1. Fill a pycnometer bottle to the upper end of the capillary tube with distilled water. Wipe dry and weigh to three decimal places. Note the temperature of the water used.

2. Empty the water and again weigh. Add about ten grams of water-free soil and again weigh. The difference in the two weights represents the exact amount of soil used.

3. Fill the bottle about half full with water and place it in a shallow water bath, heating it until all the air is expelled from around the particles.

4. Reduce the temperature of the water in the pycnometer to the original temperature, completely fill with distilled water, and weigh.

Calculation. To the weight of the water-free soil, add the weight of the flask filled with water, and deduct the weight of the flask filled with the soil and water. The difference expresses the weight of the volume of water equal to the quantity of soil used. The specific gravity can therefore be determined by dividing the weight of the soil used by the weight of the water it has displaced.

Record your results in a form similar to the following:

Soil	Weight of Flask filled with Water	Weight of Dry Soil taken	Weight of Flask filled with Water and Soil	Weight of Water displaced by Soil	Specific Gravity
	Grams	*Grams*	*Grams*	*Grams*	*Grams*
Sand					
Surface soil					
Subsoil					

References:

Lyon and Fippin: Soils, pp. 94–97.
Merrill: Rocks, Rock Weathering, and Soils, pp. 40–42.

Questions:

1. Define absolute specific gravity.
2. Why is it necessary to use water-free soil for the determination of the absolute specific gravity?
3. Why must all the air be driven out before the last weight is taken?
4. What factors influence the absolute specific gravity of soils?
5. How do you account for the small differences between the absolute specific gravities of the different soils?

EXERCISE XXXVII

APPARENT SPECIFIC GRAVITY OF FIELD SOILS

Object. The object of the exercise is to determine the apparent specific gravity and pore space of soils under field conditions.

Materials needed. Sampling auger; mallet; six sacks; balance; three cans; drying oven.

Procedure. By means of the auger secure a foot sample of the first foot of soil from three fields: an alfalfa field, a pasture, and a recently plowed field. In using the auger the tube is driven into the soil to such a depth that when the auger blade is just resting on the surface of the soil, the gauge may be set in the first notch and at the same time rest on the top of the tube. Raise the gauge one notch, and by turning the auger remove the first inch of soil, placing it in one of the sacks. In the same manner remove the soil from the first foot, placing it all in one sack if possible. It is best not to attempt to remove more than 1 inch of soil at a time, and under no consideration should more than 2 inches be

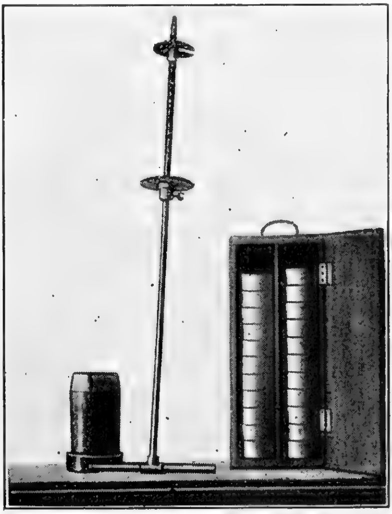


Fig. 13. Nebraska Soil Auger and sample boxes

removed at a time. After weighing the entire amount of soil removed, take a small sample of about 100 grams and determine the moisture content; then calculate the weight of water-free soil. In calculating the volume of soil removed, use the diameter of the auger bit as the diameter of the boring.

From the data collected determine the apparent specific gravity, per cent pore space, weight per cubic foot, and weight per acre foot for each field.

Tabulate your results in a form similar to the following:

Kind of Field	Apparent Specific Gravity	Porosity	Weight per Cubic Foot	Weight per Acre Foot
		Per cent	*Pounds*	*Tons*
Alfalfa				
Pasture				
Recently plowed				

References:

Exercise No. 8 (for method of calculation).
King: Physics of Agriculture, pp. 110–117.
Hall: The Soil, pp. 60–67.
Lyon and Fippin: Soils, pp. 88–97.

Questions:

1. Define apparent specific gravity.
2. What factors influence the apparent specific gravity of soils under field conditions?
3. Does the per cent porosity vary as the apparent specific gravity?
4. From the standpoint of crop production, what is the importance of soil porosity?

EXERCISE XXXVIII

SPECIFIC HEAT OF SOILS

Object. The object of the exercise is to determine the specific heat of soils.

Materials needed. Specific-heat apparatus; two thermometers; three crystal dishes; graduate (200-cc.); distilled water; drying oven; balance; water-free soils.

