THE WILEY TECHNICAL SERIES

FOR

VOCATIONAL AND INDUSTRIAL SCHOOLS

EDITED BY

JOSEPH M. JAMESON

GIRARD COLLEGE

Under the Soil in any Field is Solid Rock.

Frontispiece. (Adapted from Hall.)

FIELD AND LABORATORY
STUDIES OF SOILS

AN ELEMENTARY MANUAL
FOR STUDENTS OF AGRICULTURE

BY

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SUGGESTIONS TO TEACHERS

This little book of soil experiments has been prepared in response to the demand for a brief laboratory and field course in elementary soils, which may be given without the purchase of expensive equipment. With a few tools and the aid of the pupils, the teacher should be able to construct all of the apparatus necessary for many of the exercises. Such cooperation on the part of the students will stimulate a keener interest in the work than can be secured by the exclusive use of purchased materials. However, as funds become available, it is advised that special equipment be purchased and substituted for the less satisfactory, home-made apparatus.

In many schools apparatus from the chemical and botanical laboratories will be available for the soil work. For example, a good balance may be purchased for the joint use of the chemical and soils laboratories, and the compound microscope may serve for both botany and soils. The first purchase of equipment should include the following:

1. Gasoline or kerosene stove with oven.
2. Balance similar to the one shown in Exercise A-7.
3. Soil auger and spade.
4. Small equipment, such as sample cans, glass tumblers, tin cans, wrapping paper, cheese cloth and twine.

A supply of clean sand, and also some loam, clay and muck soil should be secured in the fall. This material should be dried, pulverized, and passed through a sieve with one-eighth-inch mesh, to remove stones and sticks.

The exercises are intended to furnish sufficient material for one period per week throughout the year or two periods per week for a half year. Although they are arranged in logical order, it is not necessary that the exercises should be taken up in the exact sequence in which they occur in the text. Indeed, it will be necessary for the teacher to vary the arrangement in order to adapt the study to the season and to the facilities of the school.

A small working library should form a part of the equipment. For a study of soils this library should include several elementary books on soils, a collection of Farmers' Bulletins from the United States Department of Agriculture and the publications of the State Experiment Station.

While much of the material in the text is original, the writer has drawn freely from all sources for suggestions and illustrative material. Some of the illustrations have been adapted from the text-books and much material has been taken from the publications of the Agricultural Extension Department. The author wishes to make especial acknowledgment of the helpful suggestions of former Superintendent A. B. Graham and Mr. Clark S. Wheeler of the Agricultural Extension Department of the Ohio State University.

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June, 1915.

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FIELD AND LABORATORY STUDIES OF SOILS

EXERCISE A-1. A STUDY OF THE FORMATION OF SOILS.

Equipment: This exercise is based upon the pupil's own observations rather than upon laboratory work. Any

Fig. 1.—The Rock may Lie but a Few Inches below the Surface.

natural formations in the neighborhood, which are illustrative of soil-making processes, should be visited by the class. Each pupil should write an account of the trip, including a discussion of the questions given below.

Questions: 1. Does solid rock come to the surface at your home?

2. Name a place where you know the depth at which solid rock is found.

3. Does your home well reach the rock?

4. At what depth?

5. Compare the shape of stones found in streams with that of crushed stone. How do you account for any difference?

Discussion: Under the soil in any field is solid rock. Sometimes this rock is very deep and again it may lie but a few inches below the surface. The soil also was once large rocks. It was made fine as we see it by natural agencies working through millions of years. These agencies are still at work and may often be observed. Water fills the crack in a large stone, freezes and bursts the stone apart. Exposed ledges of stone heated during the day and cooled at night for several years finally crumble. The roots of trees force themselves between the layers of rock and split them apart. Every little stream rolls and wears pebbles, grinding them finer and finer, finally forming soil.

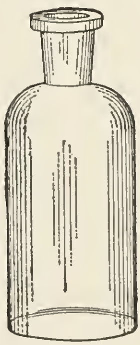
An examination of almost any soil shows that it contains not only fine rock particles, but also plant and animal remains. This organic matter may be found in the soil in all stages of decay, and constitutes the most important body of material present in the soil. It furnishes nitrogen, which is an important plant nutrient, and enables the soil to absorb and retain moisture.

FIG. 2.—Flowing Water is Continually Moving Soil from Place to Place.

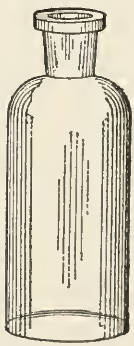
EXERCISE A–2. TO STUDY THE COMPOSITION OF SOILS.

Equipment: Spade or soil auger; two pieces of oilcloth or heavy wrapping paper sixteen inches square; two slender bottles; tablespoon.

Method: By means of the spade or soil auger, secure a sample each of a sandy soil and a heavy clay. Place a tablespoonful of each soil in separate bottles and fill each about two-thirds full with clear water. Shake each bottle



Sandy Soil.



Heavy Clay Soil.

for one minute and allow to settle for five minutes. Observe carefully the layers in each bottle, the large particles at the bottom and the finest material at the top. Use the bottles shown above to indicate what you see.

Discussion: Soils are composed of fine rock particles that have resulted from the breaking and grinding of large rocks, to which has been added some organic material which has been formed by the decay of plant and animal remains. All of the light-colored rock particles in the bottles are quite similar except as to size. The dark material at the surface or floating in the water is organic matter which may be removed from the soil by burning. Both classes of material are essential to the growth of plants, the rock particles furnishing the mineral food elements and the organic matter the nitrogen. The organic matter also increases the moisture-holding capacity of the soil.

EXERCISE A–3. TO STUDY THE GROUPS OF INDIVIDUAL SOIL PARTICLES.

Equipment: Four beakers or tumblers; samples of clay and sandy soil.

Method: Make fine and dry a small quantity of each of the two kinds of soil. Put three tablespoonfuls of the clay soil in one tumbler or beaker, and a like amount of the sandy soil in the other. Fill each one half full with water. Taking the tumblers or beakers one at a time, proceed as follows: shake gently for four minutes, let stand one minute and pour off into another tumbler all the water possible without losing the settlings. The settlings are the *sand.* Allow the water poured off to stand one hour until a distinct layer of settlings can be seen at the bottom. Now pour off and discard the clouded water. This muddy water contains *clay* so fine that it will not settle. The material which has settled in the second glass is *silt.*

Questions: (1) About what proportion of the sandy soil is silt?

(2) About what proportion of the clay soil is silt?

Discussion: Soils are classified according to the fineness of the rock particles which they contain. A soil which contains a large proportion of coarse particles is called a *sandy soil.* One which contains a large proportion of fine particles is called a *clay soil.* No soil is made up wholly of clay or of sand particles. All soils contain a certain per cent of each of these groups of fine particles. The coarser sandy soil drains more rapidly, warms up more quickly in the spring and is, therefore, better suited to early garden or truck crops. Clay soil dries out more slowly, and for this reason it is capable of furnishing water to the crop during the hot dry summer months, especially if it contains a large amount of organic matter.

EXERCISE A-4. TO COMPARE THE SURFACE SOIL WITH THE SUBSOIL.

Equipment: Soil auger or spade; piece of oilcloth or heavy paper sixteen inches square.

Fig. 3.—Soil Auger Made by Welding a Three-foot Length of Wrought Iron Gas-pipe onto the Shank of a $1\frac{1}{2}$-inch Wood Auger. Additional lengths may be added as desired.

Method: With a spade dig a narrow trench a foot deep. Make one side of the trench smooth and note the line at the bottom of plow depth. Examine a handful of soil above and below the line and fill out the following table, comparing the two:

	Color.	Moisture.	Firmness.
Surface soil.			
Subsoil.			

Observe the line between the surface soil and the subsoil wherever the earth has been cut into, either by a stream or an artificial grade. There is usually a distinct difference in color between the surface soil and the subsoil.

Discussion: If the soil contained nothing more than fine particles of rock there would be little difference between the surface soil and the subsoil. After the rocks were made fine, plants began to grow and by their death and decay they have added to the soil the dark-colored material which we call organic matter or *humus*. As the stems and leaves of plants fall on the ground and decay they are worked into the soil. Thus the surface soil is made to contain large quantities of decaying plants, while the subsoil contains but little of this material. This is the chief difference between the two. These decaying plants are an important addition to the soil. They add nitrogen and make the soil capable of holding more moisture.

EXERCISE A–5. TO STUDY THE RELATIVE PRODUCTIVENESS OF SOIL AND SUBSOIL.

Equipment: Two flower pots or quart cans; wheat seed; soil and subsoil from the same place.

Method: Fill one pot with moist surface soil, the other with moist subsoil, and plant six grains of wheat in each. Keep the pots watered and compare the growth of plants from time to time.

Discussion: Why are washed hillsides and the high points in the fields usually less productive than the level land and the lower levels? Steep land should be cultivated across the slopes and should be kept covered with some crop in order to prevent the washing away of the surface soil. Deep plowing is often desirable to increase the depth of the surface soil. If the soil has always been plowed shallow it will be better to plow only an inch or two deeper each year until the desired depth is reached, than to plow deep the first year. Why? Observe the growth of corn or wheat in the " dead furrow " between the lands.

While the plowing up of the subsoil in the humid regions frequently results in a decreased productiveness, the soil and the deeper layers in the arid regions may be mixed without injury. In these dry sections good crops are frequently grown where the top soil has been entirely removed in the preparation of the land for irrigation.

FIG. 4.—A Convenient Soil Bin, Mounted upon a Cupboard. The bins are filled from the top, the soil being removed from the open throat at the bottom. A sloping board just above the opening directs the soil back and prevents it from escaping faster that it is used.