Procedure. 1. Fill the three crystal dishes, one with each type of soil, and weigh to *three* decimal places.

2. Place one crystal dish, filled with soil, on the upper shelf of the oven.

3. Through the opening in the top of the oven insert one of the thermometers, extending it down into the soil in the dish.

4. Heat until the thermometer reads between 100° and 110° C. While the soil is heating weigh the calorimeter cup and stirring rod and determine their water equivalent in calories (weight times specific heat).

5. Measure into the calorimeter cup 200 cc. of distilled water and place it in the jacket.

6. With the other thermometer determine the exact temperature of the water in the calorimeter; immediately take the exact temperature of the soil in the oven.

7. Quickly transfer the soil from the oven into the calorimeter, covering it as soon as possible.

8. Insert the thermometer and stir for three or four minutes, until a constant temperature is obtained throughout the mixture.

9. Put the crystal dish back into the oven and let it stand there until it can be weighed to determine the exact amount of soil in the calorimeter.

10. Repeat the above operation for each soil.

Tabulation and calculation:

1. Specific heat of calorimeter cup, ...
2. Specific heat of water, 1.00.

Kind of soil used	SAND	SURFACE SOIL	SUBSOIL
Weight of calorimeter cup			
Weight of dish and water-free soil			
Weight of dish			
M — Weight of water-free soil			
T — Temperature of soil			
t — Temperature of water and calorimeter before adding soil			
C — Constant temperature of water and soil mixed in calorimeter			
W — Weight of water used plus water equivalent of calorimeter			
S — Specific heat			

Formula: $$S = \frac{W(C - t)}{M(T - C)}$$

References:

Coleman: Elements of Physics, pp. 182–185.
King: Physics of Agriculture, pp. 29, 215–217.
Hall: The Soil, pp. 128–129.
Lyon and Fippin: Soils, pp. 455–456.
Hilgard: Soils, p. 301.

Questions:

1. Derive the above formula (Coleman).
2. What is specific heat?
3. What factors influence the specific heat of soils?
4. Does a knowledge of the specific heat of a moist soil aid in determining whether it is a "late" or an "early" soil?

EXERCISE XXXIX

EVAPORATION OF WATER

Object. The object of the exercise is to study the rate of evaporation from soils as compared with the evaporation from a free-water surface.

Materials needed. Two evaporating pans; surface soil; balance; plotting paper.

Procedure. Place in one of the pans a layer of surface soil 2 inches deep and add water until the moisture content is about 25 per cent. Fill the second with water to a depth of 2 inches. The water used in both pans should be at about room temperature. Weigh, place in full sunlight, and note the loss from each by weighing every twenty minutes for two hours.

Plot two curves showing the rate of evaporation from the two pans and tabulate your results in a form similar to the following:

	Grams of Water evaporated during Each Ten Minutes								
	1st	2d	3d	4th	5th	6th	7th	8th	Total
Free-water surface . .									
Soil surface									

References:

Fletcher: Soils, pp. 88–89.

Bulletin No. 188 of the United States Department of Agriculture, Bureau of Plant Industry, pp. 16–30.

Twenty-fourth Annual Report of the Nebraska Agricultural Experiment Station, pp. 97–101.

Questions:

1. Account for the fact that evaporation from a free-water surface is slow at first and faster at the end of the period.
2. What factors influence the rate of evaporation?
3. According to the references, about how much water will be evaporated from the free-water surface in six months?
4. Compare the rate of evaporation from the soil with that from the leaves of plants.

EXERCISE XL

MOISTURE DETERMINATIONS OF FIELD SOILS

Object. The object of the exercise is to determine the moisture content of soils under field conditions.

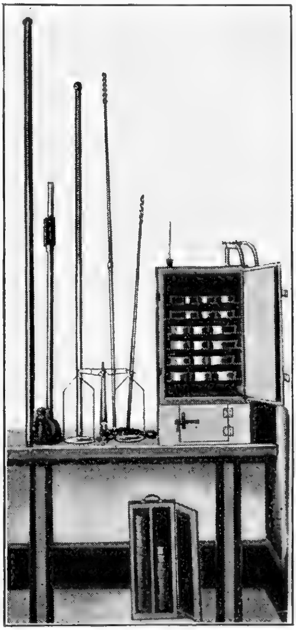


Fig. 14. Soil augers, tubes, and other apparatus for making moisture determinations

Materials needed. Two augers or tubes (one 6-foot and one 3-foot); eighteen tin boxes (in case); drying oven; balance.

Procedure. 1. Weigh the tin boxes, being sure that each is properly labeled.