EXERCISE A–6. TO STUDY THE INDIVIDUAL SOIL PARTICLES.

Equipment: Two tumblers; tablespoon; three large beakers or quart cans; samples of sand and clay soils.

Method: (**a**) Put a tablespoonful of sand in one tumbler and the same quantity of clay in the other. Fill each with water and after thorough shaking, allow the soils to settle. Which settles the more rapidly?

When a swiftly flowing stream carrying material in suspension is checked, which particles are first deposited? Find an example of the sorting power of flowing water in your neighborhood.

(**b**) A day or two before the class is to meet put three or four tablespoonfuls of sandy loam soil in a beaker or can and nearly fill the vessel with water. Shake at intervals for one day and finally after thorough shaking allow to settle one hour and pour off into another beaker (or can) the muddy water down to within one inch of the bottom. Allow to stand for one minute, again pour off the muddy water and evaporate each separation to dryness on a stove. When dry, examine the material in each can; the last residue is sand, the second is silt, and the first separation is clay. Moisten a little of each and rub between the thumb and finger. Which ones are sticky and which fall apart easily?

If a compound microscope is available, examine each separation and make a drawing of a few grains from each. Note that the soil consists of fine rock particles and dark humus or organic material.

EXERCISE A-7. TO DETERMINE THE AMOUNT OF ORGANIC MATTER IN DIFFERENT SOILS.

Equipment: Balance; small porcelain or tin dishes; soil samples; gas burner or alcohol stove.

Method: Place a teaspoonful of fine dry soil in a dish. Put the dish on the left-hand pan of the balance and add weights to balance it. Now heat the sample over the flame until all the organic matter has been consumed. Take care that the same weights are on the right-hand pan of the balances and return the dish containing the soil to the left-hand pan.

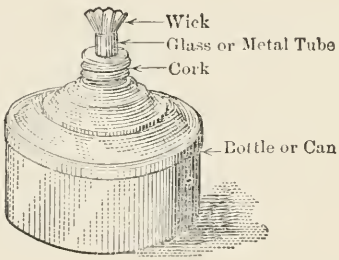


Fig. 5.—Small Alcohol Stove Made from an Ink Bottle or Oil Can.

How does this weight of the sample compare with its previous weight? How do you account for this difference? Add dry leaves or cut straw until the pans are again in balance. What does this added material represent?

Discussion: Soils vary greatly in the amount of or-

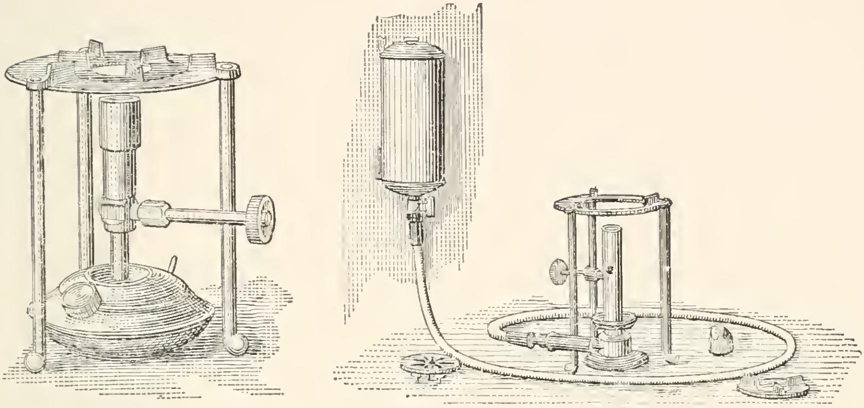


FIG. 6.—Two Types of Alcohol Stoves, which may be Made to Take the Place of Gas Burners.

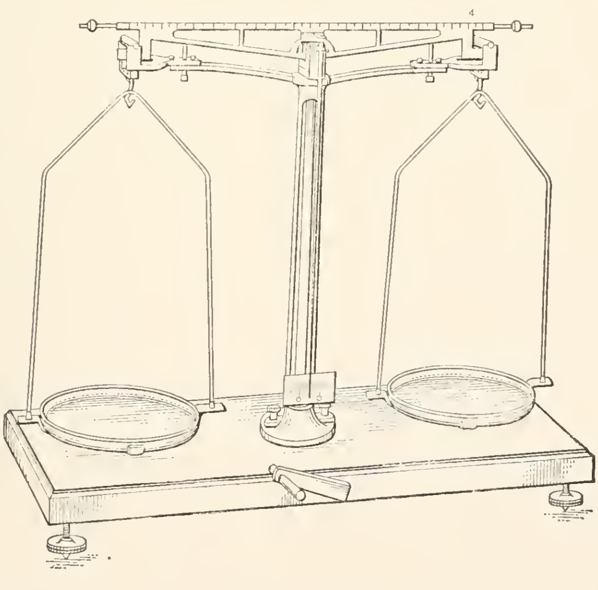


FIG. 7.—A Good Balance Costing about $12.00.

ganic matter which they contain. Muck soils are composed almost entirely of organic matter, while some sandy soils contain comparatively little dead plant and animal remains. Whenever the supply of organic matter in a soil is low the crop yields are small. Applying manure and plowing under clover are good ways of increasing the amount of organic matter in the soil.

NOTE.—A very good balance can be purchased for about $12.00. Small dishes should be about two or three inches in diameter. If tin, they must be without soldered seams.

Gas or alcohol stoves may be purchased at a small cost, or a very good alcohol lamp may be constructed in the laboratory without cost, by following the diagram shown on page 14.

EXERCISE. A-8. TO DETERMINE THE PORE SPACE IN SOILS.

Equipment: Dry samples of sandy soil and clay soil; graduated bottle or cylinder; a quart can or milk bottle.

Method: (1) Fill the can or bottle to within one-half inch of the top with the dry sand and compact by tapping

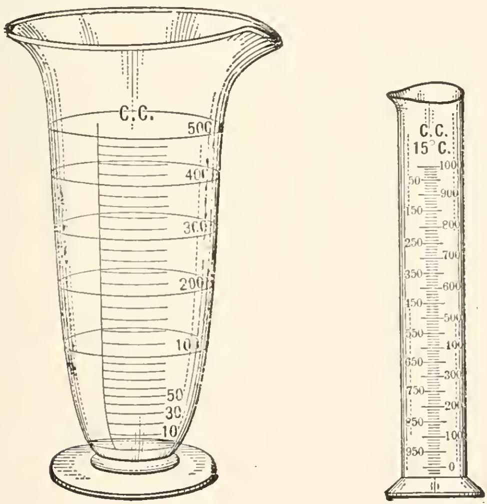


FIG. 8.—A Graduated Bottle or Cylinder is a Necessary Part of the Laboratory Equipment.

the can lightly on the desk top three times; (2) fill the graduated bottle or cylinder to the top mark with water; (3) carefully pour the water from the graduated vessel onto the top of the soil in the can and continue to do so until the water stands level with the top of the sand; (4) record the amount of water used. This represents the amount of water necessary to fill all of the open space in the sand. Repeat the above operations, using the sample of clay soil.

Report your observations in the following table:

	Cu. Centimeters of Soil Used.	Cu. Centimeters of Water Used.	Per Cent of Pore Space.
Sandy soil.........			
Clay soil..........			

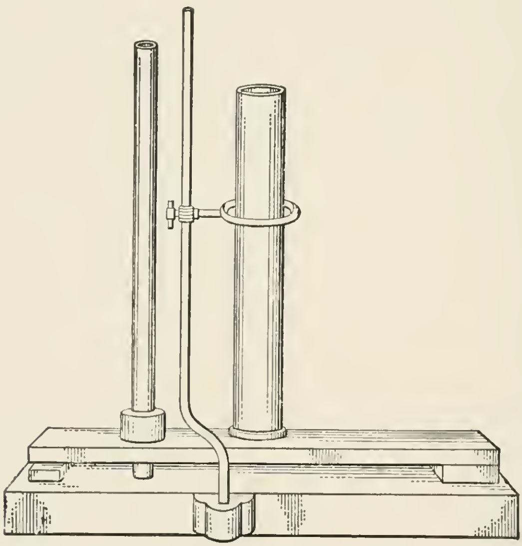


Fig. 9.—Spring-board Compactor Used to Secure Uniform Packing of the Soil. The can or tube of soil is placed at the middle of the board and the weight on the standard to the left is dropped a definite number of times from a fixed point.

Discussion: The large amount of water which a can will hold after it is already filled with dry soil serves to bring out the fact that only about half of the soil is occupied by the soil particles, the remainder being occupied by water when the soil is very wet or by air when it is perfectly dry. For the best growth of crops the space not occupied by the soil particles should be divided about equally between water and air. If the space becomes entirely filled with water, crops will not thrive, since their roots will not be able to get the air necessary for their growth. Sandy soil has larger spaces between the individual soil particles, but the total amount of pore space is less in the sandy soil than in the clay soil.

EXERCISE A–9. TO DETERMINE THE WEIGHT OF SOIL PER CUBIC FOOT.

Equipment: Balance; brass cylinder* or quart can; samples of sandy loam and clay soils.

Method: Fill the quart can with the dry sandy loam and compact by tapping it lightly on the desk four times.

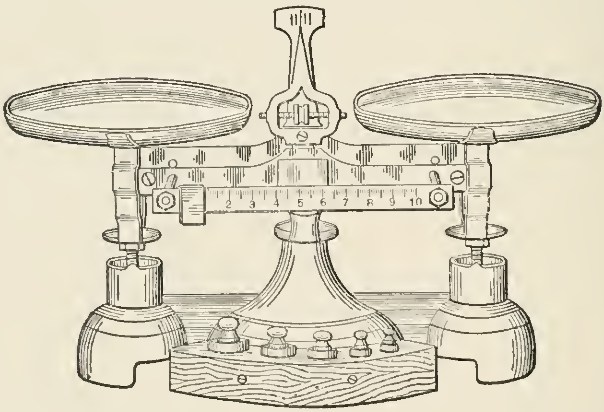


Fig. 10.—A very good Balance of this Type can be Purchased for about $8.00.

Stroke off the soil level with the top of the can and weigh. Subtract the weight of the empty can.

Calculate the capacity of the can in cubic inches and from the weight of the dry soil determine the weight of one cubic foot.

* Brass cylinders for this exercise may be purchased from laboratory supply houses at a cost of about $1.00 each.

Calculate the weight of an acre of this soil to the depth of one foot. This will give the weight of an *acre-foot.*

Repeat the determination for the clay soil and record the results in both cases in the following table:

	Weight of Can of Soil in Grams or Ounces.	Capacity of Can in Cubic Centimeters or Inches.	Weight of a Cubic Foot.	Weight of an Acre Foot.
Sandy loam..				
Clay........				

Discussion: The weight of a given volume of soil depends very largely upon the amount of organic matter present—the greater the proportion of organic matter the lighter the weight of the soil. The extent to which the soil is compacted also influences the volume weight.

EXERCISE A–10. TO STUDY SOIL GRANULATION.

Equipment: Three shallow pans; sample of heavy clay soil.

Method: Fill each of three pans nearly level full with dry clay soil. To the first pan add all the water which it will hold, continuing to pour on water as it soaks in, while working the soil with the fingers or with a stick. Over the second pan sprinkle one-half cup of water. Leave the third pan untreated. Place all three pans near a stove or in the sun, and dry thoroughly. Compare the size of the lumps of soil in the pans to which water was added. Which crumbles more easily between the fingers? Which is more like a field in good tilth? What happened to the first pan?

Discussion: The fine rock particles in a pile of clean sand always remain separate, but the very, very fine particles of rock which form the soil stick together to form crumbs or granules. When these granules are comparatively small and easily crushed, the soil is said to be *well granulated.* Large hard granules are called *clods.* When a large amount of water is added to a clay soil, the soil becomes "puddled" or "run together," and clods are formed. Similarly, if a wet clay soil is compacted by the feet of men or horses, or if it is plowed when too wet, hard clods are formed.

EXERCISE A-11. TO STUDY THE EFFECT OF FREEZING AND THAWING UPON SOIL GRANULATION.

Equipment: Shallow pans; some clay soil.

Method: Using heavy clay, make up two mud balls to about the consistency of putty. Place one on a shelf

Fig. 11.—Running Water, Freezing and Thawing, and the Roots of Trees are Powerful Agencies in the Breaking Down of Rock to Form Soil.

to dry and the other outside on the window sill where it will be frozen. Arrange to have the latter alternately freeze and thaw each day for a week or longer. When both are dry crush them with the hands. Which breaks the more easily?

Discussion: The freezing of water is one of the natural agencies which plays an important part in the breaking up of the rocks to make soil. This same force can be utilized to good advantage every year by the farmer through the practice of fall and winter plowing. Heavy clay soils by this practice can be made more loose and friable. Exposure of the plowed land to the action of freezing and thawing is especially desirable where the soil has become hard and cloddy, as the result of plowing it too wet, or by the trampling of livestock. The hard clods absorb water which, on freezing, expands and bursts them apart.

EXERCISE A–12. TO SHOW THAT SOME SOILS CAN HOLD MORE WATER THAN OTHERS.

Equipment: Four funnels; muslin or cheese cloth; scissors; well rotted manure; four graduated cylinders or bottles; funnel holder; sand; loam, and clay soil.

Method: Plug each funnel lightly on the inside with a piece of cotton or cloth. Fill the funnels as follows: (1) sand, (2) loam, (3) clay, (4) one-half sand and one-half manure. Arrange the funnels in the rack with their stems in the mouths of the bottles. Very slowly pour over each funnel exactly eight ounces (one-half pint) of water. Allow to stand till the drip ceases and read the amount of water in each bottle. Record these readings and subtract them from the amount poured into each funnel. What do these differences represent?

Mixture number..........	1	2	3	4
Amount poured in........				
Amount in bottle.........				
Amount held in soil.......				

Discussion: The capacity of soils to hold water depends upon the size of the particles and the amount of organic matter. In clay soils it is increased by granulation. Clay soils can hold more water because the individual spaces between the particles are smaller and the total amount of space is larger, than in other soils. Muck and clay soils will hold the largest amount of water and sandy soils the

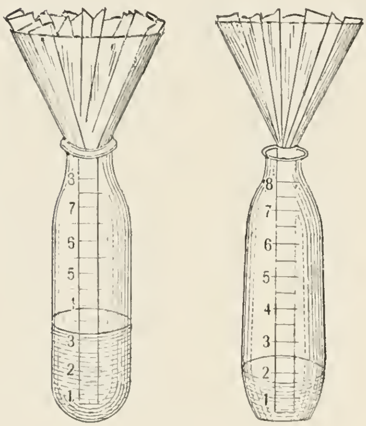


Fig. 12.—Funnels and Graduated Bottles Used to Show that Some Soils can Retain more Water than Others.

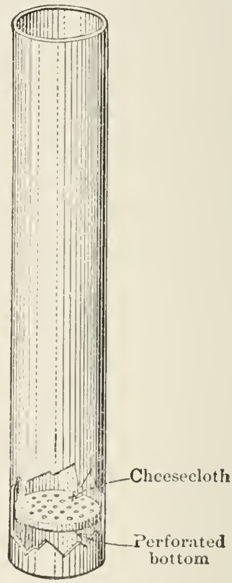


Fig. 13.—Brass Cylinder Used to Measure the Water-holding Capacity of Soils.

least. The supply of water is the most important single factor in the growth of plants. Consequently, the extent to which different soils retain moisture deserves careful study.

EXERCISE A–13. TO SHOW THAT PLANTS GIVE OFF MOISTURE THROUGH THEIR LEAVES.

Equipment: Small potted plant; wide-mouthed jar; piece of cardboard; wax.*

Method: Use a plant which is at least three or four inches high and growing in a flower pot or tomato can. Cut a slit in the cardboard from the middle of one side to the center, and place the cardboard around the plant. Seal up the slit in the cardboard with wax. Now invert the glass jar over the plant and place in a sunny window. How do the drops of water get into the glass jar?

Discussion: Plants are constantly giving off water from their leaves. The largest amount is evap-

Fig. 14.—Potted Plant Arranged to Show that Plants Give off Moisture through their Leaves. If placed in a sunny window, drops of moisture soon collect on the inside of the can.

* Beeswax, paraffin, or grafting wax will be found quite satisfactory.

orated in the hot sun and when an abundance of water is supplied to the roots. Sometimes in a drouth more water is evaporated from the leaves than is being taken in by the roots. If this is continued for some time the plant wilts. This reminds us that the water in plants gives the soft stems and leaves their stiffness. All the food which the plant takes from the soil must first be dissolved in water. It is estimated that 900 tons of water are evaporated by each acre of corn plants during the growing season.

EXERCISE A-14. TO SHOW THE EFFECT OF SOIL AIR UPON PLANT GROWTH.

Equipment: Two tumblers, or quart cans; several grains of corn.

Method: Fill two tumblers within a half inch of the top with rich soil. Plant in each three kernels of corn. Water tumbler No. 1 only enough each day to keep the soil moist. Keep water in the second tumbler so that it stands a little above the surface of the soil. Fill in the following blanks:

	No. 1.	No. 2.
Date of planting..........................		
Date first plant up........................		
Ave. height 1 wk. after coming up...........		

What kept the corn in one tumbler from growing as well as that in the other? What became of the air in the soil in tumbler No. 2?

Discussion: For the best growth of crops the space not occupied by soil particles should be divided equally between air and water. If this space becomes entirely filled with water, crops will not thrive, since their roots will not be able to get the air necessary for plant growth.

Some plants, such as the cypress and the water lily, have special structures which enable them to obtain air from the water while their roots are entirely submerged, but our common field plants do not have this ability.

EXERCISE A-15. TO SHOW HOW THE TEMPERATURE OF THE SOIL IS AFFECTED BY THE SLOPE.

Equipment: Three boxes, 6″×12″×12″; three thermometers;* soil sample.

Method: Number the boxes 1, 2, and 3, fill with the same kind of soil and set them in the sunlight, side by

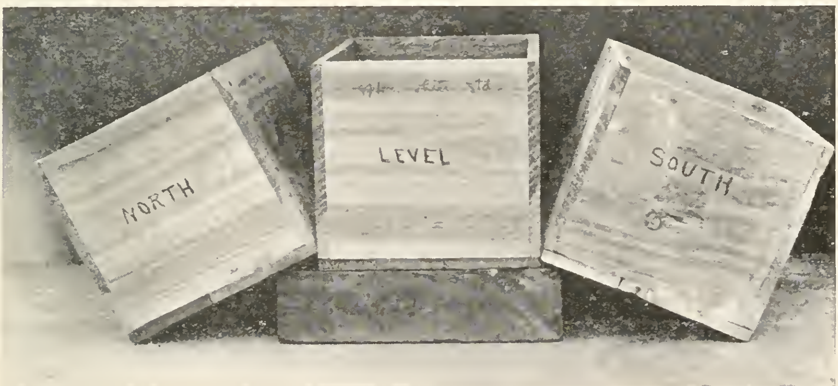


Fig. 15.—Arrangement of Boxes to Show the Effect of Slope upon the Temperature of the Soil.

side. Arrange the boxes so that No. 1 will stand level, No. 2 slope toward the south (four inches slope to the foot) and No. 3 slope toward the north at the same angle.