2. Take composite samples from each foot of soil to a depth of 6 feet in an alfalfa field, a cornfield, and a pasture. Take notes regarding topography, vegetation, etc. (Care should be taken in securing the samples to put the covers on the boxes as soon as the soil is placed in them, to prevent loss from evaporation.)

3. Weigh the samples carefully.

4. Place the boxes in an oven with the lids removed, and heat at a temperature of 110° C. until the samples are water-free.

5. Weigh samples again.

6. Compute the per cent of moisture in the samples, using the water-free soil as a basis.

Record your results in a form similar to the following:

FIELD____________________ DATE____________________

DEPTH IN FEET	WEIGHT OF BOX	WEIGHT OF BOX AND SOIL		LOSS IN WATER	WEIGHT OF WATER-FREE SOIL	AMOUNT OF WATER IN SOIL	
		Before heating	After heating			Per cent	Inches of rainfall
	Grams	*Grams*	*Grams*	*Grams*	*Grams*		

NOTE. In computing the inches of rainfall, assume the soil to have an apparent specific gravity of 1.3.

References:

Lyon and Fippin: Soils, pp. 135–165.
Twenty-fifth Annual Report of the Nebraska Agricultural Experiment Station, pp. 71–73, 106–110.
Widtsoe: Dry-Farming, pp. 94–129.
Hall: The Soil, pp. 64-67.
Hopkins: Soil Fertility and Permanent Agriculture, pp. 577–583.

Questions:

1. Comparing the moisture content of the three fields, in which foot do you find the greatest variation of moisture?
2. How do you account for the fact that the three fields differ in moisture content? Explain.
3. What factors influence the amount of moisture found in field soils?
4. Rainfall is disposed of in what way?
5. What practical methods may be employed which will favor the storing of moisture in the soil?

EXERCISE XLI

STANDARDIZATION OF THE EYEPIECE MICROMETER

Object. The object of the exercise is to standardize the micrometer scale of the microscope and learn the value of each division.

Materials needed. Microscope; stage micrometer.

Procedure. Place the micrometer scale on the microscope stage and, using the No. 10 eyepiece, determine for each of the objectives the number of divisions or spaces of the eyepiece micrometer that correspond to 1, 0.5, 0.1, 0.05, and 0.005 mm. of the stage micrometer.

Tabulate in a form similar to the following the number of spaces of the eyepiece micrometer that correspond to the size of the various classes of soil particles.

MICROSCOPE NO.________________

SOIL CLASS	DIAMETER IN MILLIMETERS	NUMBER OF SPACES IN 16 MM. OBJECTIVE	NUMBER OF SPACES IN 4 MM. OBJECTIVE
Coarse sand	1.0 to 0.5		
Medium sand	0.5 to 0.25		
Fine sand	0.25 to 0.1		
Very fine sand	0.1 to 0.05		
Silt	0.05 to 0.005		
Clay	0.005 and less		

EXERCISE XLII

MECHANICAL ANALYSIS OF SOILS

Object. The object of the exercise is to make a partial mechanical analysis of and to become acquainted with the texture of various soils.

Materials needed. Microscope (standardized); four beakers; burner; evaporating dish; crucibles; sieves; pipette; wash bottle; balance; mortar and pestle (rubber-tipped); soils.

Procedure. *Read the entire exercise very carefully before attempting to work it.* In making a mechanical analysis of soils it is very important that all composite or crumb structures be destroyed and that the entire sample be in a single-grain condition. This is accomplished by gently rubbing the sample of soil in a mortar with a rubber-tipped pestle. In rubbing there should be just enough pressure to detach adhering particles — not enough to break them. Add just enough water to make the soil into a pasty mass, and pestle for a little while. Fill the mortar about half full of water and allow to settle about five minutes, or until all particles larger than 0.05 mm. have settled; then pour into a beaker the water which contains only silt and clay. Again pestle the soil particles for a time, add water, and allow to settle, again pouring off the silt and clay into the beaker which already contains some silt and clay particles. Continue this operation until all the particles are completely disintegrated. When disintegration is complete, the particles show sharp outlines under the microscope and are glassy in appearance.