* The thermometers should be tested by placing the three side by side in a tumbler of water and after stirring the water for a few minutes compare the readings on the thermometer scales. If they do not read the same a suitable correction must be applied.

Place a thermometer in each with the bulb covered with soil. Take readings every two hours during the day.

TEMPERATURE RECORD

Hour.								
South slope.								
North slope.								
Level.								

List the three surfaces in the order of their temperature. What location would you seek for an early garden plot?

Discussion: The temperature of the soil is affected by the slope, because in one case a given amount of the sun's heat must warm a larger area of soil than in another. When the slope is towards the sun the soil stands more nearly at right angles to the sun's rays, but when the surface is level or slopes away from the sun, it is inclined away from the direct rays. The same amount of heat must then warm a larger area. This increase in area may be shown by sawing off a board at right angles and then at an obtuse angle, and measuring the cross-section each time.

EXERCISE A-16. TO STUDY THE NECESSITY FOR SOIL DRAINAGE.

Equipment: Two one-quart tin cans; a graduated cylinder or bottle; a one-foot rule; several grains of corn; a sample of loam soil.

Method: Make eight holes in one can by driving a nail through the bottom. Stand this can on blocks in a saucer. Fill both cans with loam to within one inch of the top and plant three grains of corn in each. Each day, pour water upon the surface of the soil in the tight can until it stands at the surface, noting the amount used each time. At the same time add the same amount of water to the other can, using the graduated bottle to determine the amount added. As soon as the corn appears above the surface measure its height every other day, recording the average height of the three plants in each can. The height may be regarded as the distance from the surface of the soil to the tip of the uppermost leaf.

	Average Height of Plants on the Following Dates:									
Can without holes.										
Can with holes. . . .										

From this exercise what do you conclude as to the relative length of time which would be required for corn to come up in a drained and in an undrained field?

Fig. 16.—Corn Planted the Same Day. Tumbler of soil to the left kept saturated while the one to the right is only about half-saturated with water.

What effect does drainage have upon the air in the soil?

Discussion: The rain which falls on the fields would in time completely saturate the soil if no drainage were possible. The more nearly level the land the more readily does the rain pass into it. During a long-continued rain the water soaks into the soil until, like a blotter or a sponge, it can hold no more. Then the excess of water will flow over the surface to the lowest points in the field and finally join the creeks and rivers which are a part of Nature's great drainage system.

The water which has soaked into the soil gradually passes into the subsoil and eventually finds its way to the streams. If the soil is a loam with an open subsoil, this natural drainage will be sufficient. However, in heavy loams and in clay soils Nature does her work too slowly to be of immediate benefit. Then it is that we should supply artificial drainage in the form of tile to carry away the surplus water more promptly and thus assist Nature.

EXERCISE A–17. A STUDY OF "WARM" AND "COLD" SOILS.

Equipment: Dry loam soil; two thermometers; two flower pots or quart cans; a beaker or tumbler.

Method: (a) Tie a piece of muslin cloth around the bulb of one thermometer and suspend it over a tumbler with the lower end of the cloth dipping into the water, but the bulb one inch above the surface. Suspend the other thermometer in the air near the tumbler. At the end of ten minutes read both thermometers and take the temperature of the water. Record as follows:

	Degrees.
Temperature of the air.......	
Temperature of the wet bulb..	
Temperature of the water.....	

Why is the temperature of the wet bulb lower than that of the air or water?

(b) Fill two flower pots with the dry soil and add sufficient water to one to thoroughly wet the soil. Insert the bulb of one thermometer to the depth of one-half inch into the wet soil and the other to the same depth into the dry soil. Make a reading of both thermometers at the end of fifteen minutes.

Discussion: Tile-drained soils and sandy soils with good natural drainage warm up more rapidly in the spring than poorly drained soils. Why? Sandy land is commonly spoken of as a warm soil, while clay is regarded as a cold soil. Well-drained sandy soil is used for the growing of early truck crops. Why?

Plowing or stirring the soil in the early spring hastens evaporation and as soon as the surface becomes dry the soil begins to warm up rapidly.

EXERCISE A–18. TO STUDY THE OPERATION OF TILE DRAINS.

Equipment: Drainage apparatus; dipper; glass tumbler; sample of sandy loam soil.

Method: Fill the drainage apparatus to within an inch

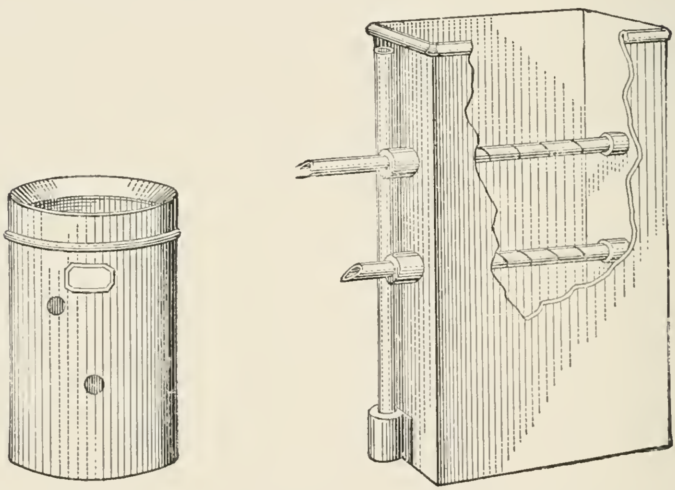


Fig. 17.—To the Left, a Tin Can Arranged to Show the Operation of Tile Drains. To the Right is the Graham-McCall Apparatus.

of the top with sandy soil. If a drainage apparatus is not available, a tin can may be used after having punched two holes in the side as shown in the diagram.

Slowly pour water over the surface of the soil and note the result.

To operate the Graham-McCall apparatus, fill the vessel with soil and pour on water at regular intervals, giving it time to soak into the soil. The water, instead of coming out at the tubes, will pass downward through the soil until the solid bottom is reached, when a water-table of free liquid will be formed at a level indicated by the height of water in the glass stand-pipe. When the free water has risen to the first opening it will pass outside the vessel, thus proving that a tile drain placed as low as soil conditions will permit removes free water before one placed nearer the surface.

Discussion: The lower tube in the drainage apparatus or the lower hole in the can represents a deep tile drain, while the upper tube or hole represents a shallow drain. The object of the tile is to prevent the rise of the ground water surface which interferes with the root development of the plants.

EXERCISE A-19. A STUDY OF SOIL TEMPERATURE.

Equipment: Two or more thermometers; a soil auger.

Method: For this exercise select a bright day about the time spring plowing begins. Go to a nearby field and take the temperature by burying the bulb of the thermometer to the depth of three inches. To avoid breaking the thermometer, first make a hole in the soil to the proper depth with a small stick or lead pencil and then insert the thermometer. The reading should not be taken until after the thermometer has been in contact with the soil about fifteen minutes. While waiting to make this reading, bore a hole to the depth of three feet and lower the other thermometer until the bulb rests on the bottom. At the end of fifteen minutes the thermometer should be drawn to the top and read immediately. Take the temperature at the three-inch depth, (1) of a north and of a south slope; (2) of unplowed and freshly plowed land; (3) of grass land and a cultivated field. Record all temperatures and discuss the results.

	Reading of Thermometer.
North slope..........	
South slope..........	
Unplowed field.......	
Plowed field.........	
Grass land...........	
Cultivated field......	

Discussion: Early in the spring the surface soil is usually cooler than the deeper layers; south slopes are warmer than north slopes; cultivated fields are warmer than uncultivated. Why?

EXERCISE A–20. TO DEMONSTRATE THE MOVEMENT OF WATER IN THE SOIL.

Equipment: Two tumblers; a saucer; a strip of blotting paper, and some fine dry soil.

Method: Fill one of the tumblers with water and suspend above it the strip of blotting paper with the lower end dipping into the water. Fill the second tumbler with fine dry soil and sprinkle three or four spoonfuls of water over the surface. Make a mound of dry soil in the center of the saucer and pour water into the saucer until it stands one-half inch deep.

Describe what happened in each case.

Discussion: The force which causes the water to move uphill in the blotting paper and in the saucer of soil is called *capillarity* and the water which moves in this way is known as *capillary water.* The capillary movement of the water is usually upward, but when a light shower falls on the surface of a dry soil the movement will be downward and laterally as shown in the second tumbler.

During the growing season, water is moving by capillarity from the deeper layers of soils toward the surface. If allowed to do so, much of the moisture stored in the soil will pass on up through the surface layer and be evaporated without having been of any service to the plants growing in the soil. To prevent this loss we practice shallow, frequent cultivation, which keeps a protective covering of loose soil over the surface.

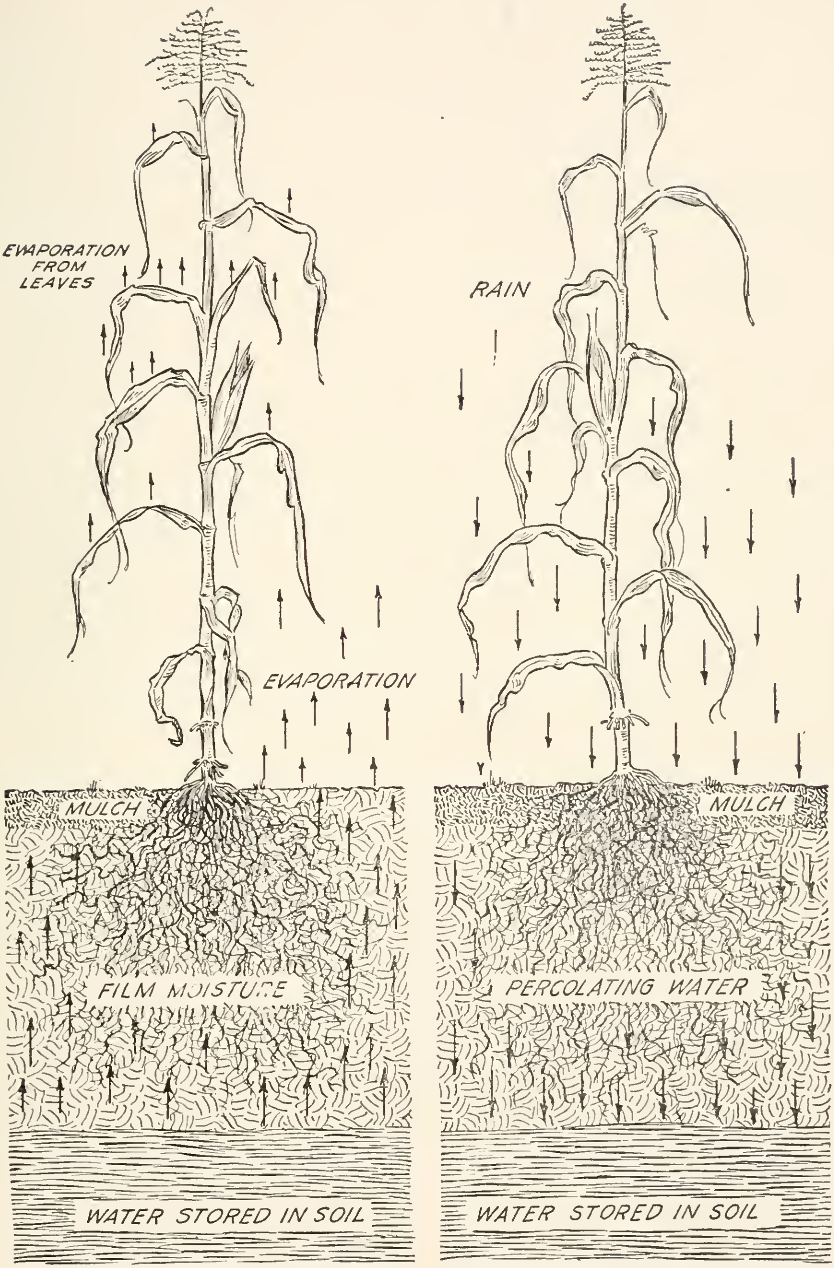


FIG. 18.—Movement of Soil Moisture. To the right the rain is soaking into the soil. It passes down into it by gravity and is stored for future use. During dry weather the water moves upward by capillarity to supply the plants as shown to the left. On one side of the plant a mulch prevents the loss of moisture, while on the other side the water is being lost by evaporation at the crusted surface. The moisture saved by the mulch is free to enter the plant with dissolved material, which it leaves behind as it evaporates from the leaf surface.

EXERCISE A–21. TO COMPARE THE MOVEMENT OF WATER THROUGH DIFFERENT SOILS.

Equipment: Four tall brass cylinders or tin cans with perforated bottoms; four graduated bottles; cheesecloth; samples of sand, muck and clay soil.

Method: Number the four cylinders or cans and cover the bottom of each with a layer of cheese cloth. After supporting them over the graduated bottles, fill the cans to within one inch of the top, as follows: No. 1, sand; No. 2 mixture of half sand and half muck; No. 3 clay; No. 4 mixture of half clay and half sand.

Taking each can separately, slowly pour water on the surface of the soil and note the time required for the water to come through and begin to drip from the bottom. Continue to pour on water and measure the amount which comes through during the next ten minutes. If the sand is coarse it may be necessary to shorten the time to one minute for that material.

	No. 1.	No. 2.	No. 3.	No. 4.
Time to come through.				
Amount in 10 minutes.				

What kind of soil is most likely to drain out naturally?
What kind of soil requires tile drainage?

Discussion: After a rain, when the capillary or film capacity of the soil has been reached, the free or gravitational water percolates down to the subsoil and runs away. The rate at which this free water gets out of the zone of the roots is called the *rate of percolation.* This rate depends upon the fineness of the particles, the degree of granulation, and the content of organic matter. In soils in which the particles are comparatively fine and the spaces between the particles correspondingly small, the percolation is slow. When a fine soil is well granulated, the larger spaces between the granules permit a more rapid flow. This is desirable, since, to have the soil saturated long is injurious to crops. On the other hand in some sandy soils percolation may be so rapid as to cause leaching, i.e., carrying away of the plant nutrients. The addition of organic matter tends to prevent leaching.

EXERCISE A–22. TO SHOW THE EFFECT OF A LOOSE SURFACE UPON THE RATE AT WHICH THE RAIN WILL SOAK INTO THE SOIL.

Equipment: Two quart cans; a graduate; sufficient moist garden or field soil to fill the two cans.

Method: Fill the two cans to within one inch of the top with the moist soil. Firmly compact the surface of the soil in one can and leave the surface of the other loose. Pour an equal amount (4 ounces) of water on the surface of each and note the time it takes it to disappear into the soil. Which takes in the water more rapidly, the loose or the compacted surface?

	Time Required for Water to Disappear.
Loose surface........	
Compacted surface...	

Discussion: When rain falls upon the surface of a field a part of the water soaks into the soil and another part runs off the surface. If the surface is dry and hard, a very large part of the rain runs off and only a small quantity enters the soil. The part which runs off the surface is not only entirely lost to the crop, but it also washes the surface and carries away with it a large amount of plant food. Observe what happens when a hard rain falls on a loose, mellow garden, and compare with what takes place on a hard path during a heavy rain. Thrifty farmers try to keep their soil mellow and loose on the surface so that it will absorb and hold sufficient water to carry the plants through the dry, hot part of the season. Persistent

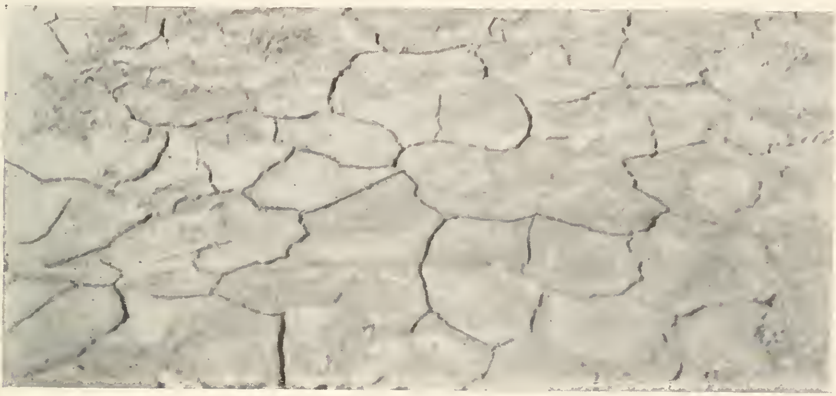


FIG. 19.—This Soil should be Cultivated at Once to Prevent the Loss of Moisture through the Shrinkage Cracks.

tillage, which keeps the surface loose, enables the rainfall to enter the soil easily. Frequent shallow cultivation also serves in a dry time to prevent the loss of moisture from below. The soil which is stirred forms a covering or *dust mulch* which protects the deeper soil and lessens the loss by evaporation at the surface.

EXERCISE A–23. TO STUDY THE FORMS OF SOIL MOISTURE.

Equipment:* Balances; drying oven; soil auger; sample boxes.

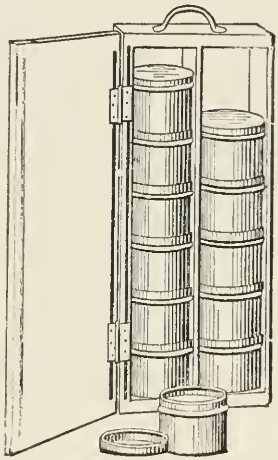


Fig. 20.—Soil Sample-case Provided with Seamless Tin Boxes for Use in Collecting Field Samples.

Method: With the soil auger secure samples of soil at a depth of six, eighteen, and thirty inches. Transfer the samples at once to tight tin boxes with lids. As soon as possible weigh the boxes and contents. Remove the lids and let the soil dry in the air for one week, then weigh. Continue the drying until constant weight is attained.

What does the loss in weight represent? Does this soil still contain any moisture?

Place the samples in an oven with the lids off the boxes and dry for two days. Weigh and record the weights.

* The balance shown in Exercise 7 or the one shown in Exercise 9 may be used. A one-burner gasoline or kerosene stove with a small baking oven may be used. The flame should be regulated to keep the temperature at about 105° C. or 212°–215° F.

A soil auger may be purchased from an implement firm or it may be constructed by a local blacksmith by welding a length (three feet) of iron pipe onto the shank of a common $1\frac{1}{4}$ or $1\frac{1}{2}$-inch wood auger. Tin salve-boxes make very satisfactory soil containers.

If the weight changed in the oven how do you account for the change? Fill out the table given at the end of the exercise and write over the fourth and fifth columns the name of the kind of soil moisture which each represents. What form of soil moisture is it that fills a post hole as soon as it is dug? Which sample contained the highest per cent of moisture.