When disintegration is complete, transfer all the soil to the beaker already containing silt and clay and probably some sand. For convenience this beaker is called A. Fill the beaker A with water and stir thoroughly. Allow the particles to settle until an examination with the microscope shows that all particles larger than 0.05 mm. have settled; then pour the turbid liquid into a second beaker B. Examine the sediment in the bottom of beaker B, to make sure that no particles larger than 0.05 mm. have been poured off. In case sand particles have been poured off, stir the contents of beaker B and allow all the sand particles to settle, pouring the liquid containing silt and clay into a third beaker C. Return the sand in beaker B to beaker A. Examine the sediment in beaker C, and if no sand particles are found, the liquid may be discarded. Again fill beaker A with water and stir. As soon as all the sand particles have settled, pour the turbid liquid into beaker B. In the same manner as above examine the sediment in beaker B, returning any sand particles to beaker A. Continue this process until all silt and clay particles have been removed from beaker A and it contains only sand or particles larger than 0.05 mm. in diameter.

Transfer the contents of beaker A to an evaporating dish and evaporate to dryness; then weigh. After weighing, transfer the particles to the sieves and shake until a thorough separation has been made. Place each separate in a weighed crucible and ignite to burn off the organic matter, then weigh and determine the exact weight of each.

By means of a separate sample of the original soil determine the per cent of volatile matter that it contains (Exercise XVIII). To determine the combined weight of silt and clay which the sample contained, add the weights of all the separates and the volatile matter, and substract from the weight of the original sample. (A complete mechanical analysis may be made by separating the silt from the clay, using the materials that are discarded in the separation of the sand and gravel classes.) In order to obtain a check on the amounts of particles lost, *analyze all samples in duplicate.*

By the above method determine the per cent (water-free basis) of coarse gravel, fine gravel, coarse sand, medium sand, fine sand, very fine sand, silt, and clay, together with the per cent of organic matter, in the samples given out at the storeroom.

Tabulate your results in a suitable form, and report as soon as the separation is completed.

References:

Bulletin No. 4 of the United States Department of Agriculture, Bureau of Soils.

Bulletin No. 24 of the United States Department of Agriculture, Bureau of Soils.

Questions:

1. Name five methods of mechanical analysis.
2. Discuss briefly the force or forces used in each of the above methods.

EXERCISE XLIII

SOIL EXAMINATION

Object. The object of the exercise is to give practice in estimating approximately the texture and physical composition of soils.

Materials needed. Graduate; soil samples.

Procedure. Procure samples of soil from the storeroom and study them according to the following outline:

- Dry soil
  - Color
  - Pulverent, crumbly, or cloddy
- Moist soil
  - Color
  - Floury, mealy, or gritty
  - Pliable or plastic
- Composition (estimated)
  - Supply of carbonates
  - Organic matter (per cent)
  - Gravel (per cent)
  - Coarse and medium sand (per cent)
  - Fine sand (per cent)
  - Very fine sand (per cent)
  - Silt and clay (per cent)

Do the work rapidly, using only a few pieces of apparatus. In estimating the physical composition of a soil a graduate is sometimes of considerable help. Place 10 cc. of the soil in the graduated cylinder with from 60 to 80 cc. of water; shake and allow to settle. The amount of sand may be read very roughly after the soil has settled. The cylinder is of little aid in studying a heavy type of soil.

In testing for carbonates place several drops of hydrochloric acid on a small portion of the sample. In case the soil contains about normal amounts, effervescence will not be readily observed; large amounts will be easily detected.

EXERCISE XLIV

EXAMINATION OF SOIL SAMPLES

Object. The object of the exercise is to study samples of soil taken from the student's home farm, or some place of interest, in order to become more familiar with them.

Materials needed. Samples of soil (first, second, and third foot of each type); apparatus necessary for the exercises named below.

Procedure. Study each type of soil that has been procured, using the following exercises as an outline:

Exercise IV, Soil Classification (Origin).
Exercise XVIII, Loss on Ignition.
Exercise XIX, Soil Acidity and Basicity.
Exercise XX, Determination of Humus.
Exercise XLII, Mechanical Analysis of Soils.
Exercise XLIII, Soil Examination.

Tabulate your results in a suitable form.

WEIGHTS AND MEASURES

1 kilogram = 2.2 pounds avoirdupois.
1 liter = 1.056 quarts.
1 inch = 25.399 millimeters.
1 pound = 453.59 grams.
1 cubic foot of water weighs approximately 62.5 pounds.
1 inch of water over 1 square foot weighs approximately 5.2 pounds.
1 acre inch of water = 113.3475 tons.
1 acre = 43560 square feet.
1 acre foot contains 43560 cubic feet.
$2\pi r$ or πD = circumference of circle.
πr^2 = area of circle.
$4\pi r^2$ or πD^2 = area of sphere.
$4/3\ \pi r^3$ or $1/6\ \pi D^3$ = volume of sphere.
$\pi r^2 h$ = volume of cylinder (h = altitude).