Sample.	1 Original Weight.	2 Air-dry Weight.	3 Oven-dry Weight.	4 Loss in Air.	5 Loss in Oven.
1					
2					
3					

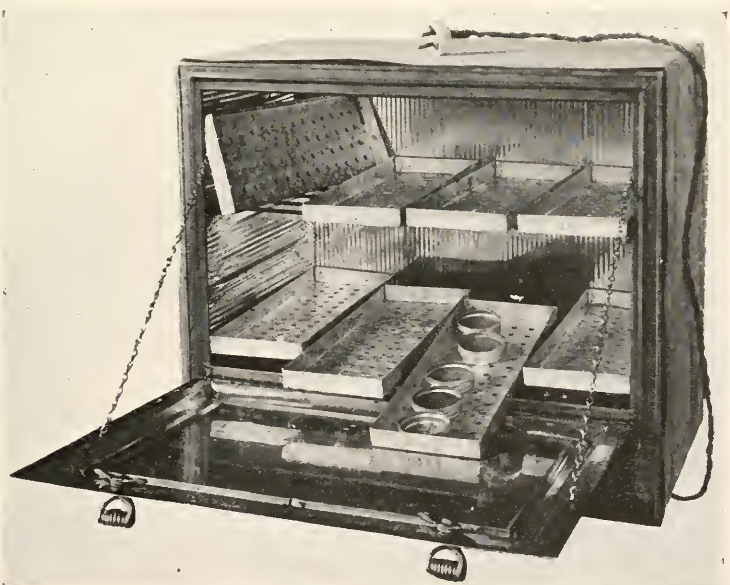


FIG. 21.—A Gasoline Stove Oven, Galvanized Iron Trays, and Tin Dishes for Drying Soil Samples.

Discussion: Moist soil as we find it under ordinary conditions in the field holds the water as a thin film around the soil grains. This form of moisture is given the name *film moisture,* because of the fact that it forms a film over the surface of the tiny soil particles. This moisture is available for the use of the plants that may be growing in the soil.

If a handful of this moist soil is spread on a board for several days and allowed to dry, it will have the appearance of containing no moisture at all. The film moisture will be gone, but the *hygroscopic moisture* will still be present. This form of moisture, which is not available to plants, varies with the moisture in the air and cannot be driven out without heating the soil.

The third form in which moisture occurs in the soil is called *free* or *gravitational water.* This form is seen seeping out of the banks of rivers and smaller streams.

EXERCISE A-24. TO STUDY THE CAPILLARY MOVEMENT OF SOIL MOISTURE.

Equipment: Four lamp chimneys; cheese cloth; twine; tray 1″×4″×12″ ; rack to support chimneys; samples of clay, loam, and sandy soils; foot rule.

Method: Tie a piece of cloth over the small end of each chimney. Number and fill them as follows: (1) sand, (2) loam, (3) clay, (4) half sand and half clay. Place the chimneys in the rack and keep the pan filled with water. Measure and record the height of the water in each, after a half hour, one hour, and every twenty-four hours for a week.

Record your data as follows:

No.	½ Hr.	1 Hr.	1 Day.	2 Days.	3 Days.	4 Days.	5 Days.	6 Days.	7 Days.
1									
2									
3									
4									

In which kind of soil did the water rise fastest at first?

In which did it finally stand highest?

Does capillary moisture always move directly upward?

Discussion: Water rises through the soil in the same way that oil rises in a lamp wick. Throughout the growing season, and especially in dry weather when the level of standing water is many feet below the surface, plant roots are supplied by capillary moisture which is moving up through the soil. The depth from which water may be

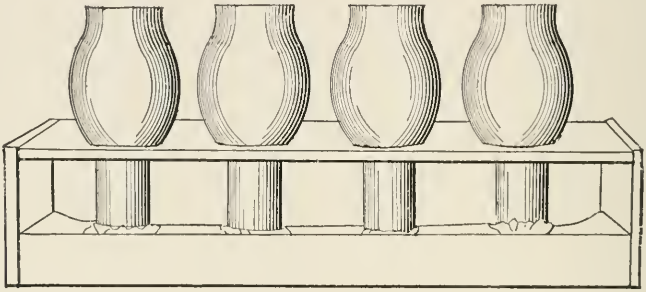


Fig. 22.—Lamp Chimneys may be Used to Show the Capillary Rise of Moisture.

raised by capillary action depends upon the kind of soil. Clay soils bring water from a greater depth than coarser soils. Sandy soil is sometimes said to "burn out," because in a drouth it furnishes little or no water to the plant, although standing water is but a few feet below the surface.

EXERCISE A-25. TO SHOW THE EFFECT OF PLOWING UNDER COARSE MATERIAL SUCH AS MANURE, GREEN COVER CROPS, OR CLODS.

Equipment: Three lamp chimneys; rack to support chimneys; tray 1′×4″×12″; cheese cloth; scissors; twine; sample of sandy loam soil; cut straw; soil lumps or clods.

Method: Cover the small end of each lamp chimney with a piece of cloth and tie it on with the twine. Number and fill the tubes as follows: (1) when about two-thirds full add enough cut straw to make a layer one inch thick, and complete filling; (2) when two-thirds full add enough round hard clods to make a layer about one inch thick, and complete filling; (3) fill with fine soil. Hang the tubes in the rack with their lower ends resting lightly on the bottom of the tray and fill the pan with water. At the end of four days note the height of the water in each tube. Since the same kind of soil was used in each tube would you not expect the water to rise to the same height in each? Explain the cause for what you find.

Discussion: When capillary water rises in the soil it passes from one tiny particle to another which lies next to it. If the particles are separated by a very wide space or by some loose substance the rise of water is stopped. This may happen when a heavy growth of green material like rye is plowed under. Harm will be prevented if the green material is thoroughly cut with a disc before being turned under and the furrows turned so as to lap and not lie flat.

EXERCISE A–26. TO SHOW THE EFFECT OF A MULCH IN PREVENTING THE LOSS OF MOISTURE AT THE SURFACE OF THE SOIL.

Equipment: Balance; sample of soil; dry sand or dust; dipper; shallow tray.

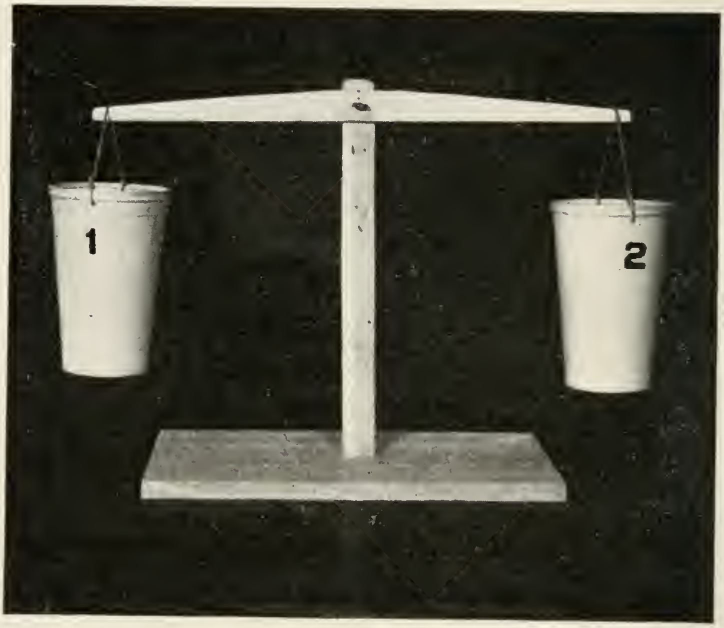


Fig. 23.—Home-made Balance Used to Show the Effect of a Dry Earth Mulch.

Method: Fill one can to within one inch of the top with moist soil and the other can to within two inches of the top with the same soil. Pour dry sand or dust over the surface of the second can to the depth of one inch. Place the cans on the scale pans or suspend them from the arms of the balance and adjust the amount of soil in the two cans until the system balances and the arms of the balance remain horizontal.

After allowing the apparatus to stand over night, it will be found that the system is no longer balanced. The soil which was covered with the dust or sand has lost but little moisture, while the unprotected surface of the other soil has lost a much larger amount. The amount of water that must be added to the can with the exposed soil surface to restore the balance represents the moisture that has been saved by the protective covering of dust—the dry earth mulch. In using the home-made balance the bar should be held in a horizontal position while the water is being added.

Discussion: Have you ever noticed how moist the soil is under a stone or a board even when the surrounding ground is quite dry? The stone or board has kept the air away from the surface of the soil and prevented evaporation. When shallow cultivation is practiced, the thin layer of stirred soil soon becomes very dry, but by keeping the air away it serves to prevent the deeper soil from losing its moisture by evaporation. This loose blanket or mulch, as it is called, also helps to absorb rainfall and to prevent it from running off the surface.

EXERCISE A–27. TO STUDY THE WATER LOSS FROM CULTIVATED, UNCULTIVATED AND MULCHED SOIL SURFACES.

Equipment: Three galvanized-iron cylinders; shallow pan; table knife; a pair of scales having a capacity of fifty pounds; a small quantity of cut straw; a quantity of dry, sifted loam soil.

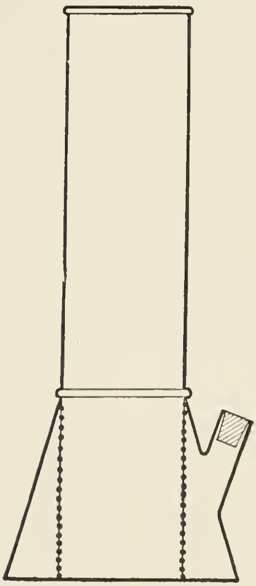


Fig. 24.—Galvanized Iron Mulch Cylinder.

Method: Number the three cylinders and fill each to within one inch of the top with the dry soil. Pour water into the jacket at the bottom until the soil appears moist at the surface. This will probably require several hours, but the experiment will need no attention during this time except to see that the water is replenished in the jackets from time to time. It is a good plan to start the exercise in the afternoon and allow the cylinders to stand over night or until the next period.

After the water has reached the surface of the soil in all of the cylinders they should receive the following treatment:

No. 1. Compact the surface.

No. 2. Remove two inches of soil and replace with cut straw.

No. 3. Remove two inches of the surface and replace it in a loose condition.

Care should be taken to have all of the surfaces at the same distance below the top of the cylinders. Why? The surface of No. 3 is to be removed to the shallow pan and mixed before it is returned to place. It should then be stirred occasionally to keep the surface in a loose condition.

As soon as the mulches are in place, fill all of the water jackets to the same level and weigh each cylinder. Repeat the weighings every other day for a week and record the weights in the accompanying table:

Cylinder. No.	Treatment.	Weight of Cylinders and Soil.				Total Water Loss.	Tons per Acre.
		First Day.	Third Day.	Fifth Day.	Seventh Day.		
1	Compacted......						
2	Straw mulch....						
3	Loose soil mulch.						

Which cylinder lost the greatest amount of water by evaporation?

How does the farmer and gardener make use of soil and straw mulches?

Discussion: Any covering placed upon the surface of the soil to prevent or lessen evaporation of moisture is called a *mulch*. An artificial mulch is a covering of straw, leaves, sawdust or other material of a like nature. A natural mulch is the layer of loose soil produced by frequent shallow cultivations.

Artificial mulches are sometimes used in gardens and in small truck patches, but in the large fields the natural mulch is the only practical means for preventing the escape of the moisture by evaporation at the surface of the soil.

EXERCISE A–28. TO SHOW THE EFFECT OF DRAINAGE UPON SOIL TEMPERATURE.

Equipment: Two one-quart tin cans; thermometer; loam soil.

Method: Make several holes in the bottom of one can by driving a nail through it. Fill each can with the same kind of soil. Wet the soil in both cans thoroughly. Push the bulb of a thermometer one inch deep in each can and place in a sunny window. Record the temperature every two hours, continuing the readings on the second and third

	First Day.					Second Day.					Third Day.				
Time	0	2	4	6	8	0	2	4	6	8	0	2	4	6	8
Can with holes															
Tight can															

How does the temperature of the soil affect the growth of crops.

When is this most important? What would you do for a soil that is wet and cold?

Discussion: If we were to place a pan of water and a pan of dry soil on a stove, we would find that it took longer to heat the water to a given temperature than the dry soil.

This is because the amount of heat required to raise the temperature of water is several times as great as that required to raise the temperature of soil. Consequently, when any soil contains a large amount of water it is warmed more slowly than a well-drained soil, which has been relieved of its surplus moisture.

EXERCISE A–29. TO SHOW THE INFLUENCE OF COLOR UPON SOIL TEMPERATURE.

Equipment: Box 4″×12″×24″; two thermometers; chalk dust; soot or lampblack; twenty grains of corn.

Method: Fill the box with moist soil and plant the corn in regular rows. Scatter chalk dust over one-half of the box and soot or lampblack over the other half to the depth of a quarter of an inch. Insert the bulb of a thermometer about one-half inch beneath the surface in the middle of each half of the box. On the first day read the thermometers every two hours from early in the morning until two hours after sunset. Make a record of the number of corn plants which come up in each half, on the day when they can first be seen.

TEMPERATURE.

Hour..................						
Light surface...........						
Dark surface............						

PLANTS UP.

Day..................						
Light surface...........						
Dark surface............						

What influence does color have on the temperature of the soil? When is this difference greatest? How would the addition of organic matter affect the temperature of a soil?

Discussion: The color of soil is due to three things: (1) The color may come from the original rock particles

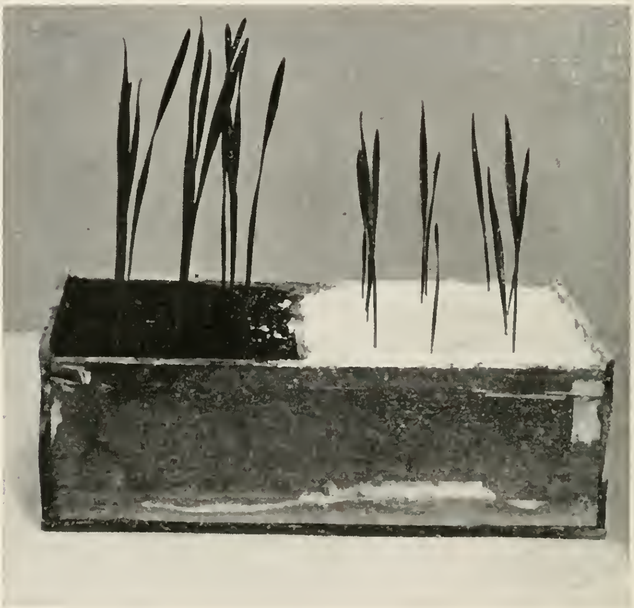


Fig. 25.—Corn Planted the Same Day. Dark surfaces absorb more heat than light objects.

of which the soil is formed. An example of this is found in white sandy soil from clear quartz sand. (2) The color usually comes from material which sticks to the particles. The coloring material may be either iron compounds or organic matter or both. Red, yellow, blue, and gray soils are colored by some form of iron, and any of these may be darkened by the presence of organic matter.

EXERCISE A–30. TO SHOW THE EFFECT OF LIME UPON THE SOIL.

Equipment: Two tall bottles or cylinders; a sample of clay soil; a lump of lime.

Method: (1) Make up a small quantity of limewater by dissolving a lump of lime in a glass of water. Add lime until no more will dissolve.

Fill each bottle or cylinder with clear water and add to each a tablespoonful of very fine, dry, clay soil. Into one cylinder pour two tablespoonfuls of limewater. Now shake each cylinder for two minutes and then allow the contents to settle for a short time. In which sample are the particles drawn together in groups or crumbs?

Note the time required for the water to become clear in each sample and record in the following table:

	Time.
With lime.	
Without lime. .	

(2) Make a mud ball of heavy clay about the size of a baseball. Make a second ball, mixing into the clay two tablespoonfuls of lime, and, as soon as both are dry, crush them. Which is the more easily broken? If a hard, cloddy soil is treated with lime what will be the effect upon its working qualities?

Fig. 26.—The Presence of these Weeds Indicates that the Soil Needs Lime. Field sorrel to the right and horse-tail rush to the left.

Discussion: The addition of lime to a heavy clay soil causes the very fine particles of which it is composed to draw together into crumbs or granules. Then when the soil dries, instead of being a hard, solid mass which will break up and form hard clods, it is loose and mellow. A similar effect is produced by the addition of organic matter in the form of stable manure, or by plowing under a crop of clover or rye.

EXERCISE A–31. TO STUDY THE NEED OF THE SOIL FOR LIME.

Equipment: Blue litmus paper; small bottle of hydrochloric acid.

Method: (**a**) Dip the end of one strip of litmus paper into vinegar or hydrochloric acid, and the end of another

Fig. 27.—A Small Outfit for Crushing and Pulverizing Limestone for Use on Acid Soils.

strip into lime water. What is the result? After thoroughly washing the hands, make a mud ball by moistening some of the soil to be tested, with distilled or fresh rain-water, and pressing it into shape. Break open the ball, place a fresh piece of the blue litmus between the two parts and press them together. After four or five minutes examine the paper; if it has turned pink there is acid present in the soil. The amount of acid is roughly indicated by the rapidity of the change and the intensity of the color.

A thorough examination of the soil requires that samples of both surface and subsoil should be tested at several places in the field.

(**b**) Place a small quantity of moist soil in a saucer, add a drop of vinegar or other acid and apply the litmus paper test. Add to the soil in the saucer a spoonful of lime and after adding a little water, mix thoroughly and allow to stand for some time. Again test with the litmus paper and note the result. What has become of the acid?

Discussion: Acid cannot exist in the presence of lime. The latter is naturally present in some soils but absent in others. The presence of any considerable amount of lime in the soil can be determined in the following manner. Moisten a sample of the soil and mold it into a shallow cup. Pour a few drops of dilute hydrochloric acid * into this cup and, if lime is present, bubbles appear at the surface of the soil. If a large amount of lime is present, foaming will occur. Put a drop of hydrochloric acid on a piece of limestone.

As in the case of the test for acidity, the test for lime should be applied to the subsoil, since an abundance of lime at a depth of two or three feet may serve a very

* One part of hydrochloric acid to one part of water. Care must be taken to prevent the strong acid from coming in contact with the skin or the clothing. In case acid gets on the fingers, injury will be prevented if the hand is washed promptly or rubbed with soil.

useful purpose. Soils that are lacking in lime are usually sour or acid and will not produce a full crop until lime has been applied to kill the acid. If a soil turns the litmus paper red and refuses to grow good clover, it should be treated with a ton or two of fine-ground limestone. If the soil bubbles freely when hydrochloric acid is applied, no lime is needed.

EXERCISE A-32. TO STUDY THE ADAPTABILITY OF SOILS TO CROPS.

Equipment: Spade or soil auger; note-book.

Method: Make a trip across several farms and note the kind of crops that are being grown on sandy soils, on clay loams and on wet clay soils.

FIG. 28.—The Effect of Lime upon the Growth of Clover.

Discussion: Some crops can be grown on a great variety of soils, while others require a particular type for profitable growth. Timothy can be grown successfully on heavy clay, clay loam or sandy loams, but it usually does best on the clays, while corn is grown most profitably on rich loam soil.. Irish potatoes require a loose rich loam for their best development, while onions and celery are grown almost exclusively on black soils, very rich in humus.

Write an account of your observations, making note of the extent to which the crops in your region vary on the different soils.

EXERCISE A-33. TO STUDY THE PLOW.

Equipment: A breaking plow; straight-edge, or yard-stick.

Method: Examine the plow thoroughly and answer the following questions:

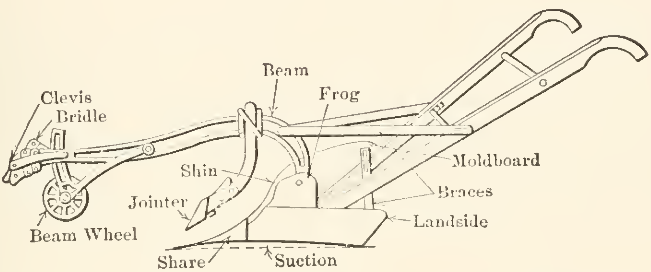


Fig. 29.—Parts of the Plow. Note the shape of landside and share to give suction.

1. Name of the plow.
2. Name and address of the manufacturer.
3. Locate the following parts: mouldboard, shin, share, point, beam, clevis, landside, heel, frog, and coulter.
4. By means of the straightedge and a rule determine the suction.
5. How is the plow adjusted to cut a wider furrow slice?
6. How is the depth regulated?

Discussion: The purpose of the plow is to invert and pulverize the surface six or eight inches of soil and to turn under weeds and other trash. The plow is a three-sided wedge, the two plane sides of which press on the bottom and the landside of the furrow while the third curved surface lifts and turns the furrow slice.

Great care should be exercised to have the plow in proper adjustment, for if improperly set the implement is difficult to operate and does inferior work. If possible make a trip to the field and observe the operation of the plow.

Care must be taken not to plow when the soil is too wet. If plowed too wet most soils become puddled and cloddy and may have their productive capacity impaired for a number of years.

EXERCISE A-34. TO STUDY PLANT ROOTS AND THEIR RELATION TO SOIL MANAGEMENT.

Equipment: Spade; yardstick.

Method: Dig down beside a corn plant in a field, and measure the depth of the first roots, also the depth to the deepest roots. Repeat this in several places and in different kinds of soil. How deep may corn be cultivated without injuring the roots?

In the same manner find the depth and lateral extent of the roots of grasses and clovers.

Of the plants examined, which would tend to deepen the soil and be the most valuable in supplying humus?

Discussion: Roots which penetrate deep into the soil open up the subsoil and increase the feeding room. The decay of roots adds humus and makes the soil more productive.

Plants are like animals in that they must have food and drink or they soon sicken and die. Animals can move about from place to place and secure their food, but plants must get their food and water by sending their roots out into the soil. The tiny roots which spread out through the soil are busy all of the time taking up water from the soil for the use of the stalk and leaves above. This water, as it goes into the plant through the roots, carries with it the plant food which it has dissolved out of the little soil particles. The water that goes in through the roots passes out through the leaves into the air and leaves the plant food behind to build up the tissues of the plant.

If the soil is hard and lumpy, the little roots cannot penetrate far into it, but must feed near the surface.

Stirring up the soil and breaking up the clods brings the water into contact with more soil surface and hastens the solution of the plant food.

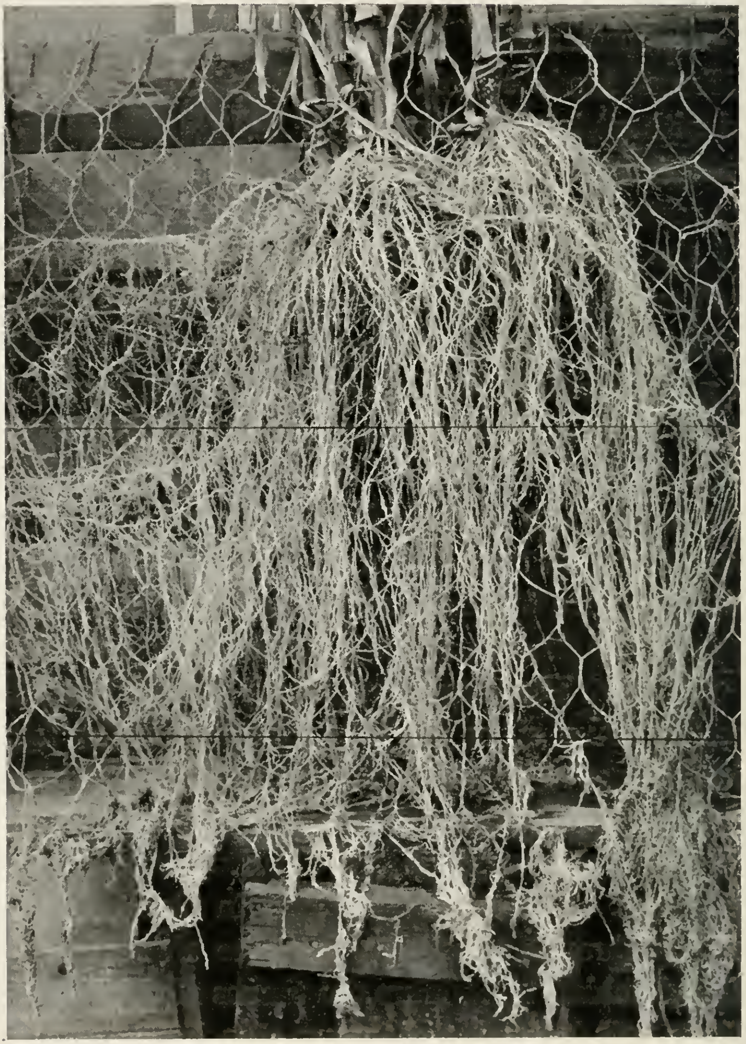


Fig. 30.—The Root System of a Mature Corn Plant to the Depth of Three Feet.

EXERCISE A–35. TO STUDY THE ROOTS OF LEGUMES.

Equipment: Spade; yardstick.

Method: Carefully dig up a clover plant in the field, noting the tiny *nodules* on the roots. Dig up other legumes and observe their root system and the presence of nodules.

These nodules are the home of the bacteria which have the power of taking the nitrogen from the soil air and making it available for the use of the clover plant.

Discussion: Nitrogen is a very important food for plants and is very expensive when purchased in fertilizer. Only the legumes that have the nodules on their roots are able to use the free nitrogen of the soil air. The legumes include the common clovers, alfalfa, soy beans, cow peas, garden peas and many other plants, all of which have a beneficial effect upon the soil.

Roots showing the nodules may be preserved in cans or wide-mouthed bottles by the use of formalin * solution, consisting of one tablespoonful of formalin to each quart of water.

Observe that the nodules on the clovers and alfalfa are quite small, while those on peas and soy beans are much larger. In addition to the nitrogen which red clover and alfalfa bring to the soil, they exercise a very beneficial effect upon the physical condition by means of their strong, deep root system.

* Formalin (40%) can be purchased at any drug store. It is a clear, colorless liquid.

FIG. 31.—Nodules on an Alfalfa Root. These nodules are the homes of nitrogen-gathering bacteria.

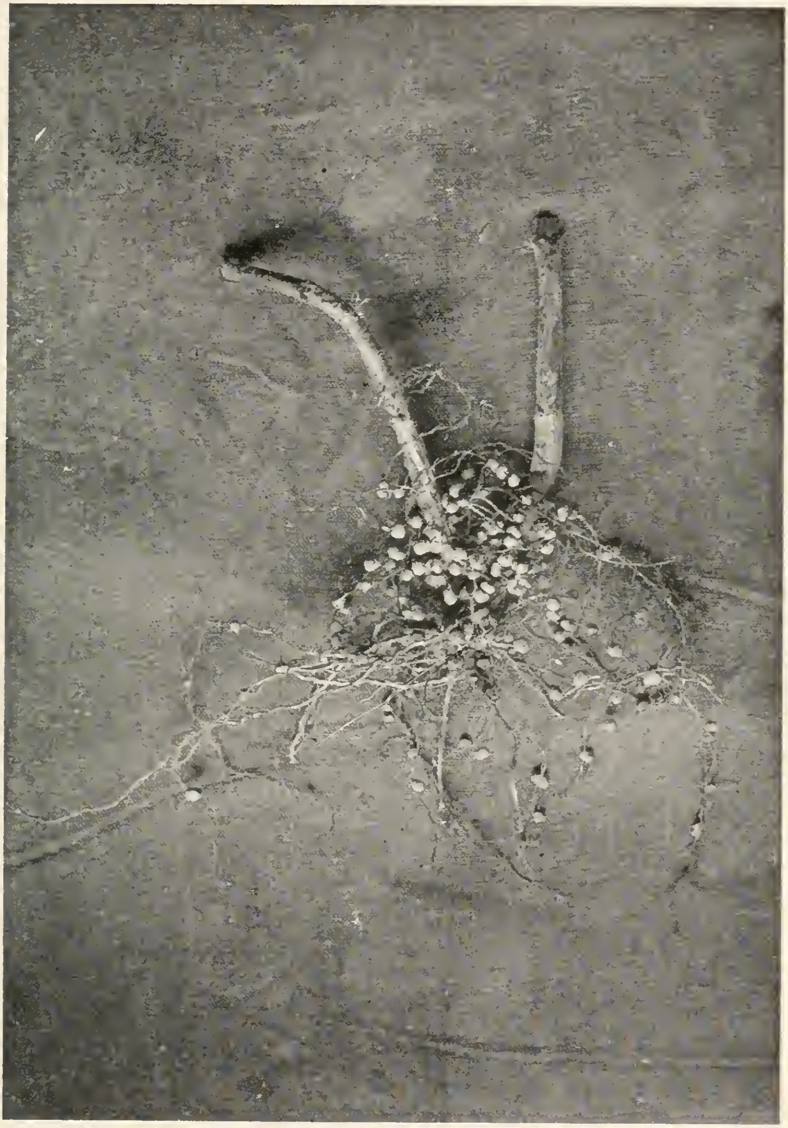


Fig. 32.—Nodules on the Roots of Soy Beans.

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